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# Hydrologic Testing Work Plan for Consolidated Unit 16-021(c)-99

Los Alamos
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## EXECUTIVE SUMMARY

This work plan describes the proposed installation of a pumping test well and a hydrologic testing program to evaluate properties of the deep-perched groundwater zone at Consolidated Unit 16-021(c)-99 (260 Outfall), located in Technical Area 16 in the southwest corner of Los Alamos National Laboratory. The tests will provide field-scale measurements of aquifer parameters for the deep-perched system that will be used to assess the potential for pumping and treatment of contaminated deep-perched groundwater associated with the 260 Outfall. The document was developed to meet the requirements of the New Mexico Environment Department's (NMED's) "Approval with Modifications: Supplemental Investigation Work Plan for Intermediate and Regional Groundwater at Consolidated Unit 16-021(c)-99."

The deep-perched groundwater is located within the Otowi Member of the Bandelier Tuff and the underlying Puye Formation sediments. The zone is recharged along the Jemez Mountain-front via the Pajarito Fault zone and along the canyon bottom. The deep-perched zone extends from west to east for more than 1.3 miles (2 kilometers), and from north to south for approximately 0.6 miles (1 kilometer). The zone has a maximum thickness of approximately 420 ft and is characterized by a series of saturated horizons separated by unsaturated strata. There remain uncertainties regarding the hydrogeologic properties of the deep-perched system, and the degree of lateral continuity and vertical hydraulic connectivity between saturated horizons and the regional aquifer.

The hydrologic testing proposed in this work plan is expected to reduce these uncertainties. Multiple-well aquifer tests are planned for well R-25b, located 50 ft west of R-25, and for well CdV-16-4ip, a new well to be installed approximately 372 ft east of R-25. The multiple-well tests should yield better estimates of formation transmissivity than single-well tests and should provide an estimate of storativity as well, provided drawdown is observed in one or more observation wells.

The new well, CdV-16-4ip, will be constructed as a 5-in.-inside-diameter, stainless-steel well with two well screens, approximately 40 to 60 ft in length. The upper screen will be located near the top of saturation in the Otowi Member of the Bandelier Tuff (where the highest high-explosives contamination levels are consistently observed), and the lower screen will be located in the Puye Formation. Well-screen depths and lengths will be selected based on data collected during drilling.

The R-25b aquifer test will consist of a 24-hr test, with drawdown and recovery monitored in pumping well R-25b and in observation wells R-25 and CdV-16-1(i). The CdV-16-4ip aquifer tests will consist of 10-d pumping tests conducted on each of the two well screens, with drawdown and recovery monitored in both screens of pumping well CdV-16-4ip and in observation wells R-25, R-25b, and CdV-16-1(i).

A tracer test will also be conducted using well R-25b as the injection point and well screens at R-25 as observation points to obtain information regarding the vertical connectivity within the deep-perched zones, and possibly within the regional aquifer in the vicinity of these two wells. These data will supplement the data collected during the aquifer tests.

The results from the hydrologic testing will be used to evaluate the pump-and-treat remedial alternative for deep-perched groundwater that was initially proposed in the "Corrective Measures Evaluation Report for Intermediate and Regional Groundwater at Consolidated Unit 16-021(c)-99." The data will be incorporated in the revised corrective measures evaluation report, planned for completion in 2011.

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## 1.0 INTRODUCTION

This work plan proposes hydrologic testing to collect additional data on aquifer properties and groundwater flow rates within deep-perched groundwater at Consolidated Unit 16-021(c)-99 (260 Outfall). The 260 Outfall is located in Technical Area 16 (TA-16), in the southwest corner of Los Alamos National Laboratory (LANL or the Laboratory). Figure 1.0-1 shows the location of TA-16 with respect to Laboratory technical areas, while Figure 1.0-2 shows the location of Consolidated Unit 16-021(c)-99 and associated features.

This document provides details regarding a proposed hydrologic test well and the proposed aquifer testing and tracer test to be conducted at the site. The document was developed to meet the requirements of the New Mexico Environment Department's (NMED's) "Approval with Modifications: Supplemental Investigation Work Plan for Intermediate and Regional Groundwater at Consolidated Unit 16-021(c)-99" (NMED 2009, 104973).

The hydrologic tests in this work plan are designed to provide a better understanding of the deep perched groundwater system in the vicinity of the 260 Outfall, and to acquire field-scale measurements of hydrogeologic properties necessary to determine the feasibility of the pump-and-treat remedial alternative proposed in the "Corrective Measures Evaluation Report, Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99" (LANL 2007, 098734). These properties include formation transmissivity and storage coefficient, as well as the relative degree of interconnectivity between various strata within the deep-perched groundwater systems.

These data will be used in the alterative selection process in the revised corrective measures evaluation (CME) for Consolidated Unit 16-021(c)-99, scheduled for completion in 2011.

### 1.1 Regulatory Context

The Laboratory completed their initial CME report for contaminated deep-perched and regional groundwater associated with Consolidated Unit 16-021(c)-99 in July 2007, and recommended a phased remediation strategy consisting of monitored natural attenuation for both the deep-perched and regional aquifers, and assessment of the feasibility of groundwater recovery and treatment (the pump-and-treat alternative) based on a pumping test.

NMED subsequently issued a notice of disapproval (NOD) regarding the CME report (NMED 2008, 101311), and requested a supplemental investigation work plan to acquire sufficient data to evaluate the feasibility of the remedial alternatives proposed in the CME. In response to NMED's NOD, the Laboratory developed the "Supplemental Investigation Work Plan for Intermediate and Regional Groundwater at Consolidated Unit 16-021(c)-99" (LANL 2008, 103165), proposing additional characterization activities to reduce or eliminate uncertainties in the hydrogeologic conceptual model at TA-16. These activities included additional monitoring well installation, additional groundwater sampling, and conducting single-well pumping tests and a multi-well pumping test and possible tracer tests to further characterize deep-perched and regional groundwater.

Activities completed under the supplemental investigation work plan include the installation of new monitoring wells R-25b, R-25c (a dry well), R-47i, and R-48; quarterly characterization sampling of R-25b, R-47i, and R-48, and completion of single-well, short-duration pumping tests in R-47i and R-48. Figure 1.1-1 shows the location of wells in the vicinity of TA-16.

Activities addressed in this work plan, include installation of a hydrologic test well (shown in Figure 1.1-2), and conducting multiple-well pumping tests and a tracer test on the deep-perched groundwater system. The data to be collected will include transmissivity, storativity, sustainable pumping rates, and groundwater flow velocities, and will be used to evaluate the feasibility of the pump and treat remedial alternative in the revised CME.

### 1.2 Overview

Section 2 of this work plan presents an updated conceptual model for the test area, and section 3 summarizes available hydrologic data for the site. Section 3 provides the details for the proposed testing, including the location and design of the test well, and a description of the aquifer testing to be conducted. Waste management is discussed in section 4; a schedule for the proposed activities is presented in section 5, and references are listed in section 6.

## 2.0 SITE HISTORY AND CONCEPTUAL MODEL

### 2.1 Site History

Building 260, located on the north side of TA-16 (shown as TA-16-260 in Figure 1.0-2), has been used for processing and machining high explosives (HE) since 1951. Because water is used to machine HE (which is slightly water-soluble) wastewater from machining operations contains dissolved HE and may contain entrained HE cuttings. Historic wastewater treatment at building 260 consisted of routing the water to 13 settling sumps to recover any entrained HE cuttings. From 1951 to 1996, the water from these sumps was discharged to the 260 Outfall that drained into Cañon de Valle. In 1994, outfall discharge volumes were measured at several million gal./yr. The discharge volumes were probably higher during the 1950s when HE production output from the 260 Outfall was substantially greater than it was in the 1990s (LANL 1994, 076858). In the past, barium was a constituent of certain HE formulations and inert components, and was present in the outfall wastewater.

During the late 1970s, the 260 Outfall was permitted by the U.S. Environmental Protection Agency (EPA) to operate as EPA Outfall No. 05A056 under the Laboratory’s National Pollutant Discharge Elimination System (NPDES) permit (EPA 1990, 012454). The last NPDES-permitting effort for the 260 Outfall occurred in 1994. The NPDES-permitted 260 Outfall was deactivated in November 1996 and EPA officially removed it from the Laboratory’s NPDES permit in January 1998. This waste stream is currently managed by pumping the sumps and treating the water at the TA-16 HE wastewater treatment plant.

Solid Waste Management Unit 16-021(c) consists of two portions: an upper drainage channel and former settling pond, and a lower drainage channel leading to Cañon de Valle. The entire length from the 260 Outfall to Cañon de Valle is approximately 600 ft. The former settling pond, which was removed during a 2000–2001 interim measure (IM) cleanup (LANL 2002, 073706), was approximately 50 ft long, 20 ft wide, and was located approximately 45 ft below the 260 Outfall. The upper drainage channel continues approximately 350 ft northeast from the former settling pond to a 15-ft, near-vertical cliff that marks the break between the upper and lower drainage channels. Beyond this cliff, the lower channel runs another 200 ft to Cañon de Valle. The IM cleanup removed more than 1300 $yd^3$ of contaminated soil from the settling pond and channel. Approximately 90% of HE in the Consolidated Unit 16-021(c)-99 source area was removed (LANL 2002, 073706).

A second phase of cleanup directed by the Corrective Measures Implementation Plan for Consolidated Unit 16-021(c)-99, Revision 1 (LANL 2007, 098192) was conducted in 2009 to remove residual soil exceeding risk-based media cleanup standards and to remove the 16-260 concrete outfall trough. This cleanup resulted in the removal of approximately 30 $yd^3$ of concrete outfall trough debris, 10 $yd^3$ of contaminated soils from beneath the trough, and 20 $yd^3$ of contaminated soil from the 16-260 drainage.

## 2.2 Conceptual Model

Based on the results of previous investigations, a conceptual site model has been developed for the northern portion of TA-16, with principal components being the outfall source areas, Cañon de Valle alluvial system, mesa vadose zone, and the deep-perched and regional aquifers. Figure 2.2-1 shows the conceptual site model with emphasis on the outfall source region, the alluvial system, and the mesa vadose zone. Figure 2.2-2 shows the conceptual site model for TA-16, with emphasis on the deep-perched and regional groundwater. The deep-perched groundwater zone is defined as those zones of saturation located between ~750 ft and 1200 ft below ground surface (bgs) in the TA-16 area.

Although several contaminant migration routes are depicted in Figure 2.2-1, the primary migration pathway likely consists of (1) discharge of HE compounds as effluent from the 260 Outfall, (2) surface flow of effluent to Cañon de Valle via a small tributary drainage, (3) down-canyon transport of contaminants by surface water flow and alluvial groundwater, (4) infiltration through the vadose zone recharging deep-perched groundwater zones, and (5) infiltration of that water into the regional aquifer. The deep-perched groundwater has the highest concentrations of HE and preliminary calculations conducted during the CME (LANL 2007, 098734) suggest that deep-perched groundwater also contains the majority of the HE mass. RDX (also known as cyclotrimethylenetrinitramine) concentrations in deep perched and regional groundwater monitoring wells are shown in Figure 2.2-3.

Investigations of deep-perched and regional groundwater at TA-16 have been conducted during the past several years and results of these investigations are summarized in several reports (Longmire 2005, 088510; LANL 2006, 093798; LANL 2007, 095787; LANL 2007, 096003). The conceptual model for deep perched and regional groundwater is discussed in further detail below.

