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John Kieling, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

**Subject: Status Report for the Tracer Tests at Consolidated Unit 16-021(c)-99, Technical Area 16**

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Status Report for the Tracer Tests at Consolidated Unit 16-021(c)-99, Technical Area 16. This report is being submitted to fulfill a milestone requirement in Appendix B of the Compliance Order on Consent, signed June 24, 2016. The milestone is for a summary report of tracer testing activities and tracer test data and is due February 14, 2017.

This report provides information on tracer deployments in perched intermediate groundwater at Technical Area 16 and summarizes tracer monitoring data for the period from December 2015 through September 2016.

If you have any questions, please contact Stephani Swickley at (505) 606-1628 (sfuller@lanl.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
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Sincerely,

David S. Rhodes, Director
Office of Quality and Regulatory Compliance
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BR/DR/SS/TG:sm

Enclosures: Two hard copies with electronic files – Status Report for the Tracer Tests at Consolidated Unit 16-021(c)-99, Technical Area 16 (EP2017-0009)

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February 2017
EP2017-0009

# Status Report for the Tracer Tests at Consolidated Unit 16-021(c)-99, Technical Area 16

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Associate Directorate for Environmental Management

EP2017-0009

# Status Report for the Tracer Tests at Consolidated Unit 16-021(c)-99, Technical Area 16

February 2017

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## EXECUTIVE SUMMARY

This report provides information on tracer deployments and subsequent tracer monitoring in perched-intermediate and regional groundwater in the vicinity of Technical Area 16 (TA-16) at Los Alamos National Laboratory. Results from two small-scale dilution tests and a series of large-scale, multi-year tracer tests are described along with details of the various deployments. The TA-16 tracer study is being conducted to test connectivity of various parts of the TA-16 hydrological system and to support corrective measures evaluation activities related to potential remedial alternatives for high explosives–contaminated groundwater. Implementation of the tracer study was based on a work plan approved by the New Mexico Environment Department.

Six different types of naphthalene sulfonates were used along with bromide as the tracers. Small dilution tests were first conducted in wells R-25b and CdV-9-1(i) screen 1. Large-scale tracer deployments were made in November 2015 in wells R-25b; CdV-9-1(i) (screen 1, piezometer 1, and piezometer 2); and CdV-16-1(i). Tracers were monitored through September 2016 in these wells and in perched-intermediate wells CdV-16-2(i)r, CdV-16-4ip, and R-47i as well as in regional aquifer wells R-18, R-47, R-48, R-58, and R-63.

The estimated linear flow rates based on the dilution tests were 0.05 m/d in R-25b and 3.1 m/d in CdV-9-1(i) screen 1. The large tracer tests showed clear dilution effects in all three deployment wells, but implied rates based on concentration differences suggest the groundwater flow velocity at R-25b is much lower than the flow velocity at CdV-16-1(i), and flow velocity in CdV-9-1(i) is greater than the flow velocity at CdV-16-1(i). Pump tests in CdV-9-1(i) and CdV-16-1(i) affected the deployed tracers in these wells, removing some of the mass from the groundwater in the vicinity of these wells. The effects in CdV-9-1(i) were minor in terms of mass removed and affected only bromide and the tracers introduced into the piezometers. The pump test in CdV-16-1(i) removed an estimated 29% of the original tracer mass during the aquifer test. Another key result is that tracers from both CdV-9-1(i) piezometers have been detected in CdV-9-1(i) screen 1, demonstrating vertical flow path connections. It is unclear whether these detections represent natural flow paths or if they are the result of short-circuiting along the well bore or in the adjacent formation. It is important to note that no credible observations have been made of cross-well tracer transport. The fact that most of the tracers have not yet fully moved beyond the vicinity of the deployment screens and no cross-well detections have occurred demonstrates the need for continued tracer monitoring. Although tracer deployment is now complete at the TA-16 monitoring wells, long-term tracer breakthrough monitoring is recommended to realize the full benefits of the TA-16 tracer study. Monitoring for tracers can be conducted efficiently and at minimal additional cost during routine groundwater monitoring activities at TA-16.

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## 1.0 INTRODUCTION

This report provides information on tracer deployments and subsequent tracer monitoring in perched-intermediate and regional groundwater in the vicinity of Technical Area 16 (TA-16) at Los Alamos National Laboratory (LANL or the Laboratory). Deployments were made in October and November 2015, and tracer monitoring results through September 2016 are presented herein. Results from two small-scale dilution tests and a series of large-scale, multi-year tracer tests are described along with details of the various deployments. The TA-16 tracer study is being conducted to test connectivity of various parts of the TA-16 hydrological system (see Figure 1.0-1) and supports corrective measures evaluation (CME) activities related to potential remedial alternatives for high explosives–contaminated groundwater. Additional information/interpretation regarding current- and future-tracer results will be discussed in the CME report.

Remedial alternatives analyses will benefit from the tracer study through an improved understanding of (1) groundwater flow paths; (2) lateral travel times and associated hydrologic parameters within the Otowi Member of the Bandelier Tuff Formation and the Puye Formation; and (3) vertical travel times between perched-intermediate groundwater and the regional aquifer. The hydrogeologic framework (Figure 1.0-1) for the contaminated deep perched-intermediate zone and regional aquifer is complex (LANL 2011, 207069). A wide range of hydrologic, geochemical, and geophysical data suggest these groundwater zones are quite heterogeneous. The perched-intermediate zone is divided into an upper and a lower zone, with the upper zone consistently more contaminated than the lower. Conservative geochemical signatures vary both spatially and, to a lesser degree, temporally (LANL 2011, 207069). Hydrologic data, including water levels, pump-test results, and drilling observations, demonstrate that deep perched-intermediate zones are hydrogeologically complex with localized hydrogeologic regimes (LANL 2011, 207069).

## 2.0 METHODS

An overview of the deployment details for the small dilution tests and large-scale tests is presented below. For reference, a summary of all of the deployments is presented in Table 2.0-1. The table includes information on the various tracers deployed and their locations, tracer masses and water volumes, and start and completion dates of deployment. Figure 2.0-1 shows the deployment and monitoring well locations. Because tracers were deployed at multiple locations, it was necessary to use a class of tracers that had similar transport properties and analytical detection levels but that could be individually recognized in a groundwater sample. The tracer work plan specified a group of naphthalene sulfonates (NSs) as most suitable. The work plan also specified deploying sodium bromide along with an NS at one location to examine the effects of dual porosity/dual permeability. The NSs can be measured easily using in-house laboratory methods (e.g., fluorescence detection) with detection limits less than 1 ppb (additional discussion of the tracer characteristics is presented in the tracer work plan [LANL 2015, 600535]). The tracers are all forms of sodium-naphthalene sulfonates, with single, disulfonate, and trisulfonate variations used (Table 2.0-1). In this report, they are abbreviated as 1 NS, 1,6 NDS, and 1,3,6 NTS, representing single sulfonate (NS), disulfonate (NDS) and trisulfonate (NTS) versions of sodium-naphthalene sulfonate.

### 2.1 Dilution Tests

Tracer dilution tests are designed to estimate the velocity of local groundwater flow in the vicinity of a well bore by calculating the rate at which a tracer solution is removed from the screened section of a well casing. Dilution tests were conducted in well R-25b from October 5 to 7, 2015, and in well CdV-9-1(i) screen 1 from October 15 to 19, 2015.

It should be noted that Table 3.0-1 of the “Work Plan for a Tracer Test at Consolidated Unit 16-021(c)-99, Technical Area 16, Revision 1” (LANL 2015, 600535) erroneously indicated that dilution testing would be conducted on screen 2 of CdV-9-1(i). However, the original intent was to conduct the dilution testing on screen 1 of CdV-9-1(i), the same screen planned for the large-scale tracer deployment. Screen 2 was abandoned after an inflatable packer became permanently lodged during well development and is currently inaccessible (LANL 2015, 600503). The implications of excluding CdV-9-1(i) screen 2 from the tracer test are minor because three screens located higher in the stratigraphy at CdV-9-1(i) are already being tested, providing ample characterization data from the testing.

The tracer work plan had also included a dilution test in well CdV-16-1(i). However, it was discovered that the well and screen configuration were not suitable for conducting a dilution test. Therefore, a dilution test was not conducted in this well.

To initiate a test, water in the well casing, pump riser, and surface apparatus was replaced with a solution of 1 NS tracer (see Table 2.0-1 for mass and volume details). During the test period, the tracer was pumped through a continuous loop to the surface, passing through an automated sampling device. Flow rates were balanced in the loop so the flow back into the well matched the pump rate out. In the case of the TA-16 tests, the solution was returned through the well casing. Dilution of the tracer by groundwater movement through the screen was measured in a series of samples collected using an autosampler directly from the circulation loop. Sampling was performed every 30 min to 1 h over the course of a few days. Tracer analyses were conducted in a field trailer using a fluorometer. Tracer measurements continued until a clear dilution trend could be established or the tracer concentrations became too low for detection. Additional details on the field activities can be found in Appendix A.

Once a suitable dilution time series was obtained, linear flow rates were estimated using the slope of a regression through the time versus concentration data. A series of spreadsheet calculations based on the point dilution method of Drost et al. (1968, 240121) were made to calculate the rates. A correction to account for distortion of the local flow field by the borehole was also applied following Halevy et al. (1967, 602137) and Palmer and Puls (1994, 107032).

## 2.2 Large Tracer Tests

Extensive details of the large tracer test deployments for each well screen and piezometer are provided in Appendix A. To summarize the overall approach for the main well screens, the appropriate amount of tracer powder (see Table 2.0-1) was preweighed in the laboratory and taken to the well location. For the first deployment in CdV-9-1(i), the tracer was added directly to a series of poly tanks (3000 gal.) containing potable water. The tracer was mixed using sump pumps. Because this was a time-consuming process, in subsequent deployments the tracer was first mixed in 55-gal. plastic barrels using an electric mixer to make a concentrated solution. Once the tracer was dissolved or nearly so, the tracer solution was transferred to a series of large poly tanks (300 to 1000 gal.) that had been brought up to the volumes indicated in Table 2.0-1 using potable water. Tracers were deployed down the well bores using a combination of sump pumps and gravity siphoning (typically in the evenings). Once the tracer was deployed, the tanks were rinsed with potable water that was then pumped or siphoned into the well. This “chase” water was used to help push the tracer solution out of the well bore and into the surrounding formation. Chase water volumes are also included in Table 2.0-1.