### 2.2.1 Deep-Perched Groundwater

The deep-perched zone in the vicinity of R-25 is approximately 420 ft thick and occurs within the Otowi Member of the Bandelier Tuff and the underlying Puye Formation sediments (Figures 2.2-1 and 2.2-4). The deep perched zone beneath the TA-16 area is recharged along the Jemez mountain-front via the Pajarito Fault zone and along canyon bottoms. There is some indication from surface geophysics, water level data, and stream flow data that a component of the deep-perched groundwater may originate as recharge associated with infiltration along upper Cañon de Valle (Figures 2.2-2 and 2.2-4). There remains uncertainty regarding the degree of saturated versus unsaturated flow, lateral continuity of saturated zones, the degree of hydraulic connection between strata, and the groundwater flow path(s) and rate of recharge to the regional aquifer.

Based on existing data, the deep perched groundwater zone extends from west to east for more than 1.3 mi (2 km), and from north to south for approximately 0.6 mi (1 km). The deep-perched zone has been detected at R-26 screen 1; R-25b; R-25 screens 1, 2, 4; CdV-16-1(i); CdV-16-2(i)r; and R-47i (Figures 2.2-4 and 2.2-5). The deep-perched zone was not observed at R-18 and R-48, defining its north-south extent (Figures 2.2-4 and 2.2-5). It is believed that the low-hydraulic conductivity Tschicoma dacite observed in R-48 (~2000 ft south of Cañon de Valle) may limit the southward flow of water within the deep-perched system (Figure 2.2-4).

Water-level data indicate groundwater within the deep-perched system generally flows from west to east (Figure 2.2-5). There is some evidence of a southerly component of flow within the Otowi Member of the Bandelier Tuff in the vicinity of R-25, possibly due to recharge along Cañon de Valle. Water-level data from multiple screens in R-25 indicate that water levels within the deep-perched system are lower with depth, suggesting significant vertical anisotropy, with vertical hydraulic conductivities perhaps orders of magnitude lower than horizontal hydraulic conductivities in some strata.

Data from wells and drilling in the TA-16 area indicate that the deep perched groundwater system is characterized by a series of saturated horizons separated by unsaturated strata, as observed at screens 3 and 4 of R-25.

The deep-perched zone is present both within the Otowi Member of the Bandelier Tuff (R-25, R-25b, CdV-16-1[i]) and within the Puye Formation (CdV-16-2[i]r). The top of the overall deep perched groundwater system declines in elevation from west to east (Figure 2.2-4).

Based on water-level measurements from R-25 screen 1, R-25b, CdV-16-1(i), and observations during the drilling of R-25c, the portion of the perched zone within the Otowi Member of the Bandelier Tuff is believed to be vertically and laterally continuous, and may be perched on top of the Puye Formation on a thin, fine-grained horizon (paleosol) observed at R-25. Borehole video and formation micro-imager logs at CdV-16-1-(i) and R-25 screen 1 indicate that the Otowi Member in the TA-16 area is highly fractured.

Saturated conditions within the Puye Formation are believed to be more discontinuous vertically and laterally, as evidenced by the persistent saturation observed in R-25 screens 2 and 4, and the persistent lack of saturation observed in R-25 screen 3 and well R-25c. Because the Puye Formation is a highly-stratified proximal alluvial fan deposit; its hydraulic properties would be expected to be highly heterogeneous.

The specific nature of vertical connection between the deep-perched groundwater system and the regional aquifer is unknown.

### 2.2.2 Regional Groundwater

The regional aquifer in the vicinity of TA-16 is predominantly unconfined, with the water table located within the Puye Formation (Figure 2.2-4) at a depth of approximately 1300–1350 ft bgs. Most regional wells near TA-16 have screens installed near the regional water table; the exception is R-26 where the regional screen (screen 2) is placed deep (~319 ft) beneath the regional water table. Water levels in regional wells near TA-16 show little influence from transient effects of water-supply pumping (LANL 2006, 091450).

A water-table map of the regional aquifer near TA-16 is presented in Figure 2.2-6, incorporating preliminary water-level data from the R-47i open borehole and from well R-48. The water-table contours indicate that regional groundwater generally flows from west to east, with some perturbation near R-25, perhaps reflecting local recharge. Downgradient (east) of R-25, the regional groundwater flow direction incorporates a northerly component of flow, near R-18 and R-17. This may be a result of aquifer heterogeneity/anisotropy, or may reflect the influences of water-supply pumping.

### 2.2.3 Uncertainties

There remain uncertainties in the conceptual model for the deep-perched groundwater system. As discussed above, there are uncertainties due to limited data regarding the hydrogeologic properties of the deep-perched system, and the degree of lateral continuity and vertical hydraulic connectivity between saturated horizons is uncertain. Table 2.2-1 summarizes the hydraulic conductivity data based on single-well pumping tests conducted on wells completed in deep-perched and regional groundwater in the vicinity of TA-16. Single-well tests have been conducted on (1) the Cerro Toledo (Qct) interval of the Bandelier Tuff at screen 1 of R-26 (k = 0.9 m/d), (2) the Guaje Pumice beds at CdV-16-1i (k = 0.1 m/d), the Puye Formation at CdV-16-2i(r) (k = 0.9 m/d) and at R-47i (k = 0.1 m/d); and the Tschicoma Dacites at R-48 (k = 0.2 m/d; former CdV-16-3i) (Figure 1.1-1). Because drawdown and recovery responses were observed only in the pumping wells during these tests, storativity could not be determined.

The data summarized in Table 2.2-1 reflect localized hydraulic properties in the vicinity of the wells tested. Larger, field-scale hydraulic properties of the deep-perched groundwater system have not been measured, but are necessary to evaluate the feasibility of the pump-and-treat remedial alternative for groundwater remediation. The multi-well tests proposed in the next section of this work plan will provide field-scale measurements of formation transmissivity and storage coefficient, and will help to reduce the uncertainty regarding the deep-perched groundwater system, and the degree of hydraulic connection between perched strata.

## 3.0 FIELD TEST DESIGN

### 3.1 Objectives

One of the primary objectives of the aquifer tests is to characterize the hydrogeologic properties of the deep-perched zone near R-25. The total thickness of saturation within the perched zone is more than 400 ft (130 m). Based on the observations during drilling of R-25, R-25b, and R-25c, the perched zone is vertically stratified, with perching horizons of variable thickness and unknown hydraulic interconnection.

The large-scale hydraulic conductivity estimates, storage coefficient and hydraulic gradient are important parameters for considering the viability of the pump-and-treat remedial alternative. Model predictions of the pumping drawdown propagation through the deep-perched zone are significantly affected by the storage coefficient. Model predictions of transient capture zones of the pumping wells proposed for any type of pump-and-treat system are impacted by the large-scale hydraulic conductivity, the effective porosity and the ambient groundwater flow velocity. Steady-state capture zones are dependent on hydraulic conductivity and ambient groundwater gradient.

The aquifer tests will allow estimating of the large-scale hydraulic conductivity and storage coefficient (specific yield) of the deep-perched zone. The tests will also provide information about the relative degree of hydraulic connection between the deep-perched groundwater and the regional aquifer, based on pressure responses within the regional screens of R-25. A tracer test is also proposed to supplement the pumping test results, and to provide additional information regarding the connectivity within discrete perched horizons.

Key objectives of the proposed pumping tests include

- acquiring field-scale measurements of hydrogeologic properties, such as formation transmissivity and storage coefficient, necessary to evaluate the viability of the pump-and-treat remedial alternative for groundwater remediation;
- evaluating lateral and vertical hydraulic connectivity within the perched zone;
- providing data regarding concentrations of contaminants in the vicinity of the test well;
- potentially evaluating heterogeneity/anisotropy of the flow medium;
- evaluating boundary conditions to assess the lateral extent of the deep-perched zone; and
- potentially providing information about the hydraulic connectivity between the deep-perched zone and the regional aquifer.

Key objectives of the proposed tracer test include

- providing additional data for refining the conceptual model of groundwater flow at the site and
- providing information regarding the connectivity within discrete perched horizons.

## 3.2 Test Well Location and Design

The proposed CdV-16-4ip pumping well location, shown in Figure 1.1-2, is east of the current cluster of observation wells that include multiple-well screens at R-25 and single-well screens at R-25b, R-25c, and CdV-16-1(i). This location is selected to optimize the spatial distribution of potential pressure responses from the observation wells. The distances of the observation wells from the pumping well range between 372 and 483 ft (Table 3.2-1). Pressures will also be monitored at well CdV-16-2(ir) during the test, but it is probably too far from CdV-16-4ip (1224 ft) to produce a measurable response to pumping.

Well CdV-16-4ip will be drilled to a depth of 1150 ft using fluid-assisted, air-rotary drilling methods. Drilling fluids will include municipal water and AQF-2 foam to a depth of 700 ft; an attempt will be made to use only municipal water for circulation below 700 ft in order to minimize the effects of drilling fluids on the groundwater chemistry and formation hydraulic properties. Surface casing will be advanced to a depth of 700 ft, and an attempt will be made to drill an open borehole to 1150 ft so that the perched groundwater zone can be characterized by open-borehole geophysical logs. If borehole conditions become unstable, the borehole may be advanced to total depth using drill casing, limiting geophysical analyses to a cased-hole suite.

Characterization of CdV-16-4ip will include (1) a lithologic log prepared from drill cuttings, (2) water-level measurements in the borehole during drilling and in the completed well, (3) groundwater samples collected during well development, (4) driller's observations about drilling conditions and water production, (5) borehole video and geophysical logs, and (6) aquifer tests conducted in conjunction with the pumping tests at the completed well. Details of these characterization activities will be included in a separate drilling work plan submitted for well CdV-16-4ip.

CdV-16-4ip will be constructed as a 5-in. inside-diameter, stainless-steel well with two 20-slot, wire-wrapped well screens, 40 to 60 ft in length. The upper screen will be located near the top of saturation in the Otowi Member of the Bandelier Tuff (where the highest HE-contamination levels are consistently observed), and the lower screen will be located in the Puye Formation. Well screen depths and lengths will be selected based on characterization data collected during drilling. The primary filter packs for each screen will extend 5 ft above and 5 ft below the screen openings. A 2-ft secondary filter pack will be placed above each primary filter pack. Bentonite above and below the filter packs will provide isolation between screens in the well annular space, and a packer will be used to isolate the screens inside the well casing.

## 3.3 Pumping Test Design

Pumping tests at two wells completed in the deep-perched groundwater, R-25b and CdV-16-4ip, are proposed in this work plan. The design of the pumping tests is based on the following assumptions about the hydrogeologic properties of the perched zone:

- Hydraulic conductivity estimates for the Puye Formation near TA-16 range over several orders of magnitude (Table 2.2-1). Limited information is also available for the hydraulic conductivity of the Otowi Member of the Bandelier Tuff. It is assumed that the effective hydraulic conductivity for both units is about ~1 ft/d (0.3 m/d), which can be considered to be a low estimate, taking into account the relatively long length of the well screens (40 to 60 ft) in the proposed test well. The long screen will allow the pumping well to capture groundwater flow through more conductive sections of the pumped strata. As a result, the actual effective hydraulic conductivity might be higher than the low estimate above.