The deployments in the two CdV-9-1(i) piezometers (Figure 1.0-1 shows the depths of the piezometers) were modified from what was performed in the main well screen deployments because of concerns about how quickly the tracers could be deployed in the 1-in. piezometer tubes. To avoid overly protracted deployments, especially in piezometer 2, the tracer volumes were reduced from 6000 gal. proposed in the tracer work plan (LANL 2015, 600535) to 2900 and 200 gal., respectively, in piezometers 1 and 2. NMED was informed about this deviation before the tracers were deployed. The masses of tracer deployed adhered to what was specified in the work plan, and the solubilities of the tracers were high enough that there was no problem dissolving the same tracer masses in smaller volumes of water (see Table 2.0-1). For these deployments, tracers were weighed in the laboratory and mixed in poly tanks using a pump. Once mixed, the tracers were pumped into the piezometer tubes using a sump pump for piezometer 1 and a peristaltic pump for piezometer 2. Chase water was applied using the same pumps once the tracer solution was deployed.

The large tracer deployments began at CdV-9-1(i) screen 1 starting on October 29, 2015, and injection was completed on November 6, 2015. Injection of tracer at CdV-9-1(i) piezometer 1 began on November 9, 2015, and was completed on November 10, 2015. Injection of tracer at CdV-9-1(i) piezometer 2 began on November 10, 2015, and was completed on November 16, 2015. Injection of tracer at R-25b began on November 18, 2015, and was completed on November 20, 2015. Injection of tracer at CdV-16-1(i) began on November 20, 2015, and was completed on November 21, 2015.

All investigation-derived waste (IDW) generated during the dilution tests and large tracer tests was managed in accordance with EP-DIR-SOP-10021, Characterization and Management of Environmental Programs Waste. This procedure incorporates the requirements of all applicable U.S. Environmental Protection Agency (EPA) and NMED regulations, U.S. Department of Energy orders, and Laboratory implementation requirements, policies, and/or procedures.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Dilution Tests

Time series of the dilution data for R-25b and CdV-9-1(i) are shown in Figures 3.1-1 and 3.1-2, respectively. The two tests show good linearity, indicating that both tests were satisfactory for estimation of flow rates. The R-25b test was shorter in duration because of well pump failure. However, sufficient data were collected to establish the dilution line. For R-25b, the estimated linear flow rate was 0.05 m/d. In contrast, the value for CdV-9-1(i) was 3.1 m/d. Both these values showed that flow was sufficient to warrant conducting the large tracer tests. The larger rate in CdV-9-1(i) suggested it was a better choice for deployment of the bromide tracer during the large tests.

### 3.2 Large Tests

The tracers used in the large tests in wells R-25b, CdV-9-1(i), and CdV-16-1(i) have been deployed only under 1 yr (Table 2.0-1), so the results presented here represent early data. Results from each of the three tracer deployment wells will be discussed individually, after which results from the other monitoring wells in the TA-16 area will be discussed.

The tracer 1,6 NDS was injected into R-25b and the time series shows a clear dilution trend through June 2016 (Figure 3.2-1). Because of pump testing at TA-16, no sample was collected in September 2016. Even though a clear dilution trend was evident, tracer concentrations were still over 1500 mg/L during the June sampling round (Figure 3.2-1), and concentrations were substantially higher than the deployed tracers in CdV-9-1(i), and CdV-16-1(i) for the same sampling dates (the results from these two wells are discussed below). The high R-25b concentrations suggest a relatively low rate of transport, which is consistent with the dilution test results where local flow velocities at R-25b were substantially lower than at CdV-9-1(i) screen 1 (see dilution test section above). Both 1,5 NDS and 2,6 NDS were also detected in the March and June sampling rounds from R-25b at the level of about 1 mg/L or less (Appendix B). These detections are probably related to impurities in the 1,6 NDS tracer and not from transport from other wells. Because the

1,6 NDS concentrations were still quite high, it seems reasonable that tracer impurities could be detectible. Laboratory analyses of stock solutions also showed the presence of NS impurities. It is expected that the 1,5 NDS and 2,6 NDS concentrations will likely decrease in the future. Bromide was also detected but was not above background. No other deployed tracers were detected in R-25b since the June sampling event.

Four tracers were deployed in well CdV-9-1(i): 1,3,6 NTS in piezometer 1; 1,3,5 NTS in piezometer 2; and 2,6 NDS and bromide in screen 1. Because of the small-diameter configuration, the two piezometers could not be sampled after tracer deployment, and only screen 1 was monitored. As with R-25b, the deployed 2,6 NDS tracer in CdV-9-1(i) screen 1 shows a clear dilution trend (Figure 3.2-2). However, unlike R-25b, screen 1 shows rapid dilution, and 2,6 NDS was below detection by March 2016. It has remained below detection even during the July 2016 CdV-9-1(i) pump test period. This result suggests the tracer moved relatively rapidly downgradient beyond the point where it could be recovered during the pump test. Bromide showed a similar dilution behavior, but concentrations have not fully returned to background values. Some bromide tracer was removed during the July pump test (< 0.5 kg). The differences in bromide and 2,6 NDS transport were expected, and thus both tracers were included in the tracer work plan (LANL 2015, 600535). Bromide has different diffusion properties than the much-larger 2,6 NDS molecule, and the dual-tracer approach should help clarify transport characteristics in the TA-16 area in the future.

Both the tracers from the two CdV-9-1(i) piezometers have also been detected in screen 1 (Figure 3.2-3). The piezometer 2 tracer, 1,3,5 NTS, was detected in the first sampling round in December 2015 in CdV-9-1(i) screen 1 about 1 mo after the tracer was deployed in the piezometer. The concentration then dropped below the detection limit in January 2016, after which it rose to about 0.1 mg/L by the March 2016 sampling round. Repeated higher detections occurred during the July pump test period. The first detection in December 2015 may be related to impurities in the tracer introduced into screen 1, and detection of 1,6 NDS during this sampling round supports this interpretation (Appendix B). However, by March 2016, there is clear indication of transport from piezometer 2 to screen 1, and it appears that the July pump test induced additional transport.

The piezometer 1 tracer, 1,3,6 NTS, was first detected in March 2016 and increased in concentration once the pump test was initiated. Concentrations of 1,3,6 NTS were about an order of magnitude lower than the 1,3,5 NTS from piezometer 2, which is consistent with the fact that piezometer 1 is farther above screen 1 than piezometer 2. Concentrations of both tracers followed fairly smooth trends during pumping. However, after pumping was terminated on July, 12, 2016, concentrations began to fluctuate as is evident in Figure 3.2-3 for the most recent measurements. These fluctuations may be related to switching the pump on and off for sampling during the rebound period.

The detections of 1,3,5 NTS and 1,3,6 NTS from March to July 2016 demonstrate flow path connections from the shallower parts of the perched-intermediate zone to screen 1. These detections are not impurity related because the screen 1 tracer, 2,6 NDS had already reached values below detection. The March detections imply about a 3- to 4-mo transport time to screen 1. However, this transport time does not represent rates under natural hydraulic gradients because the tracer deployments in piezometers 1 and 2 increased heads substantially during addition of the tracers, and the pump test at screen 1 appeared to have increased gradients that would also promote faster transport. At this time, it is also unclear whether the connections between the piezometers and screen 1 represent natural flow paths or if the detections of tracers in the piezometer are related to short-circuiting along the well bore or in the adjacent formation. Additional data and evaluations are required to evaluate this issue.

The tracer 1,5 NDS was injected into well CdV-16-1(i). Because of adverse winter conditions in the canyon bottom, well monitoring did not begin until March 2016. By that time, concentrations of 1,5 NDS had dropped to about 50 mg/L (Figure 3.2-4). Concentrations declined slowly through early August and then increased sharply during the August pump test period. Approximately 11.4 kg of 1,5 NDS was removed during the pump test, that is, about 29% of the original mass. After the pump test was completed, a fairly symmetrical reduction in concentrations occurred during the rebound period. During the last sampling round in September 2016, 1,5 NDS could still be detected in the well at about 1 mg/L.

In addition to the deployed 1,5 NDS tracer, multiple detections of 1,3,5 NTS were detected in well CdV-16-1(i) (Figure 3.2-4). Concentrations peaked at about 1 mg/L during the August 2016 CdV-16-1(i) pump test and then declined to near- or below-detection levels by early September. In piezometer 2 of CdV-9-1(i), 1,3,5 NTS was deployed; however, it is likely that the detections are related to impurities in the 1,5 NDS tracer used at CdV-16-1(i). During the first two sampling rounds, 1,3,5 NTS was detected and the general shape of the tracer time series is similar to 1,5 NDS during both the early dilution phase and the pump test (Figure 3.2-4). Early detections of 2,6 NDS and 1,3,6 NTS are few and as with 1,3,5 NTS are likely the result of impurities.

Perched-intermediate wells CdV-16-2(i)r, CdV-16-4ip, and R-47i and regional aquifer wells R-18, R-47, R-48, R-58, and R-63 were also monitored for tracers. No tracer detections were observed for CdV-16-2(i)r, R-18, R-47, R-58, and R-63. Wells CdV-16-4ip, R-47i, and R-48 each had single detections of 1,6 NDS that were just above the detection limit. These detections are likely false positives. Apparently,1,6 NDS is sometimes prone to an interference that can result in concentrations just above the 0.002-mg/L detection limit. A one-time sampling of screens 1, 2, 4, and 5 in well R-25 also occurred in May 2016. No tracer detections were observed, including detections of 1,6 NDS, which had been deployed in nearby well R-25b. The lack of detection of 1,6 NDS is consistent with the slow movement of the tracer away from R-25b.

## 3.3 DEVIATIONS

The tracer study work plan included a task to deploy a tracer into surface water in Cañon de Valle to assess the connection between surface water, alluvial groundwater, and deeper perched-intermediate groundwater. This tracer was not deployed because of permitting issues described below.

Notices of intent (NOIs) to discharge the groundwater and surface water tracers were submitted to the NMED Ground Water Quality Bureau (GWQB) and Surface Water Quality Bureau Surface Water Quality Bureau (SWQB) on July 28, 2015, and August 6, 2015, respectively. The NOI from GWQB was approved on September 22, 2015 (NMED 2015, 600924). The NMED-SWQB responded in a September 11, 2015, letter that stated that NMED neither approved nor disapproved deployment of tracers in Cañon de Valle but advised the Laboratory to contact EPA Region 6 to inquire whether a federal permit may be required (NMED 2015, 600928).

The Laboratory contacted EPA Region 6 several times regarding deployment of the tracer, but EPA did not respond with a determination of whether a permit was required for the tracer. Because no regulatory determination was received for tracer deployment, the Laboratory was unable to implement this task. In lieu of the surface water tracer, additional environmental data associated with high alkalinity measured in post-fire (Cerro Grande and Las Conchas) storm water runoff are being evaluated as a possible surrogate for a surface water tracer.

## 4.0 SUMMARY AND RECOMMENDATIONS

Although this report describes only the initial phase of the large tracer tests, useful results have been obtained that will increase the understanding of subsurface flow and transport in the TA-16 subsurface. The large tracer tests showed clear dilution effects in all three deployment wells, but implied rates based on concentration differences suggest the groundwater flow velocity at R-25b is much lower than the flow velocity at CdV-16-1(i), and flow velocity in CdV-9-1(i) is greater than the flow velocity at CdV-16-1(i). These results are consistent with the R-25b and CdV-9-1(i) flow rates estimated from the small dilution tests. The spatially variable flow conditions implied by the large tracer results support the idea of a heterogeneous flow system as described by the TA-16 conceptual model (LANL 2011, 207069).

Another key result is that tracers from both CdV-9-1(i) piezometers have been detected in screen 1, demonstrating vertical flow path connections. It is unclear whether these detections represent naturally occurring flow conditions or if they are the result of short-circuiting along the well bore or in the adjacent formation. Additional tracer monitoring may help clarify this issue, and numerical modeling using existing CdV-9-1(i) pressure transducer data would also be useful in evaluating the problem.

The pump tests in CdV-9-1(i) and CdV-16-1(i) affected the deployed tracers in these wells. The effects in CdV-9-1(i) were minor and only affected bromide (and the piezometer tracers). The test in CdV-16-1(i) had a much more substantial effect (Figure 3.2-4), showing clear pumpback of a significant quantity (29%) of the introduced tracer. This result is useful from a qualitative perspective but could also provide an opportunity to quantify flow conditions around the well using numerical modeling. Because it was not possible to conduct a small-scale dilution test in CdV-16-1(i), the pumpback tracer data could potentially be used instead to understand more about the subsurface near the well screen.

Another important observation is no credible cross-well detections have occurred yet. This result is not surprising given the fact that it has taken months to perhaps over 1 yr (e.g., in R25b) for the tracers to move beyond the vicinity of the deployment screens. Only 2,6 NDS in CdV-9-1(i) is no longer detectible in the screen where it had been deployed. Over time it is expected all the tracers should reach below detection limits in the screens where they were deployed.

The fact that most of the tracers have not yet fully moved beyond the vicinity of the screens where they were deployed and no cross-well detections have occurred is not surprising. However, these two observations demonstrate the need for continued monitoring to quantify the complete dispersal behavior of tracers from the wells where they were deployed and to observe any potential transport to downgradient monitoring wells. Although tracer deployment is now complete at TA-16 monitoring wells, long-term tracer breakthrough monitoring is recommended to realize the full benefits of the TA-16 tracer study.

## 5.0 REFERENCES AND MAP DATA SOURCES

### 5.1 References

*The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ERID or ESHID. This information is also included in text citations. ERIDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESHIDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.*

*Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the ESH 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), September 11, 2015. “SWQB Response to Notice of Intent to Discharge, Tracer Test, Los Alamos National Laboratory (LANL), Technical Area (TA) 16, Cañon de Valle near Burning Ground Spring,” New Mexico Environment Department letter to G.E. Turner (DOE) and A. Dorries (LANL) from J. Hogan (NMED-SWQB), Santa Fe, New Mexico. (NMED 2015, 600928)

NMED (New Mexico Environment Department), September 22, 2015. “Response to Notice of Intent to Discharge; Permit Not Required to Add Tracers to Ground Water at Technical Area (TA) 16, AI:856 (PRD20150013),” New Mexico Environment Department letter to G.E. Turner (DOE) and A. Dorries (LANL) from M. Hunter (NMED-GWQB), Santa Fe, New Mexico. (NMED 2015, 600924)

Palmer, C.D., and R.W. Puls, October 1994. “Natural Attenuation of Hexavalent Chromium in Groundwater and Soils,” EPA/540/5-94/505, EPA Ground Water Issue, Office of Solid Waste and Emergency Response, Washington, D.C. (Palmer and Puls 1994, 107032)

### 5.2 Map Data Sources

Sampling Locations; Los Alamos National Laboratory, Waste and Environmental Services Division; Locus EIM database pull; ERRP#, PKG-1729, PKG-1872.

WQH Drainage_arc; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; 1:24,000 Scale Data; 03 June 2003.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Potential Release Sites; Los Alamos National Laboratory, ESH&Q Waste & Environmental Services Division, Environmental Data and Analysis Group, EP2010-1C; 1:2,500 Scale Data; 02 December 2010.

Groundwater Contours; Los Alamos National Laboratory; Associate Directorate for Environmental Management (ADEM); 09 February 2017; as published GIS project 15-0041; February 2017.

RDX Contamination Plume; Los Alamos National Laboratory; Associate Directorate for Environmental Management (ADEM); 09 February 2017; as published GIS project 15-0041; February 2017

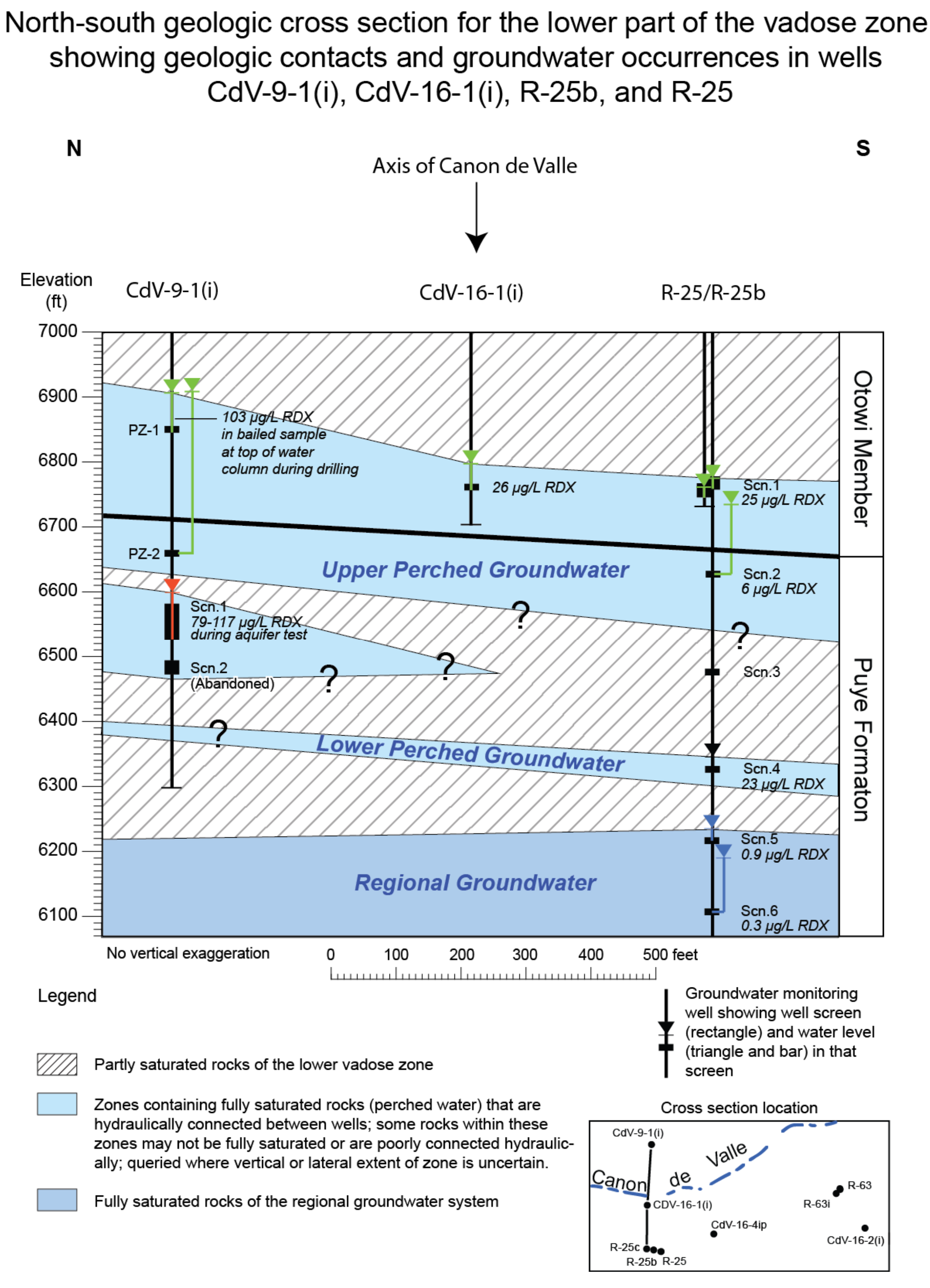


**Figure 1.0-1 Hydrogeological conceptual model of the vicinity TA-16. Screen and piezometer locations in wells CdV-9-1(i), CdV-16-1(i), R-25b, and R-25 are also shown.**