- The specific yield of the deep-perched zone may be relatively high. The specific yield characterizes the capacity of the deep-perched zone to release groundwater from storage in response to a decline in hydraulic head. Specific yield, also known as the drainable porosity, is typically less than or equal to the effective porosity in unconfined aquifers. The total porosity of the Puye Formation can be as high as 0.3. Similar porosity values are expected in the Bandelier Tuff. However, due to stratification of the Puye Formation, the groundwater flow in the deep-perched zone is expected be affected by local zones of confinement that can reduce the specific yield by orders of magnitude. A similar effect has been observed during some of the other pumping tests conducted in the Puye Formation. A range of storage coefficient values characterizing different flow conditions (S = 0.3, 0.03, and 0.003) was used to evaluate the range of possible drawdown responses during the proposed pumping tests.

### 3.3.1 Pumping Test at R-25b

A 24-hr pumping test will be conducted on R-25b, although this well has a relatively low yield (<1 gpm). During the test, pressure responses will be monitored at all functioning screens of R-25 and CdV-16-1(i).

To design the pumping tests, the following assumptions are made about the hydrogeologic properties of the perched zone:

- The saturated thickness at R-25b is on the order of 11 ft (~3.4 m). The screen interval is from 750 to 770 ft bgs; and the water-level is about 759 ft bgs. The screen is not submerged, and the water level is within the screen interval.
- Transmissivity is assumed to be 11 $ft^2$/d (~1 $m^2$/d) based on conservative hydraulic conductivity and saturated-thickness estimates.
- It is assumed that the screen can sustain pumping at a rate of about 0.6 gpm.

Based on assumed hydrogeologic properties, a pumping rate of 0.6 gpm will cause several ft of drawdown at the pumping well. The pumping rate might be sufficient to cause observable drawdown at R-25, which is about 16 m from R-25b. Figure 3.3-1 shows predicted drawdown versus distance from the pumping well (R-25b) for a series of specific yield values after 1 d of pumping at 0.6 gpm. The figure suggests that 1 d of pumping could be sufficient to observe cross-hole responses if the storage coefficient is on the order of 0.003. The actual duration of the pumping test will be determined based on drawdown observed at R-25b and R-25.

### 3.3.2 Pumping Test at CdV-16-4ip

The pumping test well, CdV-16-4ip, will be located 372 ft from R-25 and 483 ft from CdV-16-1i. The location is selected to allow detection of drawdown responses in both R-25 and CdV-16-1(i). Observing pressure response in multiple monitoring wells will result in (1) a better estimate of specific yield of the deep-perched zone and (2) may allow potential evaluation of aquifer heterogeneity/anisotropy. Multiple-well aquifer testing should yield better estimates of hydraulic conductivity than single-well testing, as cross-hole responses will be less influenced by well skin or well completion artifacts.

The proposed pumping well will have two screen zones 40 to 60 ft in length, and separate pumping tests will be conducted on each screened zone. The actual location and configuration of the screens will depend on hydrogeologic conditions encountered during drilling and will be based on data from cuttings, geophysics, and drillers observations. During each aquifer test, pressure responses will be monitored in the test well (CdV-16-4ip) and in functioning screens of R-25, R-25b,CdV-16-1i, and CdV-16-2-ir. Figure 3.3-2 presents a cross-section showing the spatial relationships between the screens of the pumping well (CdV-16-4ip) and the observation wells.

To design the pumping tests, the following assumptions are made about the hydrogeologic properties of the deep-perched zone.

- The total thickness of the deep-perched zone is about 400 ft near R-25. However, saturation thickness is expected to decline to the east of R-25. It is assumed that each of the test well screens will be fully submerged. Although the actual screen length may range from 40 to 60 ft, a saturated-thickness value of 50 ft was assumed for each zone in the analyses below.
- Transmissivity of the deep perched zone at each well screen is assumed to be 50 $ft^2/d$ (~4.6 $m^2/d$) based on conservative hydraulic conductivity and saturated-thickness estimates.
- Based on the well diameter, a pump with capacity of up to 30 gpm can be used during the pumping test. This should be sufficient to allow each screened interval to be pumped near its maximum rate.

Based on these assumptions, the predicted drawdown versus distance from the pumping well for a range of specific yield values after 1 and 10 d of pumping is shown in Figures 3.3-3 and 3.3-4, respectively. As the storage coefficient value increases (i.e., approaches unconfined values), the radius of influence is diminished. The figures suggest that 1 d of pumping may not be sufficient to cause drawdown responses at R-25 and CdV-16-1i. The anticipated storage coefficient may be on the order of 0.03 or higher. The projected drawdown calculations indicate that a 10-d pumping test may be sufficient to produce drawdown responses at R-25 and CdV-16-1i. The actual duration of the pumping tests will be determined based on drawdown responses at R-25 and CdV-16-1i. If significant drawdown responses are measured during the early part of the test, the test may be not need to be conducted over the full 10-d period. Alternatively, if no pressure responses are observed in R-25 and CdV-16-1i during 10 d of pumping, the duration of the test may be extended, if necessary.

### 3.4 Tracer Test

An ambient-flow tracer test is proposed, to be conducted using well R-25b as the injection point and well screens at R-25 as observation points, to obtain information regarding the vertical connectivity within the deep-perched zones, and possibly within the regional aquifer in the vicinity of these two wells. The data collected from this test will supplement the aquifer pumping tests described above by providing an additional means of evaluating connectivity within discrete perched horizons. Although the tracer test may not provide quantitative information on travel times (using breakthrough curves) between the wells and between specific horizons, the test may provide key insights into general connectivity of the zones and may be especially useful in the event that no response is observed in R-25 screens from pumping at the new pumping well. It is proposed that the tracer test would be initiated following the pumping test at R-25b and prior to the pumping test conducted with the new pumping well. The goal of the tracer test is to evaluate flow under ambient conditions. A nonreactive tracer would be released from R-25b, and concentrations monitored over time during routine groundwater sampling of the various screens at R-25.

## 4.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

This section describes the management of the investigation-derived waste (IDW) to be generated from the drilling and aquifer testing activities proposed in this work plan. All IDW will be managed in accordance with Standard Operating Procedure (SOP) EP-SOP-5238, Characterization and Management of Environmental Program Waste (http://www.lanl.gov/environment/all/qa/adep.shtml). This SOP incorporates the requirements of applicable EPA and NMED regulations, U.S. Department of Energy orders, and LANL requirements. The primary waste streams include drill cuttings, drilling water, development water, purge water, groundwater from aquifer testing, decontamination water, and contact waste.

Drill cuttings will be managed in accordance with the NMED-approved Notice of Intent (NOI) Decision Tree for Land Application of IDW Solids from Construction of Wells and Boreholes (November 2007). All waters (i.e., drilling, development, purge and groundwater from aquifer testing), with the exception of decontamination waters, will be managed in accordance with the NMED-approved NOI Decision Tree for Drilling, Development, Rehabilitation, and Sampling Purge Water (November 2006). Initially, drill cuttings and drilling water will be stored in lined pits. The drill cuttings may contain drilling additives (i.e., drilling foam and bentonite clay). The contents of the pits will be characterized with direct sampling following completion of drilling activities, and waste determinations will be made from validated data. If validated analytical data show these wastes cannot be land-applied, they will be removed from the pit, containerized, and placed in accumulation areas appropriate to the type of waste. Cuttings, drilling water, development water, purge water, and groundwater from aquifer testing that cannot be land-applied and are designated as hazardous waste will be sent to an authorized treatment, storage, or disposal facility within 90 d of containerization.

Development water, purge water, groundwater from aquifer testing, and decontamination water will be containerized separately at their point of generation, placed in an accumulation area appropriate to the type of waste, and directly sampled. Contact waste will be containerized at the point of generation, placed in an appropriate accumulation area, and characterized using acceptable knowledge of the media with which it came in contact.

Significant volumes of water may be generated during the aquifer tests planned for the test well, CdV-16-4ip. Assuming a pumping rate of 15 gpm and a test duration of 10 d for each screen, the total pumped groundwater may be on the order of 430,000 gal. Purge water from each screened interval will be sampled for waste characterization. The data will be evaluated against criteria in the NMED-approved NOI Decision Tree document or its successor. If the criteria in the decision tree are met, the purge water will be land-applied. Otherwise it will be disposed of at an appropriate on-site or off-site facility.

## 5.0 SCHEDULE

The proposed pumping test well (CdV-16-4ip) is scheduled for completion by September 30, 2010, consistent with the Laboratory’s proposed date for this well as submitted in the Proposed Integrated Well Installation Schedule submitted to NMED on October 14, 2009 (LANL 2009, 107088).

The results of the tests proposed in this work plan will be presented in a report to NMED by March 25, 2011.

## 6.0 REFERENCES

*The following list includes all documents cited in the main body of this plan. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.*

*Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.*

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NMED (New Mexico Environment Department), January 26, 2009. "Approval with Modifications, Suppl[e]mental Investigation Work Plan for Intermediate and Regional Groundwater at TA-16 (Consolidated Unit 16-021(c)-99)," New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2009, 104973)

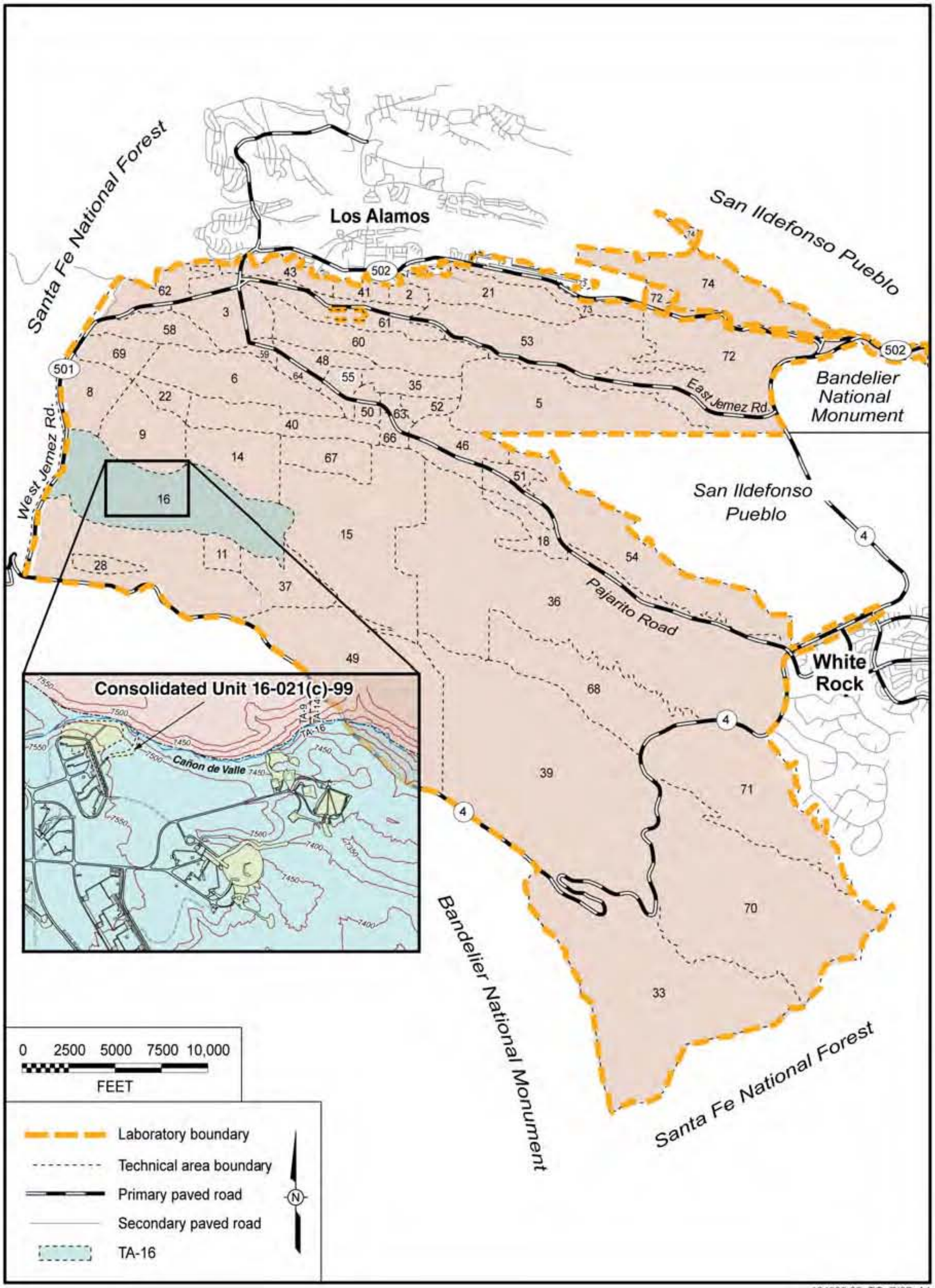



**Figure 1.0-1 Location of TA-16 with respect to Laboratory technical areas and surrounding land holdings; Consolidated Unit 16-021(c)-99 is also shown**

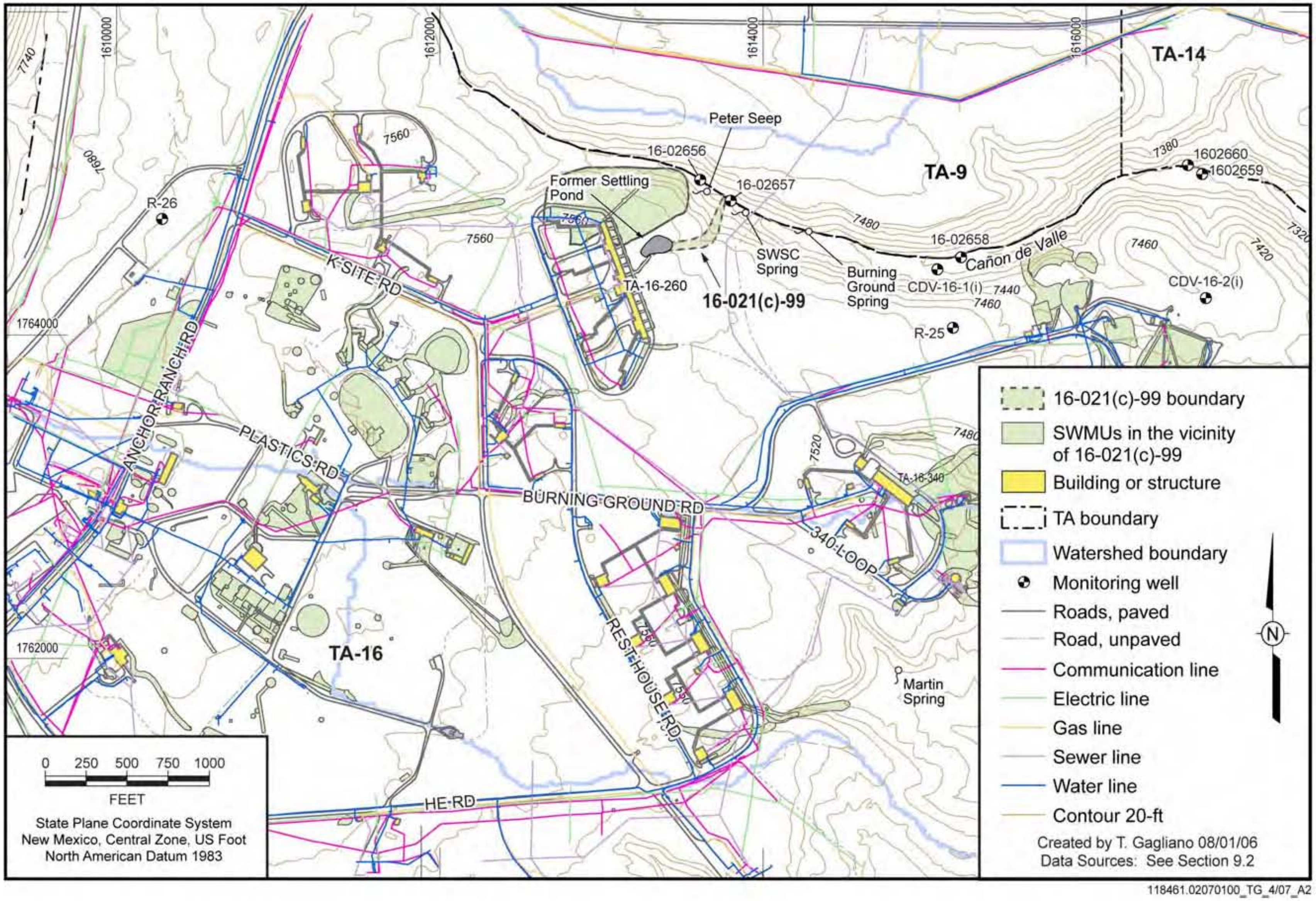



**Figure 1.0-2 Location of Consolidated Unit 16-021(c)-99 and associated features**

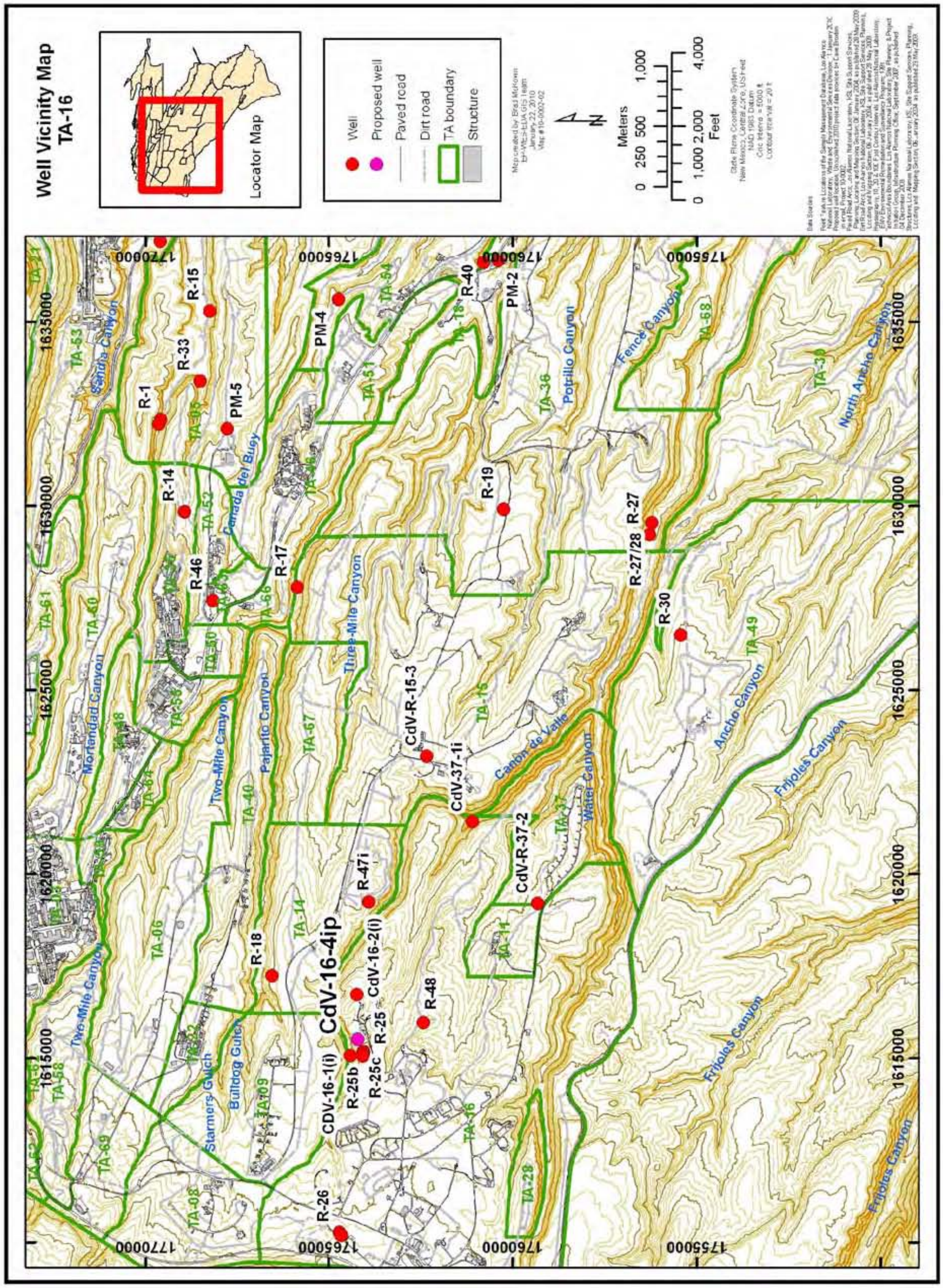



**Figure 1.1-1 Locations of wells in the vicinity of TA-16**

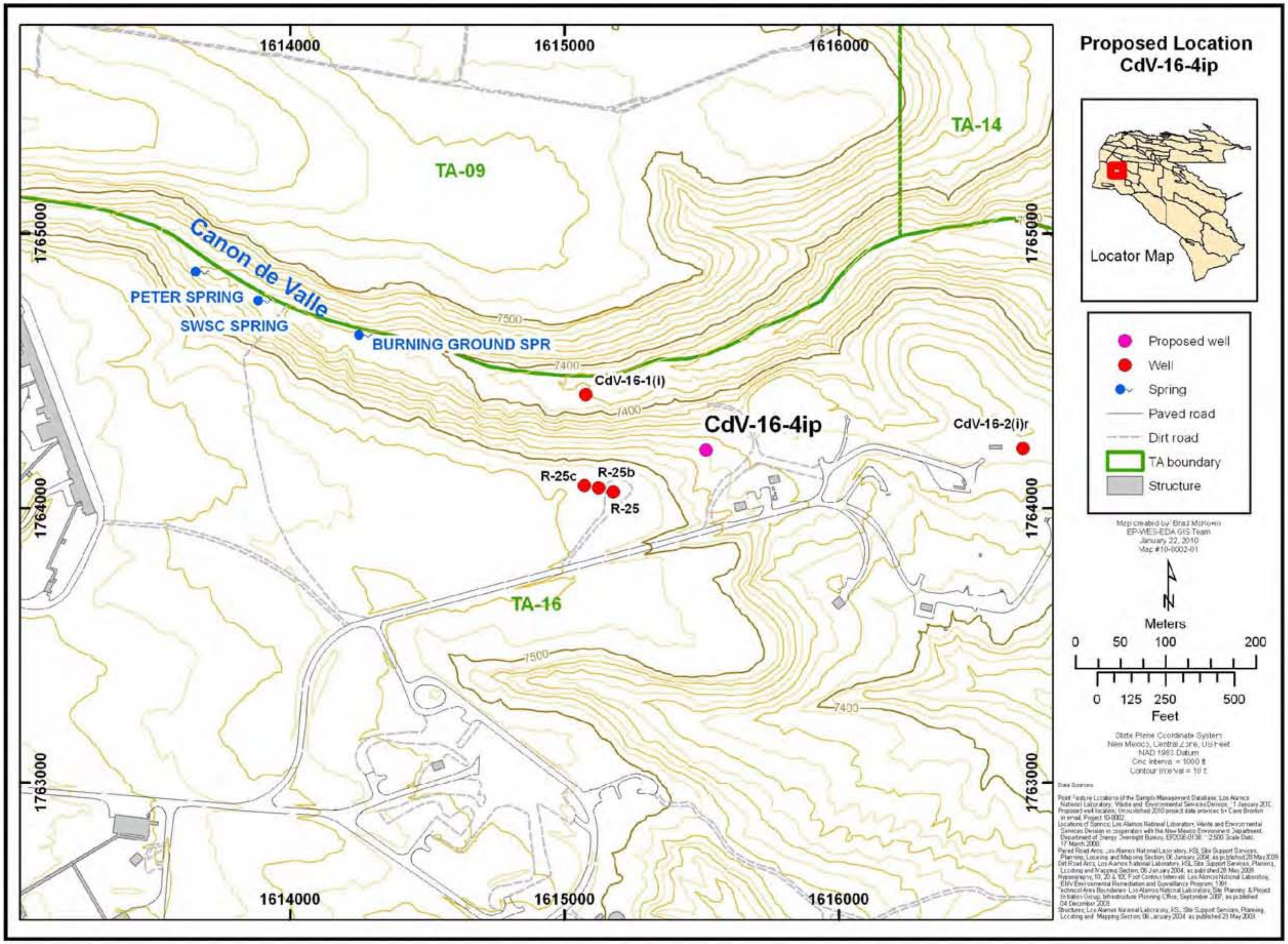



Figure 1.1-2 Location of proposed test well CdV-16-4ip