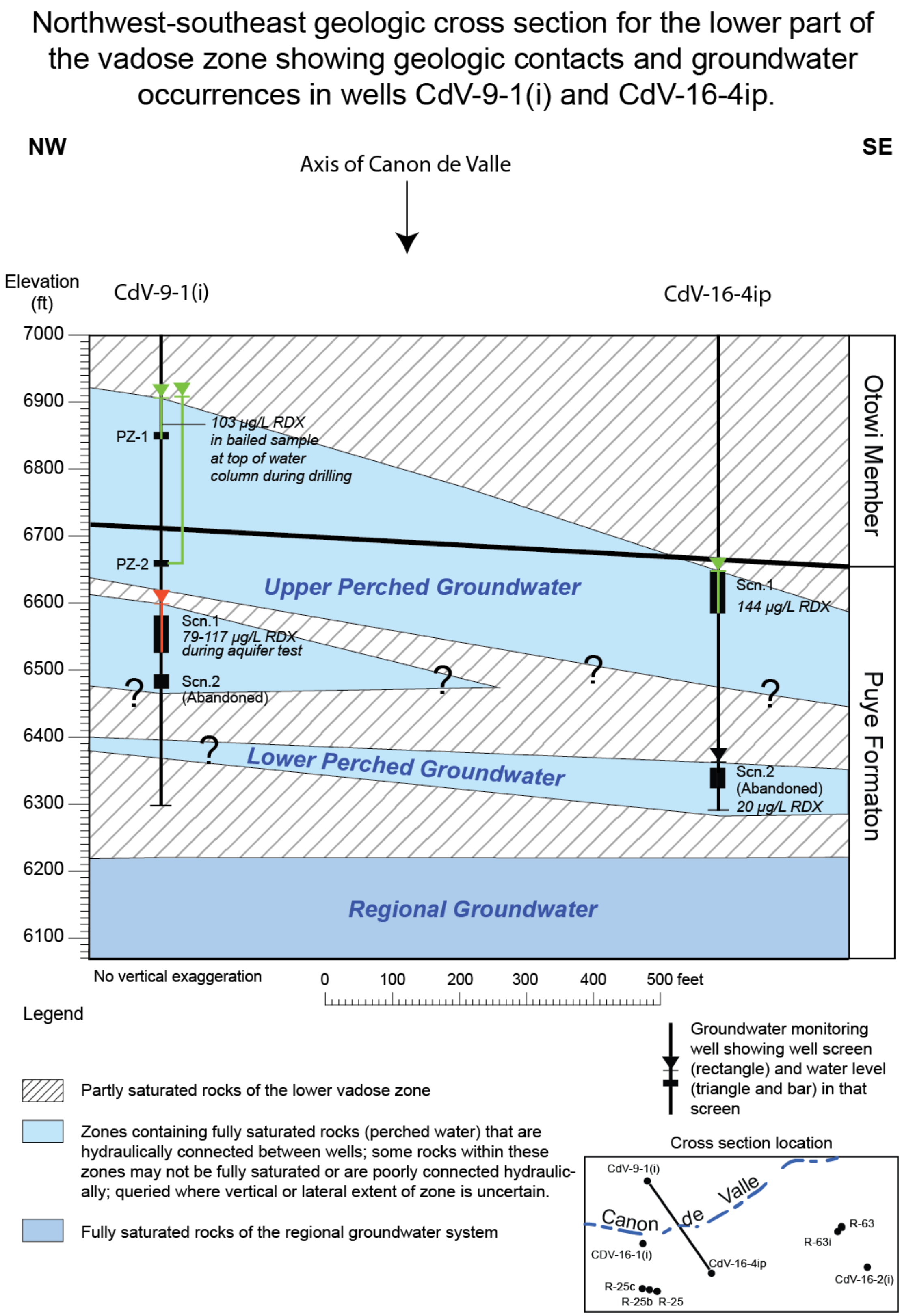


**Figure 1.0-1 (continued)** **Hydrogeological conceptual model of the vicinity TA-16. Screen and piezometer locations in wells CdV-9-1(i) and CdV-16-4ip are also shown.**

West-northwest to east-southeast geologic cross section for the lower part of the vadose zone showing geologic contacts and groundwater occurrences in wells CdV-9-1(i), R-63i, R-63, and CdV-16-2(i)r

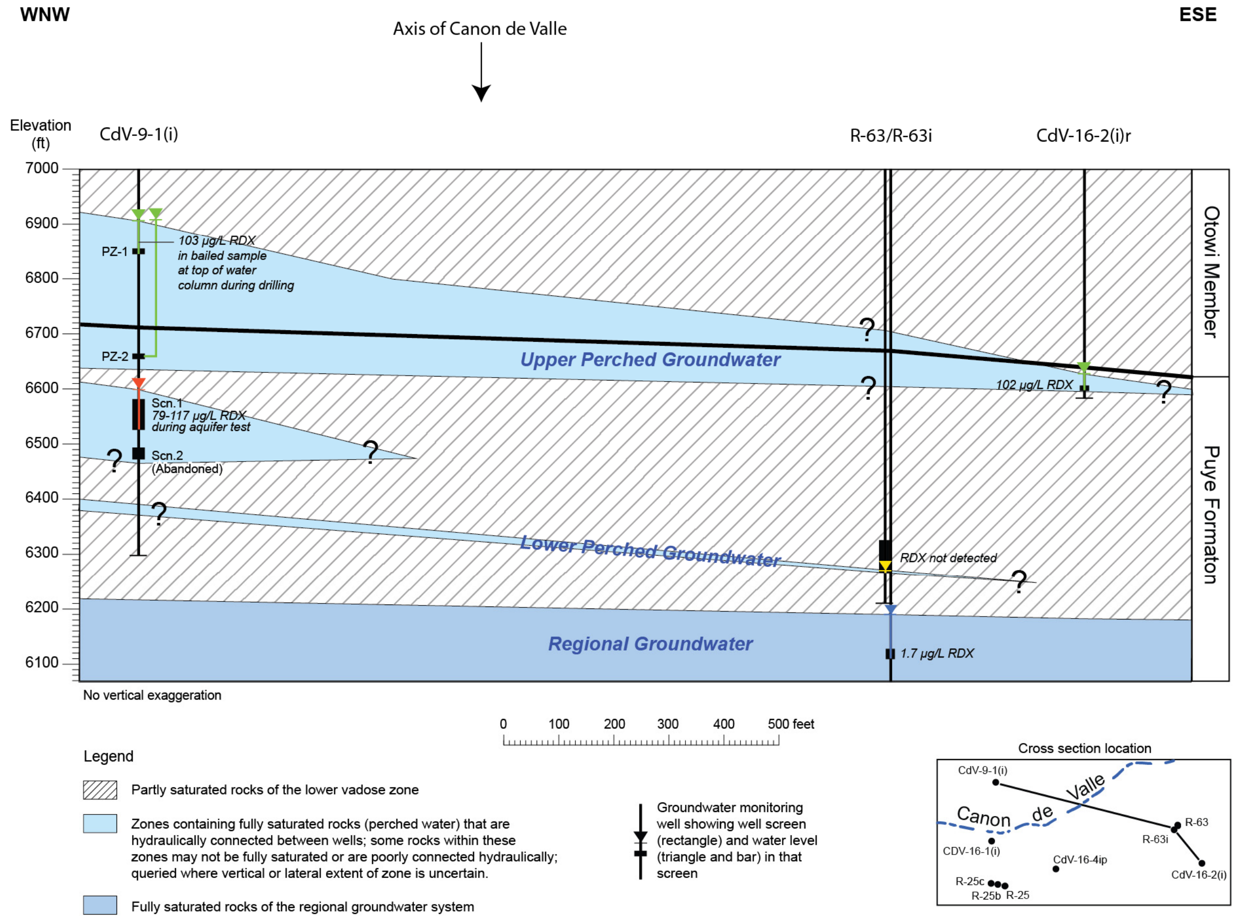


**Figure 1.0-1 (continued)** **Hydrogeological conceptual model of the vicinity TA-16. Screen and piezometer locations in wells CdV-9-1(i), R-63, R-63i and CdV-16-2(i)r are also shown.**