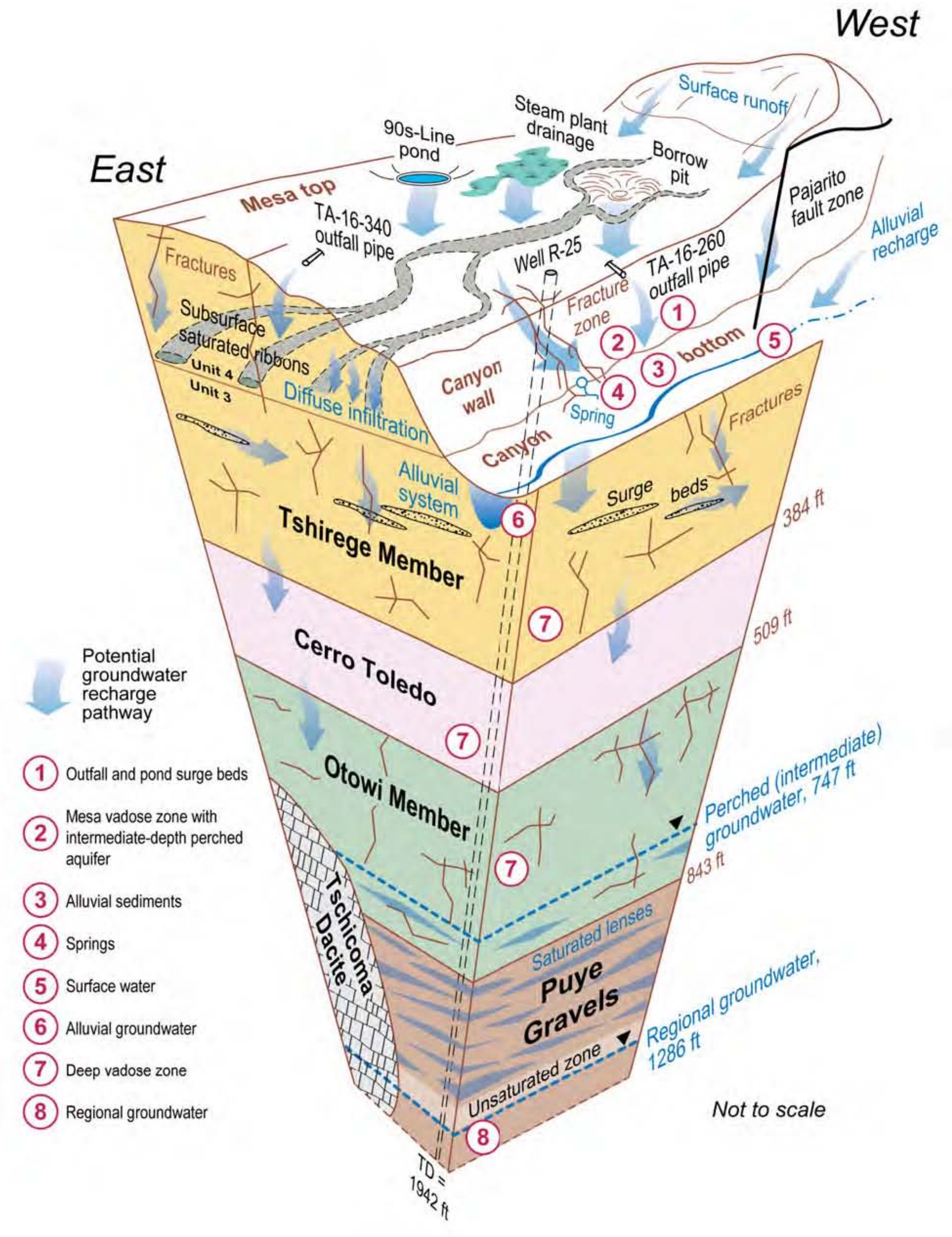



**Figure 2.2-1 Conceptual site model for contaminant transport at TA-16, with focus on the outfall source region, alluvial system, and mesa vadose zone**

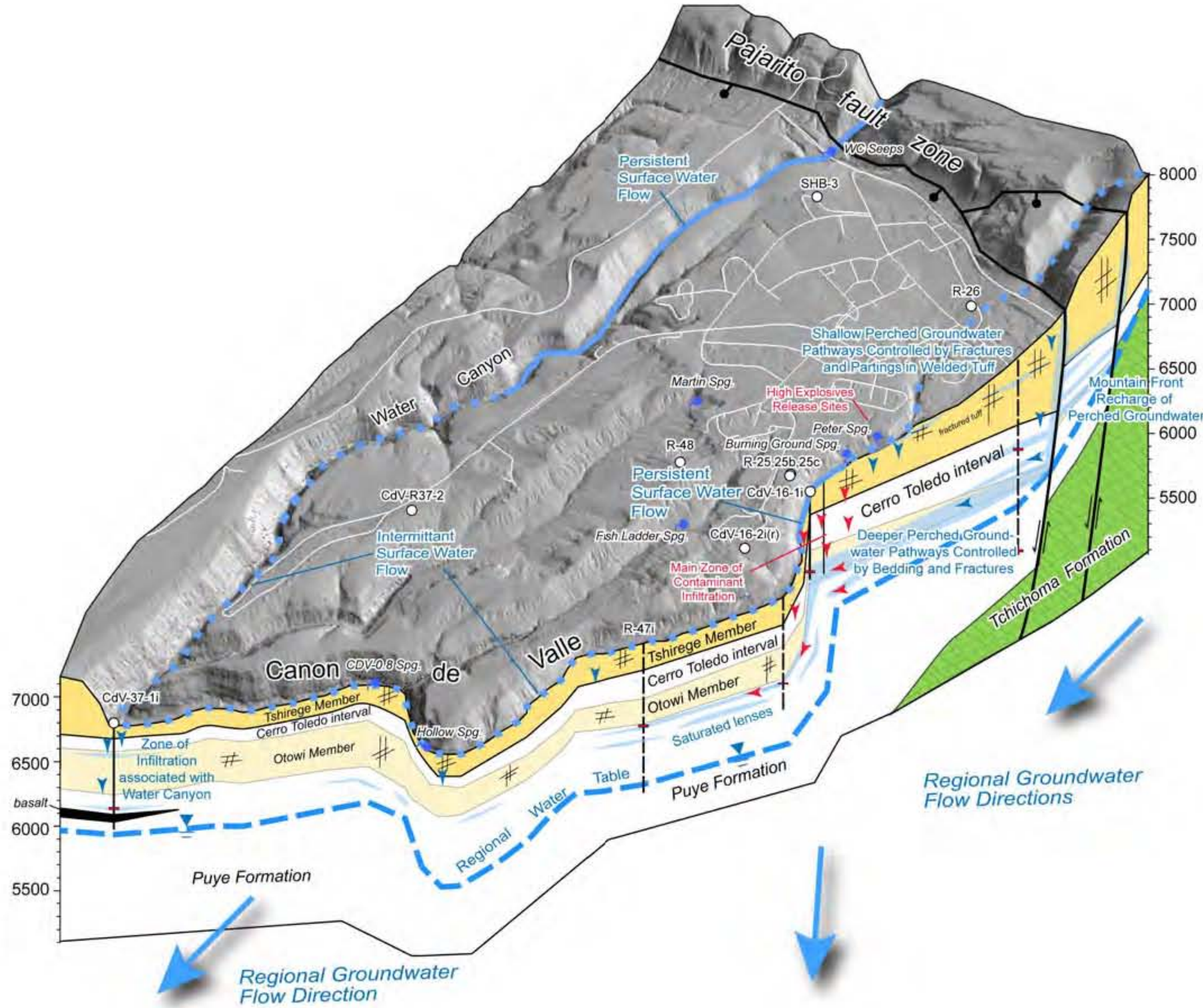



**Figure 2.2-2 Conceptual site model for contaminant transport at TA-16, with focus on deep-perched and regional groundwater**

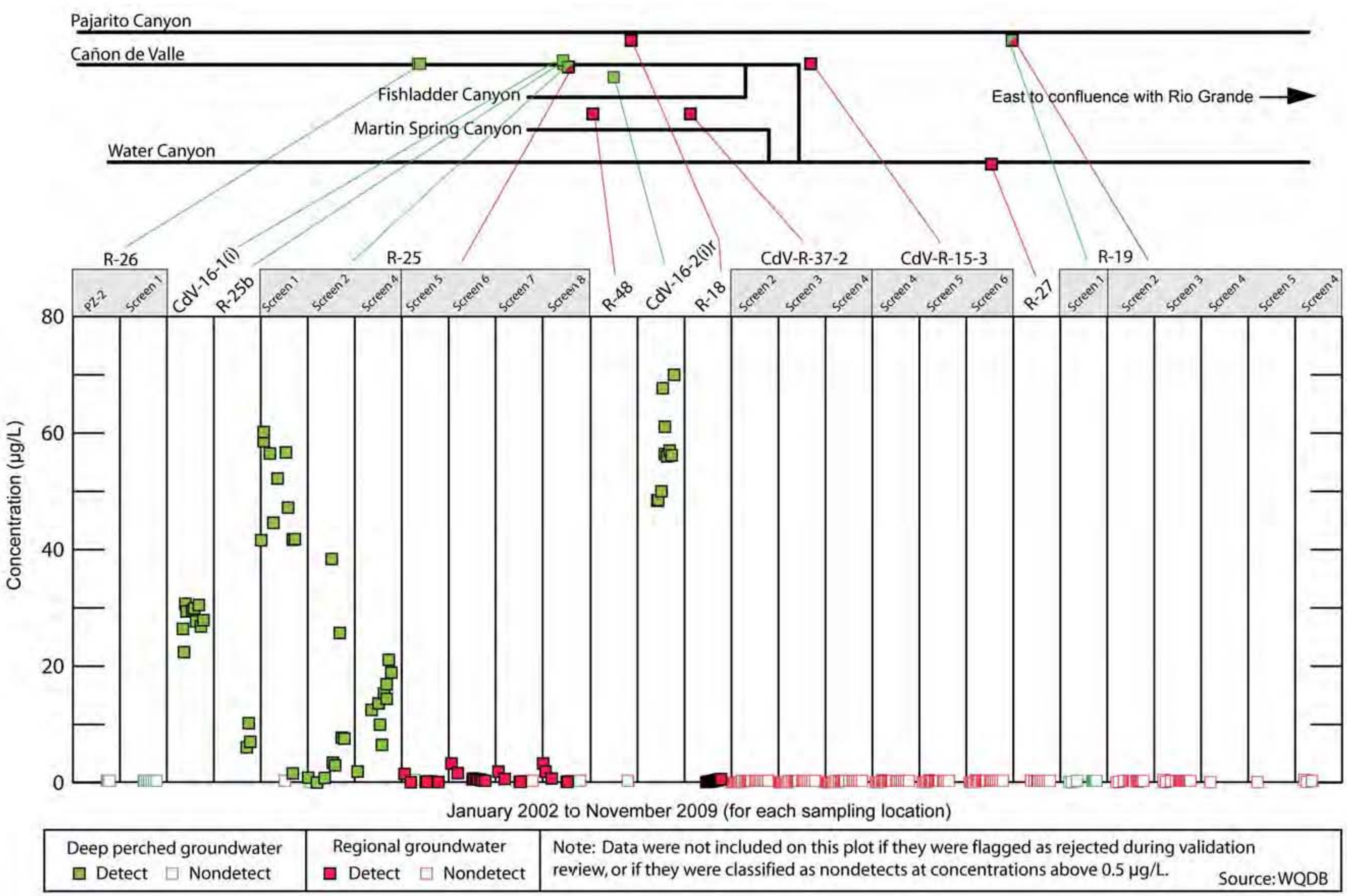



**Figure 2.2-3 RDX concentrations in deep-perched and regional groundwater monitoring wells**

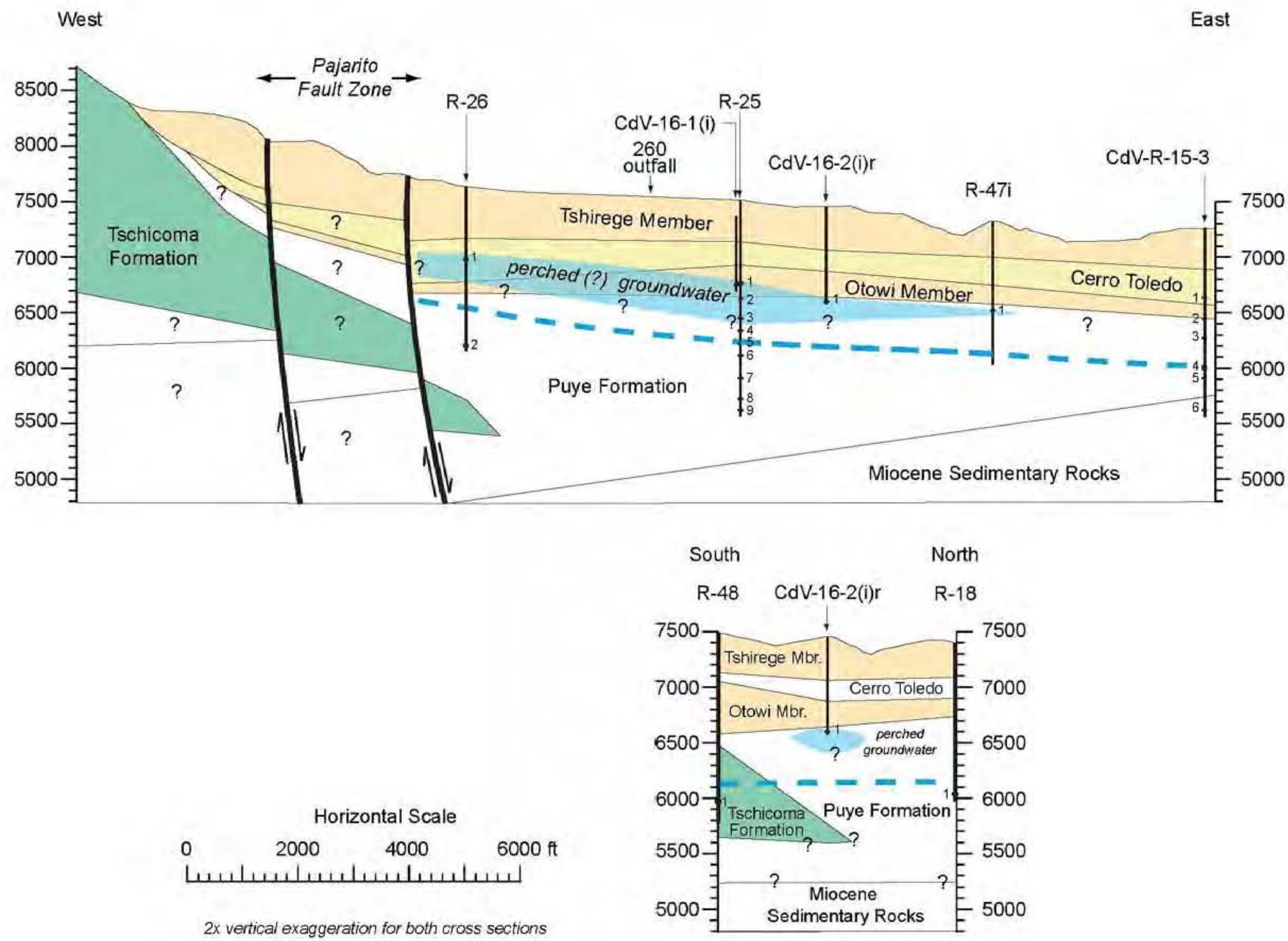



**Figure 2.2-4 Geologic cross-sections (east-west and north-south) through the northern portion of TA-16**

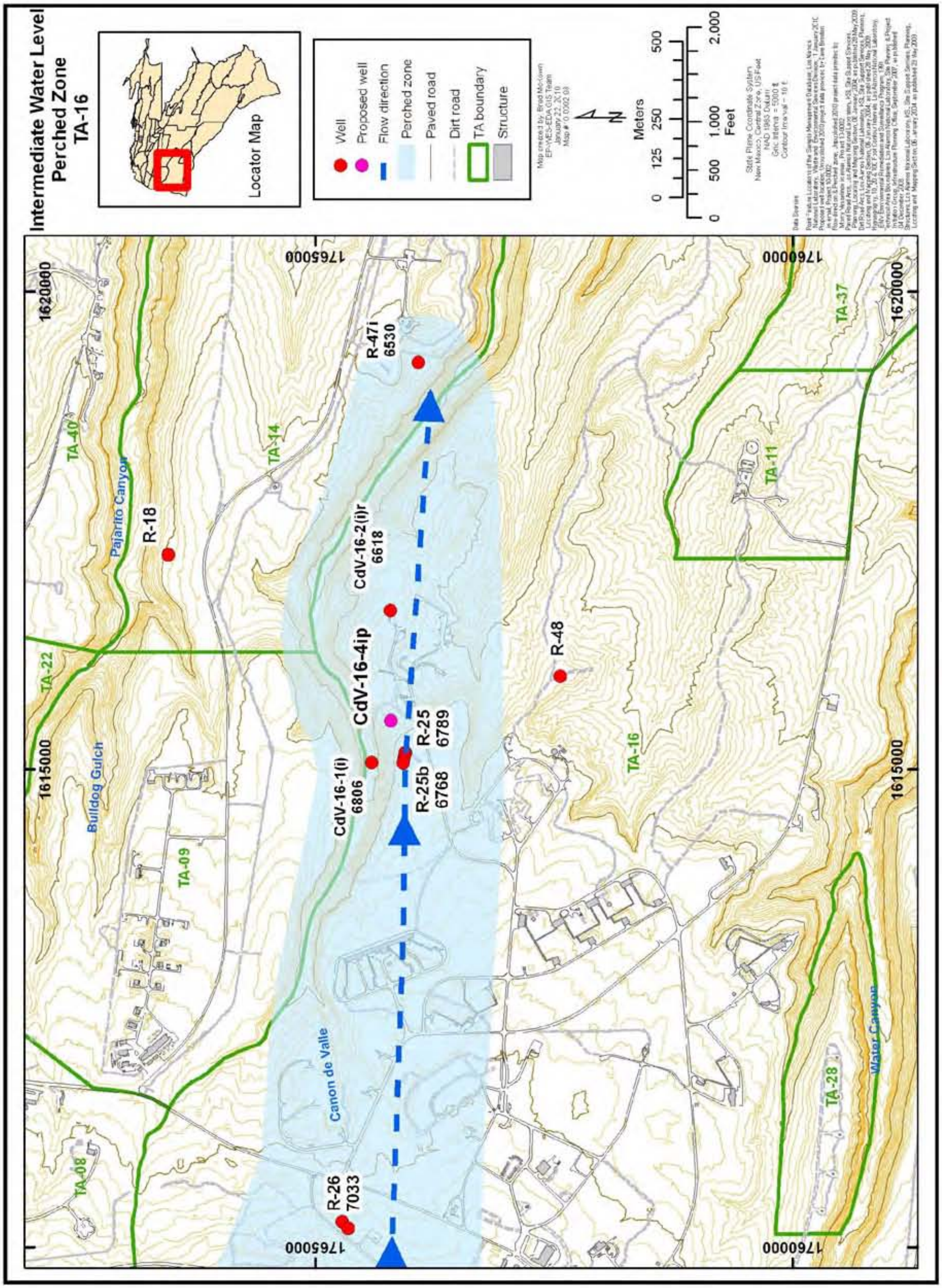



**Figure 2.2-5 Map of water-levels within the deep-perched zone beneath TA-16**

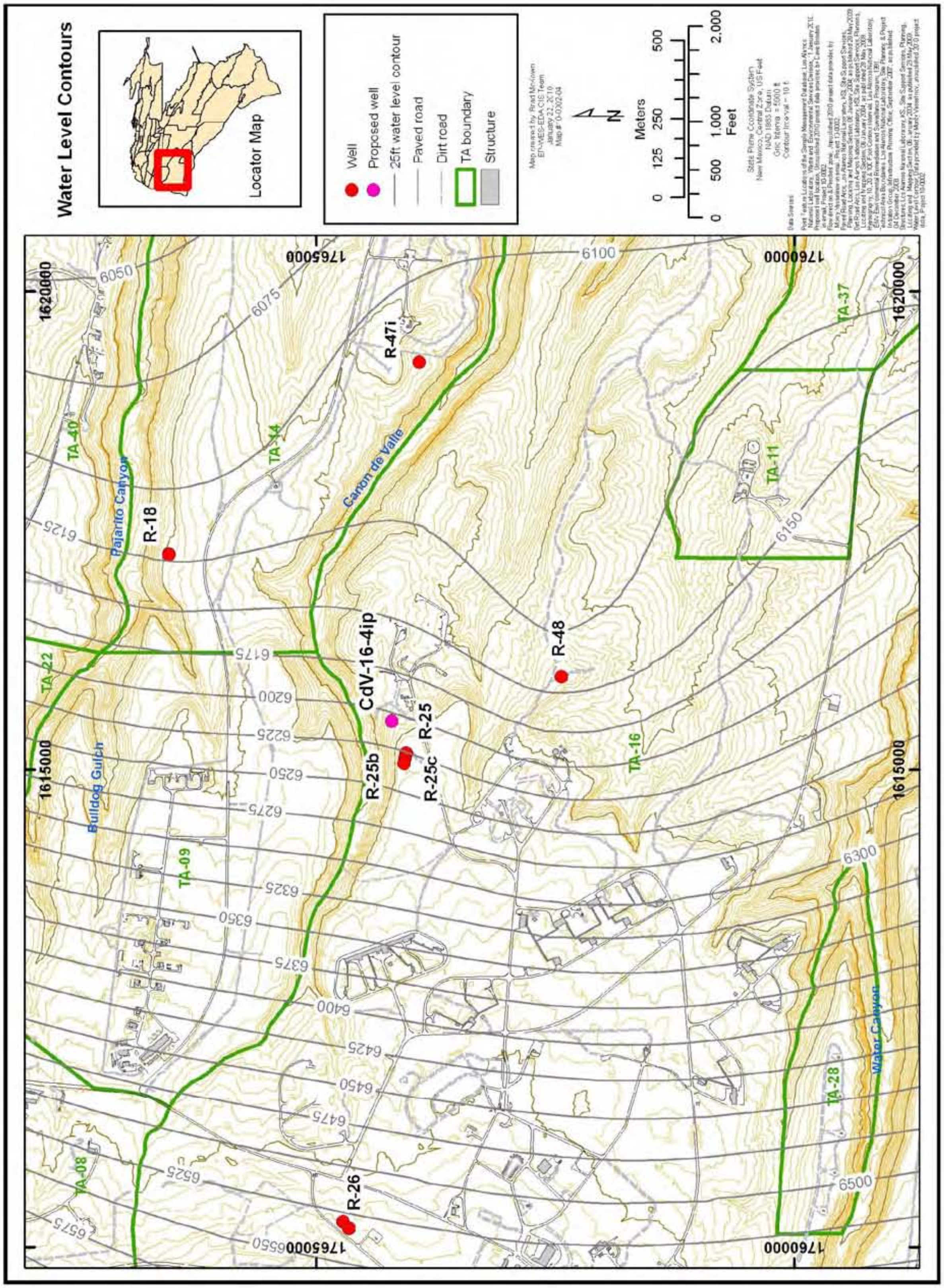