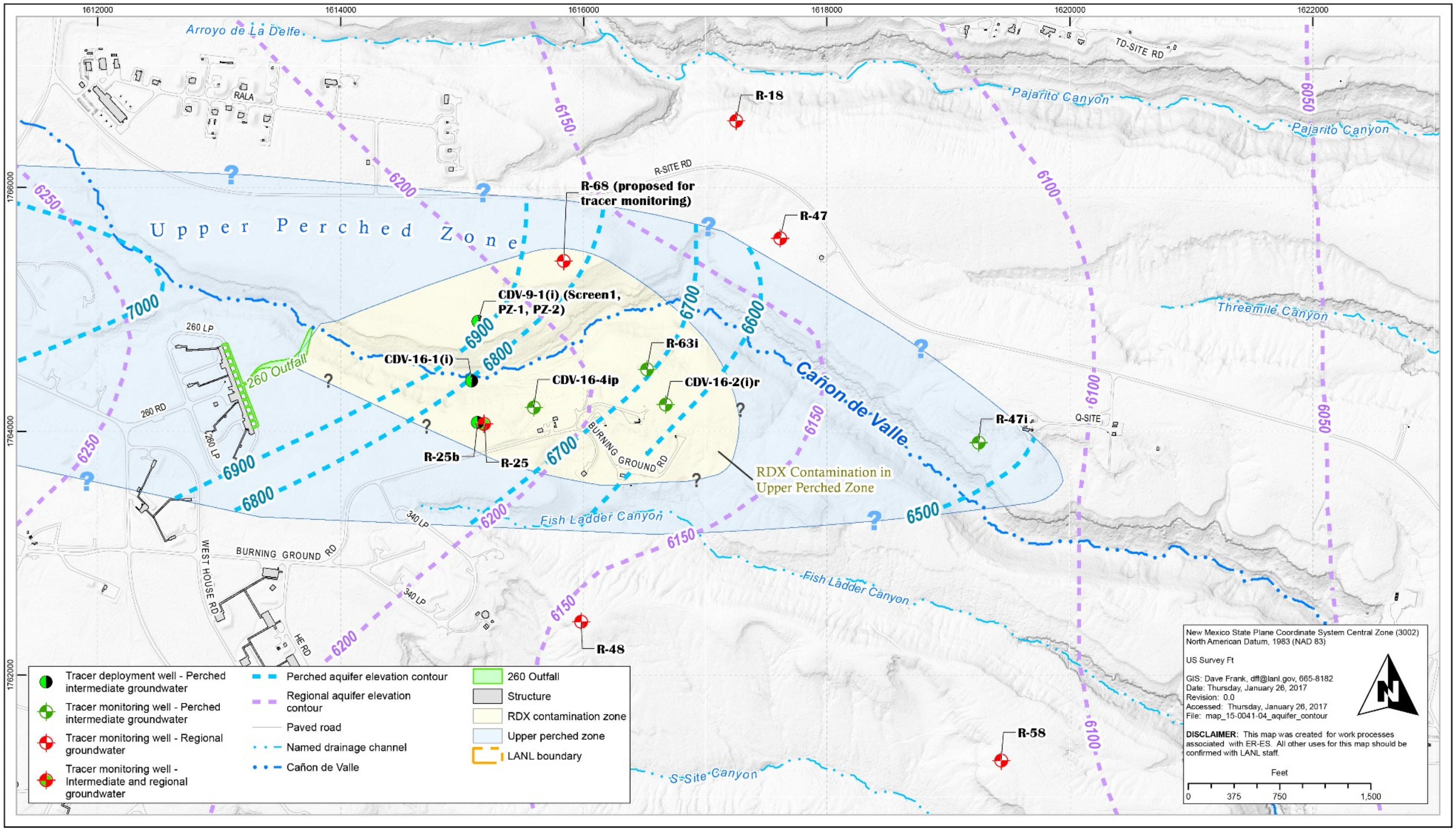


**Figure 2.0-1** Location of tracer deployment wells, monitoring wells, and other hydrologic features in the vicinity of TA-16. The extent of the upper perched zone (with water-elevation contour lines) and the extent of RDX contamination in this zone are shown as an example of the subsurface conditions at TA-16.

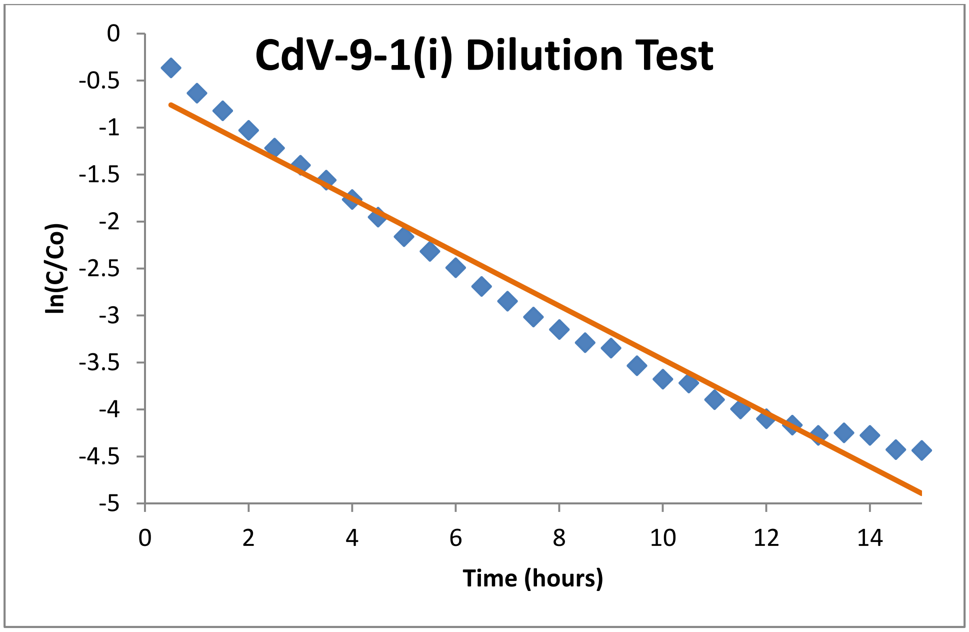


**Figure 3.1-1** **CdV-9-1(i) dilution test results. Y-axis represents the natural log of the measured tracer concentration at a particular time divided by the original tracer concentration at the start of the test. A linear regression is shown by the orange line ($R^2$=0.97).**

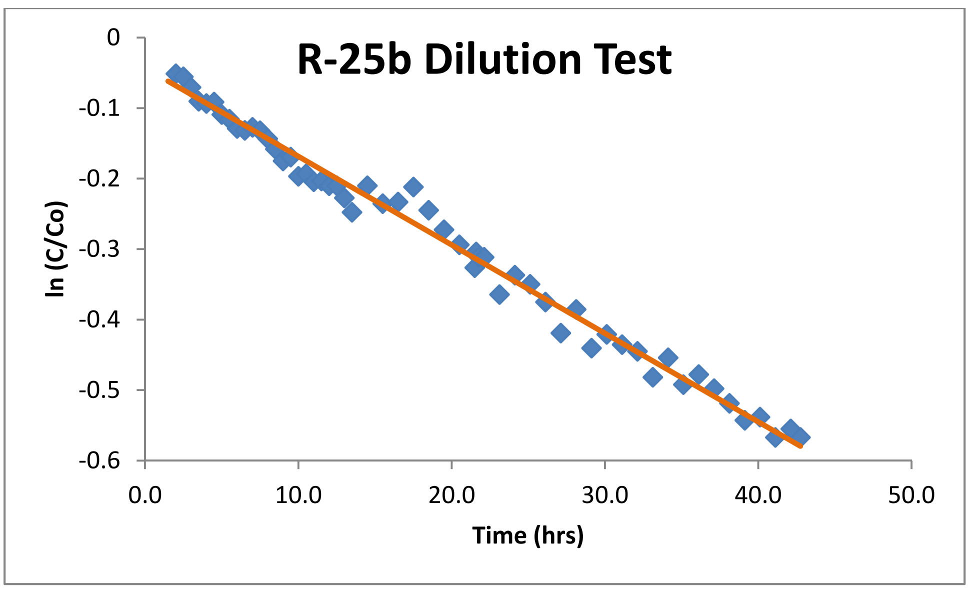


**Figure 3.1-2** **R-25b dilution test results. Y-axis represents the natural log of the measured tracer concentration at a particular time divided by the original tracer concentration at the start of the test. A linear regression is shown by the orange line ($R^2$=0.99).**