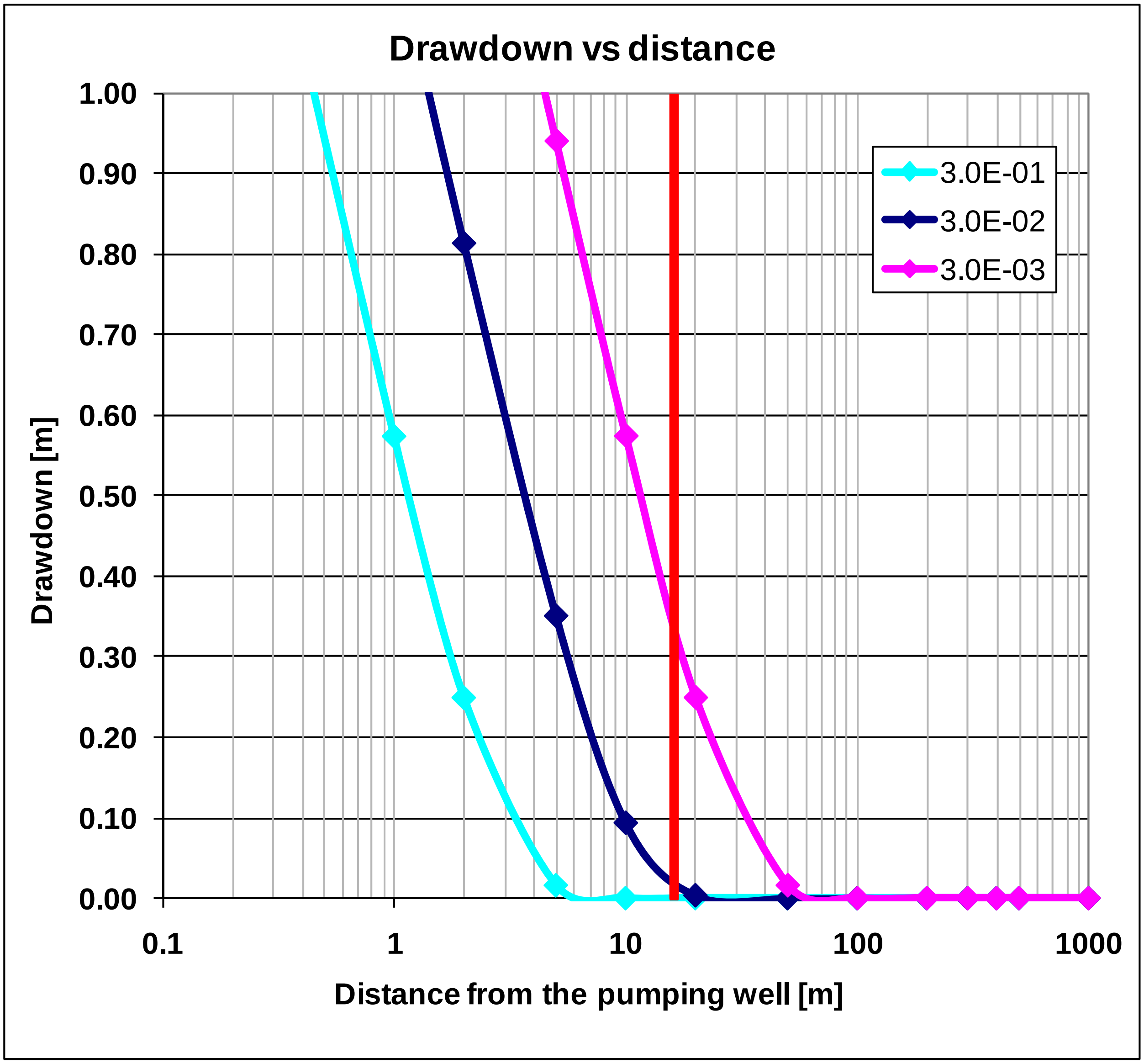



**Figure 2.2-6 Water-table map for the regional aquifer based on preliminary water-level information from wells R-47 and R-48**




Note: Red line marks the distance from pumping well R-25b to observation well R-25

**Figure 3.3-1 Estimated drawdown versus distance from pumping well R-25b for a series of specific yield values after 1 d of pumping at 0.6 gpm**