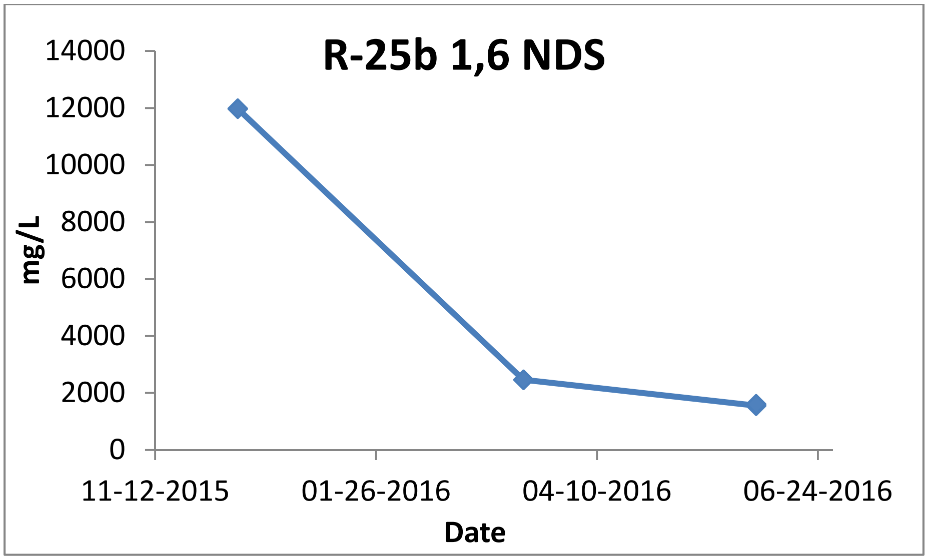


**Figure 3.2-1 Time series of deployed tracer 1,6 NDS in well R-25b**

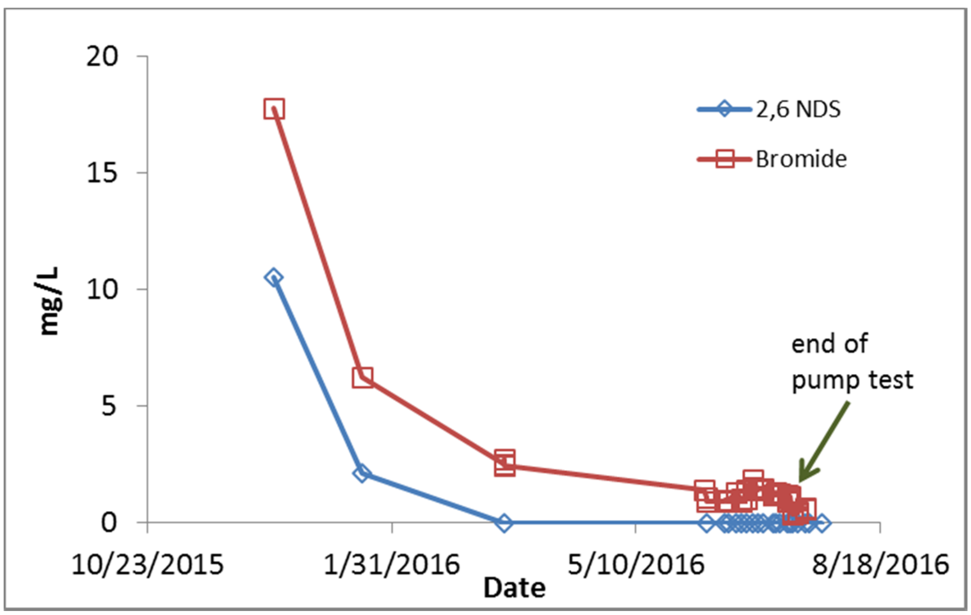


**Figure 3.2-2 Time series of deployed tracer 2,6 NDS and bromide in screen 1 well CdV-9-1(i)**

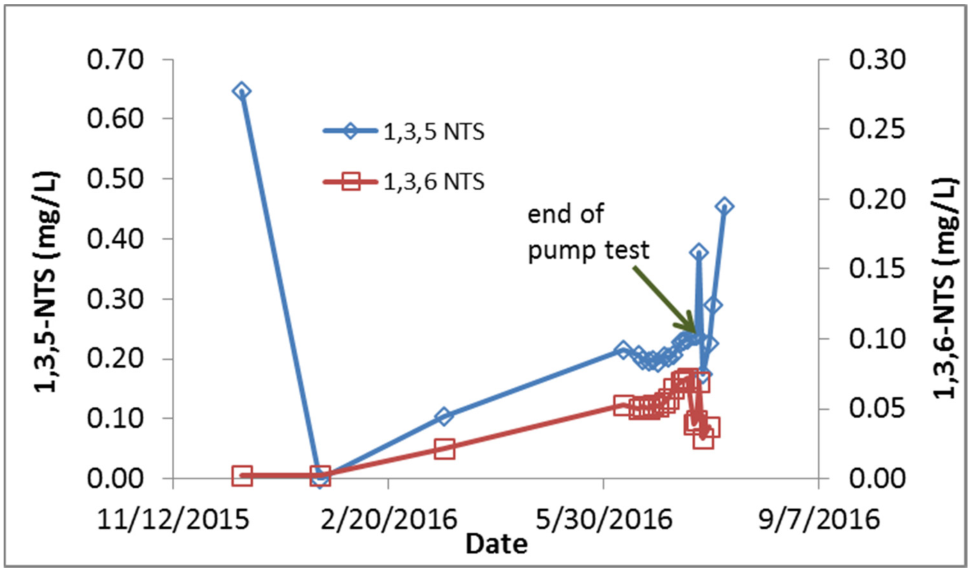


**Figure 3.2-3** **Time series of piezometer 1 tracer 1,3,6 NTS and piezometer 2 tracer 1,3,5 NTS in screen 1 well CdV-9-1(i)**

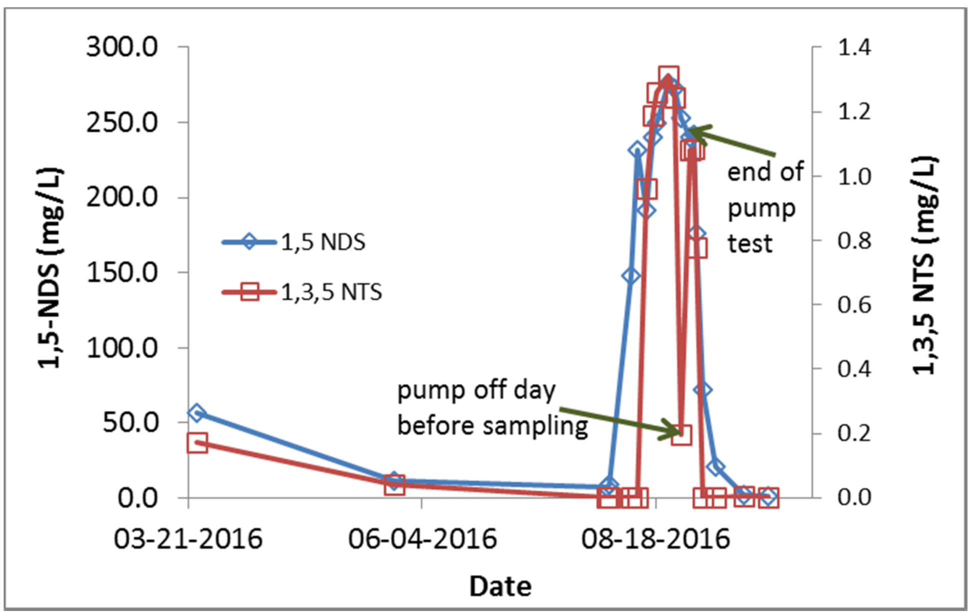


**Figure 3.2-4** **Time series of deployed tracer 1,5 NDS and probable impurity 1,3,5 NTS in well CdV-16-1(i). Peaks near the end of the time series are related to the pump test period.**

**Table 2.0-1**
**Summary of TA-16 Tracer Deployment Details**

| Well Name | Tracer Test Type | Tracer(s) Added | Quantity Injected (g or kg) | Tracer Added Start | Tracer Added Finish | Volume of Tracer Solution Injected (gal.) | Chase Water Volume (gal.) |
|---|---|---|---|---|---|---|---|
| R-25b | Dilution | 1 NS | 2 g | 10/5/2015 | 10/05/2015 | 40 | n/a[a] |
| CdV-9-1(i) | Dilution | 1 NS | 2 g | 10/15/2015 | 10/15/2015 | 270 | n/a |
| CdV-9-1(i) Screen 1 | Injection<br>Injection | 2,6-NDS<br>NaBr | 40 kg<br>150 kg | 10/29/2015<br>10/29/2015 | 11/06/2015<br>11/06/2015 | 10,550 (2,6-NDS plus NaBr) | 82 |
| CdV-9-1(i) Piezometer 1 | Injection | 1,3,6-NTS | 25 kg | 11/09/2015 | 11/10/2015 | 2900 | 50 |
| CdV-9-1(i) Piezometer 2 | Injection | 1,3,5-NTS | 25 kg | 11/10/2015 | 11/16/2015[b] | 200 | 55 |
| R-25b | Injection | 1,6-NDS | 40 kg | 11/18/2015 | 11/20/2015 | 6000 | 30 |
| CdV-16-1(i) | Injection | 1,5-NDS | 40 kg | 11/20/2015 | 11/21/2015 | 6000 | 60 |

[a] n/a = Not applicable.

[b] Injections occurred during the day on 11/10/2015, 11/12/2015, and 11/16/2015.

# Appendix A

*Field Note Summaries for the Technical Area 16 Tracer Tests*

**R-25b Dilution Tracer Test**

Work began on 10/5/15. Approximately 33 gal. of groundwater was purged from the well using a Bennett pump. 2 g Na-1 NS premixed in 500 ml DI water was added to 50 gal. potable water in a 55-gal. drum and mixed with an electric hand drill-mounted 3 ft stainless steel mixing paddle for about 15 minutes total, mixing the solution for around 5 minutes at a time and taking a reading on the field fluorimeter until consistent readings were established. A Geotech (peristaltic) pump was utilized to input the well water to balance the flow where a little more was coming out of the well than what was being inputted. Once this balance was reached injection of the 2 g Na-1 NS solution began. Two hours after injection began, consistent readings were detected on the field fluorometer, injection was terminated and a closed dilution loop was established using only the Bennett pump. Autosampling began to collect samples every 30 minutes overnight. On the morning of 10/6/15 the overnight samples were collected, the autosampler was reset to 1 hour sampling and sampling continued until 10/7/15 when sampling terminated at 3:56 pm due to a malfunctioning Bennett pump. Enough data was collected to determine a flow rate as shown in Figure 3.

**CdV-9-1i Screen 1 Dilution Tracer Test**

Work began on 10/15/15. At 9:17 am the well pump was turned on and initially the inlet and outlet flowmeters on the wellhead gave consistent ~ 2 gpm readings. After 15 minutes the inlet flowmeter malfunctioned dropping to 0 gpm. Attempts were made to get the flowmeter operational, but by 11:05 am both of the meters malfunctioned dropping to 0 gpm. At 11:20 am started purging 200 gal. from the well at ~ 2 gpm. 2 g Na-1 NS premixed in 500 ml DI water was added to 300 gal. potable water in a 305 gal. poly tank and mixed with an electric hand drill-mounted 3 ft stainless steel mixing paddle for about 15 minutes total, mixing the solution for around 5 minutes at a time and taking a reading on the field fluorometer until consistent readings were established. Stopped groundwater purging at 1:00 pm and added ~ 30 gal. of potable water to a 55-gal. drum to begin balancing well inlet/outlet flow using a sump pump. At 2:00 pm system "balanced" with outlet flow a little faster than the inlet flow and began injection of the 2 g Na-1 NS solution from the 305 gal. poly tank into CdV-9-1i Screen 1. Took periodic groundwater samples over the next 2-1/2 hours analyzing them on the field fluorometer to check for tracer. At 4:30 pm began picking up Na-1 NS tracer in the well. At 5:19 pm got consistent tracer readings, terminated the injection and a closed dilution loop was established using only the CdV-9-1i Screen 1 pump. 30-minute sampling began using the autosampler for overnight sampling. Overnight samples were collected on 10/16/15 and the autosampler was reloaded with new bottles for 2-hr collections. Samples were again collected on 10/17/15 and 10/19/15. The dilution test data looked good (see Figure 4) and the last samples were at the limit of detection so the dilution testing was terminated around 3:00 pm on 10/19/15.

**CdV-9-1i Screen 1 Large Volume Tracer Injection**

Work began on 10/21/15. A total of 40 kg of Na-2,6-NDS was preweighed in 5–gal. plastic buckets and large zip-lock bags at the GGRL. The tracer was portioned approximately in quarters to add a quarter of the amount of tracer to each of four 3000 gal. poly tanks with potable water. Also, 6 bags (25 kg/bag) of NaBr were obtained and 1.5 bags to be added to each of the 4 poly tanks.

On 10/27/15 the fieldwork began. 10 kg of Na-2,6-NDS and ~ 37.5 kg NaBr was added to Tanks 1 and 2, each containing ~3000 gal. potable water. Initially, the tracer was mixed in Tanks 1 and 2 using an electric hand drill-mounted 3 ft stainless steel mixing paddle for about 5 minutes followed by 10 minutes using the sump pump. Unmixed tracer at the bottom of the tanks was observed so Tank 1 was mixed an additional 40 minutes with the sump pump. At 4:50 pm obtained three consistent concentration readings from Tank 1 and took a grab sample for the GGRL to analyze.

On 10/28/15 at 1:30 pm an ER-FS tracer fieldwork safety briefing was held at the site. From 2:30 to 3:10 pm mixed the tracer in Tank 2 using the sump pump. Three consistent concentration readings from Tank 2 matched well with Tank 1's readings.

On 10/29/15 arrived at site at 9:55 am and a new 500 psi transducer was being installed in CdV-9-1i Screen 1. A garden hose was hooked up to the wellhead plumbing tree and dropped down into Tank 1 in preparation for injection. At 12:00 pm a laptop equipped with transducer reading software was installed to the well transducer cable to begin monitoring the groundwater elevation. The initial groundwater elevation was 6606 ft (7417 is the upper limit). A Geotech (peristaltic) pump was installed on one of the wellhead plumbing tree bibs to initiate syphoning the water from Tank 1, but it failed to draw much water. After a cracked PVC section on the wellhead was fixed and the correct adapter was installed the sump pump was installed and turned on in Tank 1 to initiate flow. The groundwater level increased several feet using the sump pump. At 4:00 pm the sump pump was turned off and the injection was monitored for an hour to determine how fast the tracer was siphoning out of Tank 1. The flow with the sump pump on was ~ 2 gpm and with it off (siphoning on it's own) 1 gpm. The water level dropped slightly with the pump off so it was agreed there would be no backup problems letting it syphon overnight. 350 gal.lons was injected by the end of the day.

On 10/30/15 Tank 1 water level was measured and 750 gal. had siphoned out overnight (or 0.735 gpm) and the GW elevation had only increased by 2 ft. At 10:02 am the sump pump was turned on pumping at 2.5 gpm and the elevation only increased several feet to 6613 ft. By 1:30 pm the tracer solution in Tank 1 dropped to 1400 gal. remaining so the sump pump was switched to Tank 2 (with 2600 gal. tracer solution) to facilitate syphoning continuously unattended over the weekend. Tank 2 was pumped for 1-1/2 hours for 50 gal. pumped then left to syphon over the weekend.

On 11/2/15 Tank 2 water level was at 1600 gal. or 1000 gal. syphoned out over the weekend. GW elevation at 6611 ft (or 5 ft net increase). Using a second pump pumped water from Tank 1 at 1400 gal. to Tank 2 to be able to reuse Tank 1 for Tank 3 tracer solution preparation and pumping. At 2:20 pm finished pumping water into Tank 2 and at 2:35 pm unplugged the sump pump to begin syphoning Tank 2 now at 2850 gal. to syphon overnight. GW elevation at 2:51 pm read 6612 ft (for 6 ft net increase).

On 11/3/15 water level on Tank 2 at 2700 gal. (or 150 gal. syphoned out overnight). The sump pump was removed from Tank 2 to use for water transfer from potable water tank into Tank 3. The second pump (Simer Model 282555-01) was used to inject tracer solution from Tank 2 into well. At 10:37 am 10 kg of Na-2,6-NDS and ~37.5 kg NaBr was slowly added to Tank 3 as is was filling up and stirred with the hose as it was filling. The "bucket/watch" test indicated both pumps pumping at a rate of 10 gpm but only 0.5 to 2 gpm was being injected into the well. Water level on Tank 2 at 4:00 pm at 2590 gal. for a net decrease throughout the day of 110 gal.. As of 4:00 pm 2710 gal. of tracer solution was injected into CdV-9-1i Screen 1 or 22.6% of 12,000 gal. was injected. GW elevation at 2:18 pm read 6612 ft (6 ft net increase).

On 11/4/15 the pipefitters removed the flowmeters (clogged with sand) from the wellhead and set it up to flow into the master and slave tubes. Flow improved five-fold. At 10:30 am Tank 2 level at 800 gal. (1790 gal. injected overnight). Tanks 1 and 2 injection (~5450 gal. injected) was completed at 12:45 pm. Finished filling Tank 3 (2700 gal.) containing mixed tracer and began injecting at 2:35 pm. By 4:05 pm 800 gal. had been injected pumping at a 8.88 gpm pump rate, and a calculated syphoning overnight rate of 3.33 gpm. GW elevation at 4:45 pm read 6643 ft (37 ft net increase). As of COB on 11/4/15 a grand total of 6450 gal.lons of tracer solution had been injected or 54% of injection completed.

On 11/5/15 completed Tank 3 tracer solution injection at 1:08 pm. Finished filling Tank 4 up to 2400 gal. as 10 kg of Na-2,6-NDS and ~37.5 kg NaBr was slowly added continuing to mix tracer with the hose as it was filling. After establishing consistent concentration readings at 4:00 pm began injection of the tracer solution from Tank 4 syphoning in at ~ 2 gpm. Last GW elevation reading was at 6642 ft (36 ft net increase).

On 11/6/15 arrived at site at 10:15 am and < 100 gal. remained in Tank 4 (~2300 gal. injected overnight). Ran sump pump about 10 minutes to finish the injection of the tracer solution. On 11/9/15 the CdV-9-1i Screen 1 large volume injection was completed with the flushing of the borehole with ~ 82 gal. potable water. Total volume of Na-2,6-NDS/NaBr tracer solution injected into CdV-9-1i Screen 1 = 10,550 gal. + 82 gal. potable water.

**CdV-9-1i Piezometer 1 Large Volume Tracer Injection**

In preparation for the two CdV-9-1i piezometer injections, 25 kg of Na-1,3,6-NTS tracer was weighed out for Piezometer 1 (9-1i PZ#1) injection and 25 kg of Na-1,3,5-NTS was weighed out for the Piezometer 2 (9-1i PZ#2) injection. At 12:00 (noon) on 11/9/15 the tracer field crew was notified that NMED had approved the same amount of tracer mass could be injected in ½ the original volumes that had been planned.

On 11/9/15 the CdV-9-1i piezometer work began. At 12:45 pm 25 kg of Na-1,3,6-NTS was slowly added to a pre-filled 3000 gal. poly tank containing 2900 gal. of potable water and was mixed using the sump pump. The 9-1i PZ #1 transducer cable was attached to the field trailer laptop in preparation for GW elevation readings. At 2:03 pm finished mixing tracer in 3000 gal. poly tank, took grab sample and concentration readings from top and bottom of tank and both readings matched. Set up to begin injection into 9-1i PZ #1. GW elevation was at 6910 ft. From 2:39 to 3:00 pm ran sump pump in the 9-1i PZ#1 3000 gal. poly tank and began injecting tracer solution into 9-1i PZ #1. GW elevation rose to 6989 ft (79 ft net increase). At 3:00 pm the sump pump was turned off. At 3:05 pm water level in 9-1i PZ#1 3000 gal. poly tank read 2640 gal. (260 gal. injected in about 25 minutes). At 3:15 pm GW elevation had dropped 10 ft to 6979 ft. At 4:00 pm GW elevation at 6982 ft and water level in 9-1i PZ#1 3000 gal. poly tank read 2440 gal. (460 gal. injected in about 1 ½ hrs or 200 gal./hr for an overnight syphon rate of 3.33 gpm). 2440 gal./(200 gal./hr) = 12.2 hrs needed to inject remaining amount left in 9-1i PZ#1 3000 gal. poly tank. The GW elevation in the well only climbed a small amount and should be okay to syphon overnight. Before leaving the site at the end of the day good flow could be heard at the wellhead being injected into 9-1i PZ#1.

On 11/10/15 at 9:53 am GW elevation in 9-1i PZ #1 at 6910 ft (at beginning/original GW elevation). Approximately 250 gal. remained in the 9-1i PZ#1 3000 gal. poly tank. Turned on the sump pump and tilted the 3000 gal. poly tank to pump out remaining amount of Na-1,3,6-NTS tracer solution into 9-1i PZ#1. At about 10:45 am finished injecting the last of the 9-1i PZ#1 tracer solution and immediately began injection of an additional 50 gal. of chase (potable) water into the piezometer using the sump pump. At 10:53 am all the chase water had been injected to complete the 9-1i PZ#1 injection. The last GW elevation reading for 9-1i PZ#1 read 6979 ft (for a net increase of 69 ft).

**CdV-9-1i Piezometer 2 Large Volume Tracer Injection**

On 11/9/15 the CdV-9-1i PZ#2 (or 9-1i PZ#2) work began. A 305 gal. poly tank was thoroughly rinsed out and 100 gal. of potable water was added to it to use for the 9-1i PZ#2 tracer injection.

On 11/10/15 at 10:00 am, 25 kg of Na-1,3,5-NTS tracer was slowly added to the 305 gal. poly tank containing 100 gal. of potable water. An electric hand drill-mounted 3 ft stainless steel mixing paddle was used to do the mixing for about 5 to 10 min. This much tracer could not be dissolved in 100 gal. of potable water so an additional 75 gal. of water was added. At 11:02 am finished mixing tracer in 175 gal. potable water and realized two times the amount of tracer had been added. Only 12.5 kg was supposed to be added. After upper management consultation it was decided to add an additional 25 gal. of potable water (bringing the total volume to 200 gal.) and to inject only 100 gal. into 9-1i PZ#2. The 9-1i PZ #2 transducer cable was attached to the field trailer laptop in preparation for GW elevation readings. Initial GW elevation reading 6914 ft. After further mixing after the additional 25 gal. of water had been added a concentration reading on the field fluorometer was taken and by 1:52 pm a series of 2 to 3 concentration readings matched. The 25 kg of Na-1,3,5-NTS tracer in 200 gal. of potable water solution was ready to be injected into 9-1i PZ#2. At 2:00 pm started injection into 9-1i PZ#2 using a Geotech (peristaltic) pump. Starting GW elevation was 6913 ft. At 3:05 pm 25 gal. had been injected or ~ 25 gal./hour. GW elevation rose 109 ft to 7022 ft. At 4:01 pm 45 gal. had been injected and the last GW elevation reading of the day read 7011 ft (i.e., dropped 11 ft). Turned off Geotech pump and terminated injection for the day. No tracer work was done on 11/11/15 due to holiday.