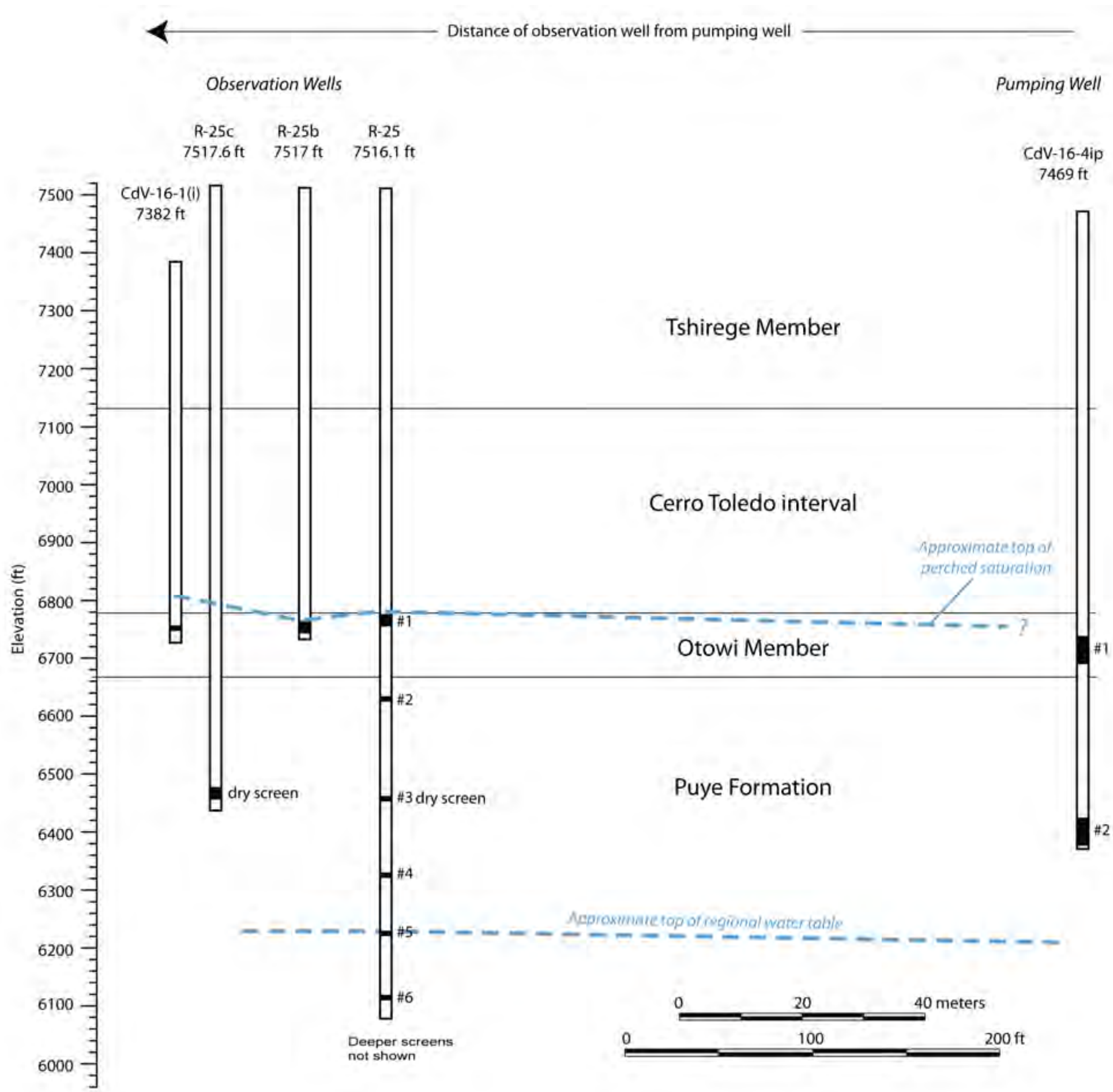
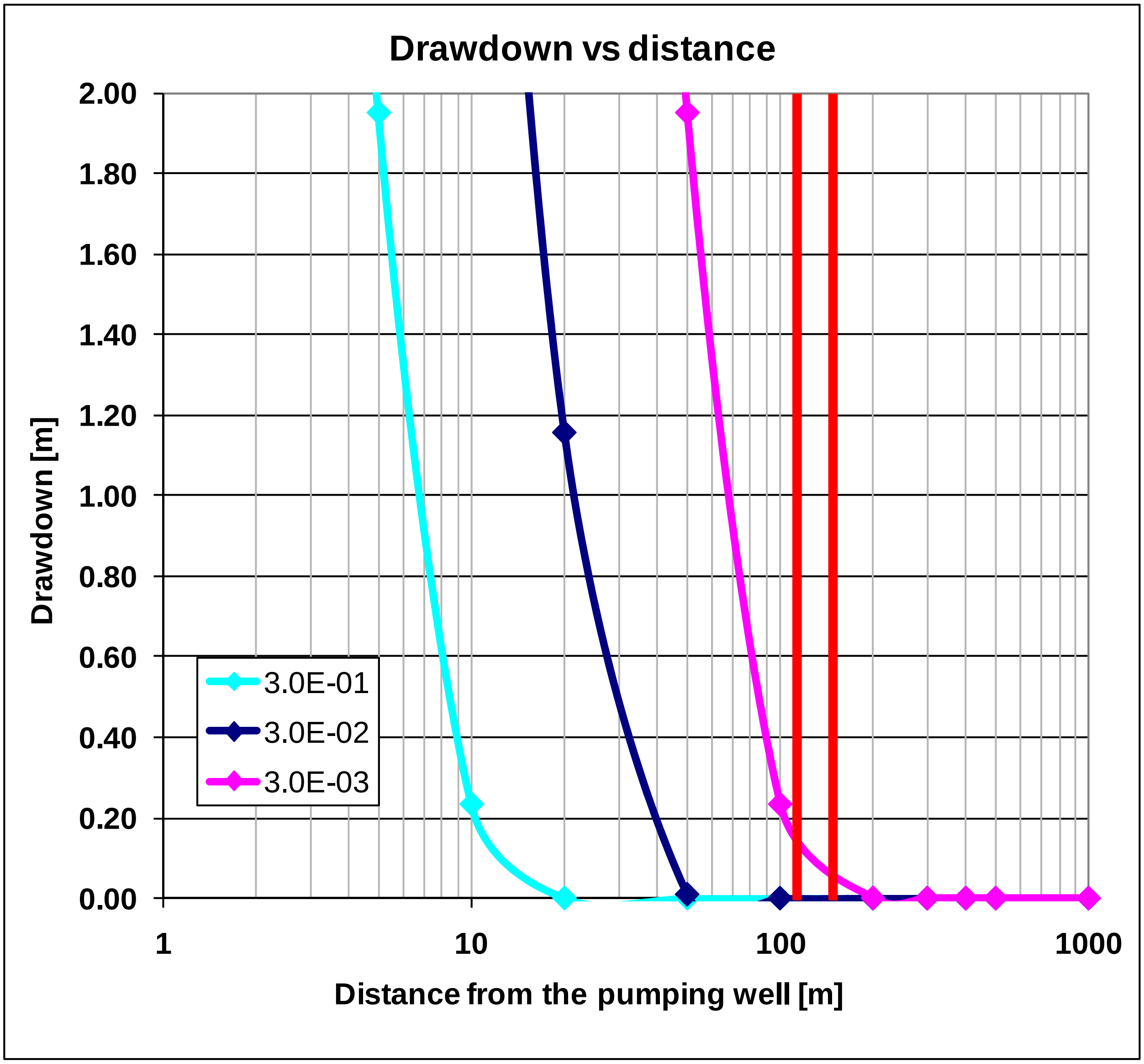
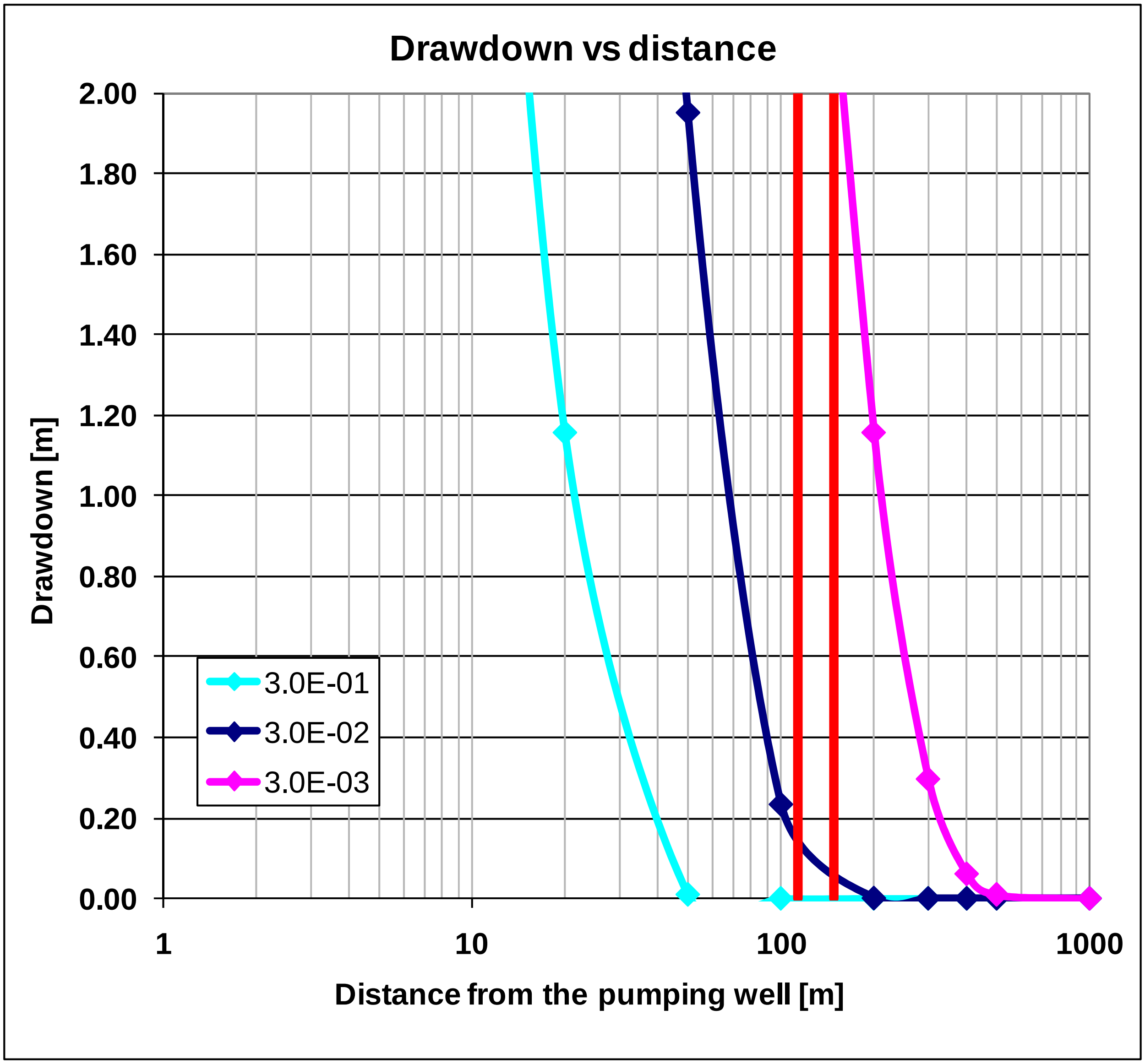



**Figure 3.3-2 Conceptual layout of pumping test showing the depths of observation well screens relative to pumping well screens**




Note: Red lines delineate the distance from pumping well CdV-16-4ip to observation wells R-25 and CdV-16-1(i).

**Figure 3.3-3 Estimated drawdown versus distance from pumping well CdV-16-4ip for a series of specific yield values after 1 d of pumping at 15 gpm**




Note: Red lines delineate the distance from pumping well CdV-16-4ip to observation wells R-25 and CdV-16-1(i).

**Figure 3.3-4 Estimated drawdown versus distance from pumping well CdV-16-4ip for a series of specific yield values after 10 d of pumping at 15 gpm**

**Table 2.2-1**
**Hydraulic Conductivity Estimates for Wells in the Vicinity of TA-16**

| Well | Geologic Unit | Completion Zone | Dry | k (ft/d) | k (m/d) |
|---|---|---|---|---|---|
| CdV-R-15-3-1 | Qbof | Intermediate | Dry | —* | — |
| CdV-R-15-3-2 | Qbog | Intermediate | Dry | — | — |
| CdV-R-15-3-3 | Tpf | Intermediate | Dry | — | — |
| CdV-R-15-3-4 | Tpf | Regional | — | — | — |
| CdV-R-15-3-5 | Tpf | Regional | — | — | — |
| CdV-R-15-3-6 | Tpf | Regional | — | — | — |
| CdV-R-37-2-1 | Tpf | Intermediate | Dry | — | — |
| CdV-R-37-2-2 | Tvt2 | Regional | — | — | — |
| CdV-R-37-2-3 | Tvt2 | Regional | — | — | — |
| CdV-R-37-2-4 | Tvt2 | Regional | — | — | — |
| CdV-16-1(i) | Guaje Pumice | Intermediate | — | 0.5 to 0.7 | 0.18 |
| CdV-16-2(i) | Tpf | Intermediate | Dry | No test | |
| CdV-16-2(i)r | Tpf | Intermediate | — | 3 | 0.91 |
| CdV-16-3(i) | Tsch | Intermediate | Dry | No test | |
| R-1 | Tjfp | Regional | — | 5 | 1.65 |
| R-14#1 | Tpf/Tjfp | Regional | — | No test | |
| R-14#2 | Tjfp | Regional | — | 1 | 0.31 |
| R-17#1 | Tpf | Regional | — | 2 | 0.52 |
| R-17#2 | Tpf | Regional | — | 147 | 44.81 |
| R-18 | Tpf | Regional | — | 6 | 1.88 |
| R-19#1 | Qbog | Intermediate | Dry | — | — |
| R-19#2 | Tpf | Intermediate | Dry | — | — |
| R-19#3 | Tpf | Regional | — | — | — |
| R-19#4 | Tpf | Regional | — | — | — |
| R-19#5 | Tjfp | Regional | — | — | — |
| R-19#6 | Tjfp | Regional | — | 19 | 5.76 |
| R-19#7 | Tjfp | Regional | — | 23 | 7.14 |
| R-25#1 | Qct | Intermediate | — | No test | — |
| R-25#2 | Tpf | Intermediate | — | No test | — |
| R-25#3 | Tpf | Intermediate | — | Damaged | — |
| R-25#4 | Tpf | Intermediate | — | No test | — |
| R-25#5 | Tpf | Regional | — | No test | — |
| R-25#6 | Tpf | Regional | — | No test | — |
| R-25#7 | Tpf | Regional | — | No test | — |
| R-25#8 | Tpf | Regional | — | No test | — |
| R-25b | Qct | Intermediate | — | No test | — |

**Table 2.2-1 (continued)**

| Well | Geologic Unit | Completion Zone | Dry | k (ft/d) | k (m/d) |
|---|---|---|---|---|---|
| R-25c | Tpf | Intermediate | — | No test | — |
| R-26#1 | Qct | Intermediate | — | 3 | 0.91 |
| R-26#2 | Tpf | Regional | — | 0.002 | 0.0006 |
| R-27 | Tpf | Regional | — | 5 | 1.52 |
| R-47i | | Intermediate | — | 0.2 | 0.061 |
| R-48 | Tpf | Regional | — | 0.8 | 0.24 |

* — = Not available.

**Table 3.2-1**
**Observation Well Distance from Pumping Well CdV-16-4ip**

| Observation Well Name | Distance (ft) from Pumping Well |
|---|---|
| R-25 | 372 |
| R-25b | 415 |
| R-25c | 462 |
| CdV-16-1(i) | 483 |
| CdV-16-2(i)r | 1224 |