On 11/12/15 CdV-9-1i PZ#2 tracer injection resumed. To avoid creation of additional waste it was decided to inject the entire 200 gal. of tracer solution into the piezometer. At 10:10 am GW elevation 6903 ft (10 ft below starting GW elevation). 155 gal. of Na-1,3,5-NTS tracer solution remained in the 305 gal. poly tank to inject into 9-1i PZ#2. Injection began at 10:17 am using the Geotech pump. At 11:19 am GW elevation at 6968 ft (55 ft above starting elevation) and at 11:25 am 130 gal. remained to be injected (at ~25 gal./hr). At 12:25 pm GW elevation was at 6989 ft and by 12:52 pm GW elevation was at 6994 ft with 100 gal. left in the 305 gal. poly tank. GW elevation continued to slowly climb throughout the afternoon with final reading of the day (1:46 pm) at 7003 ft (90 ft above starting elevation). At 2:04 pm 75 gal. of tracer solution left in 305 gal. poly tank. 55 gal. of potable (chase) water will be added to 9-1i PZ#2 after the injection to rinse the piezometer. Work will resume on 11/16/15 after the long 3-day weekend.

On 11/16/15 CdV-9-1i PZ#2 tracer injection resumed to pump the last 75 gal. of tracer solution using the Geotech pump. Starting GW elevation at 10:41 am was at 6934 ft (21 ft above starting elevation) and fluctuated throughout the day reaching equilibrium at around 6980 ft. Last 75 gal. of tracer was injected into 9-1i PZ#2 by 2:20 pm. Work will resume on 11/17/15 to inject the 55 gal. of potable (chase) water to clean out the piezometer.

On 11/17/15 CdV-9-1i PZ#2 tracer injection resumed to pump the 55 gal. of chase water. Pumping began at 12:11 pm with a starting GW elevation of 6905 ft (8 ft below the starting elevation) reaching equilibrium at around 6990 ft after ~ 2 ½ hrs of pumping. Finished injecting the chase water at 2:20 pm to complete the CdV-9-1i PZ#2 injection.

**R-25b Large Volume Tracer Injection**

40 kg of Na-1,6-NDS tracer was weighed out for R-25b injection and 40 kg of Na-1,5-NDS was weighed out for the CdV-16-1i injection. On 11/17/15 the R-25b injection work began. Set up tracer field trailer. Checked the three 3000 gal. poly tanks on the NW section of the pad for the amount of potable water they contained: one had 4500 gal., the second 2500 gal. and the third < 500 gal. Using the sump pump transferred 1000 gal. of potable water out of the 4500 gal. poly tank into the < 500 gal. poly tank and 500 gal. into the poly tank with 2500 gal. of water. This left two of the tanks with 3000 gal. of potable water to add the same amount of Na-1,6-NDS tracer to each tank and allow for a more homogeneous injection into R-25b. The winds were too high to add tracer to the two tanks so quit for the day to resume in the morning.

Arrived at R-25b on 11/18/15 at 10:45 am and set up sump pump to pump potable water into a 55-gal. drum to use for the tracer mixing. About 50 gal. of water was added to the 55-gal. drum and then ½ of the total tracer (20 kg Na-1,6-NDS) was added, i.e., as one person slowly added large scoopfuls of tracer the other person did the mixing utilizing an electric hand drill-mounted 3 ft stainless steel mixing paddle (about a ½ hour operation per tank). Once ½ of the total tracer was added to the 55-gal. drum and it was thoroughly mixed in the ~ 50 gal. of potable water, the mixture was transferred to the 3000 gal. poly tank using the sump pump. After all the mixture had been transferred into the 3000 gal. poly tank, the sump pump was placed in the poly tank to mix it in the 3000 gal. total volume for an additional 10 to 15 minutes. This mixing method was tried to ensure a more thorough mixing before adding it to the large 3000 gal. poly tank. Tracer concentration readings were taken on the field fluorometer for 3000-gal. poly Tank #2 and at 12:00 pm obtained two similar readings. At 12:10 pm finished mixing tracer in Tank #1 and took an initial concentration reading. The R-25b transducer cable was connected to the field laptop computer to begin monitoring the GW elevation and the initial GW elevation read 6760 ft (R-25b surface elevation = 7518 ft). At 12:24 pm obtained two matching concentration readings for Tank #1. Both 3000 gal. poly tanks of Na-1,6-NDS tracer solution were ready to be injected so set up the garden hoses and the sump pump to begin injecting into Well R-25b. At 1:39 pm started injecting tracer solution from Tank #1 into R-25b using the sump pump. The initial GW elevation was at 6823 ft. At 2:09 pm the GW elevation rose to 6894 ft (71 ft higher than starting elevation). At 2:55 pm the sump pump was turned off to see if the tracer solution would continue to syphon out. A good flow could be heard at the wellhead. At 3:11 pm the GW elevation was at 6874 ft (about a 20 ft drop after pump was shut off). By 3:41 pm approximately ½ of the 3000 gal. in Tank #1 had been injected (tracer solution level was at 1500 gal.) or a combined sump pump/syphon rate of 750 gal./hr [~12.5 gpm). Left site at 3:43 pm to resume work the next day.

Arrived at R-25b at 9:58 am on 11/19/15. At 10:10 am noted only about 100 gal. of tracer solution remained in Tank #1 (2900 gal. injected into R-25b). At 10:37 GW elevation was at 6763 ft (60 ft below starting elevation). The residual amount in Tank #1 could not be pumped out with the sump pump so switched the pump to Tank #2 at 11:00 am. At 11:35 am GW elevation at 6965 ft (142 ft above starting elevation). At 12:51 pm GW elevation at 7075 ft (443 ft bgs). Tank #2 volume was at 1700 gal. at 12:55 pm (1300 gal. injected or ~650 gal./hr [about 11 gpm]). At 1:32 pm GW elevation 7095 ft and at 2:00 pm only about 800 gal. remained in Tank #2. At 3:06 pm ~400 gal. remained in Tank #2 and the GW elevation at 7117 ft. The sump pump was shut off and the last GW elevation of the day at 3:14 pm was 7079 ft.

On 11/20/15 arrived at site at 10:00 am. GW elevation reading was at 6764 ft (59 ft below initial elevation). At 10:47 am noted that all the tracer solution that could be syphoned out of Tank #2 had syphoned out overnight. Tried pumping out remaining amount with sump pump and tipping the tank, but 5000 gal. poly tank was two bulky and heavy to tip. The Simer (Model 282555-01) pump was hooked up to pump remaining tracer solution from Tank #2 and most of it was removed (only a residual amount, ~ 30 gal. remained). Switched the Simer pump to Tank #1 and by 11:57 am pumped out all possible tracer solution (~ 30 gal. remained in tank). R-25b Na-1,6-NDS tracer solution injection completed by 12:00 (noon) on 11/20/15. At 12:04 pm finished pumping ~ 30 gal. of potable (chase) water into R-25b using both the sump pump and the Simer pump to clean out both pumps and get ready to use for last (CdV-16-1(i)) injection.; completing the R-25b 6000 tracer injection. Final R-25b GW elevation 6863 ft (40 ft above initial elevation).

**CdV-16-1(i) Large Volume Tracer Injection**

Prior to the CdV-16-1i (or 16-1i) injection, dry runs of the plumbing manifold feed from the 5000 gal. poly tanks which were connected to a garden hose which ran down a 300 ft cliff down to the wellhead were completed to make sure fluid transfer worked satisfactorily. Initially the transfer was unsuccessful, but, after excess hose was cut off for a more direct feed, the transfer was successful.

The CdV-16-1i tracer injection work began immediately following the completion of the R-25b injection on 11/20/15. Prior to the mixing of Na-1,5-NDS tracer into the two 5000 gal. poly tanks, the sump pump was used to transfer potable water to come up with equal 3000 gal. volumes for the first two tanks hooked up to the plumbing manifold. The third (farthest west) poly tank had left over (~ 1000 gal.) potable water. All three tanks were hooked up to the base plumbing manifold at the bottom bung opening of each tank. At 12:16 pm, using the “55-gal. drum mixing method” explained in the R-25b tracer injection section (above), began mixing Na-1,5-NDS tracer for Tanks #1 and #2. By 1:00 pm two similar tracer concentration readings were obtained from both tanks and it was ready to be injected into CdV-16-1(i). Two workers stayed on the mesa top on the R-25b pad where the 5000 gal. poly tanks were located while the other two went down the canyon using the ATV to reach the well. Readings were taken at the 16-1i wellhead using the portable, battery-operated RuggedReader hooked up to the well transducer cable because there was no electricity to take readings on the laptop. At 1:30 pm the initial 16-1i GW elevation was 6796 ft (16-1i Well surface elevation = 7382 ft). At 2:05 pm began injecting tracer solution into 16-1i. By 2:30 pm the Well GW elevation had jumped up to 6971 ft (175 ft increase). At 3:13 pm GW elevation at 7007 ft with 600 gal. injected (500 gal. from Tank 2 and 100 gal. from Tank 1). At 3:58 GW elevation at 7022 ft. Computations were made where in 8 hours of continuous injection the maximum GW elevation would be at 7138 ft, well below the ground surface elevation of 7382 ft (> 100 ft below). At this gravity flow injection rate by 12:00 (midnight), 11/21/15, or in 8 hrs, all the tracer solution will be injected. At 4:02 pm just before leaving the site, there was 2600 gal. remaining in Tank 1 and 2250 gal. left in Tank 2. On 11/21/15 (Saturday), ER-FS personnel checked the two CdV-16-1i tracer solution poly tanks and they were empty except for a residual amount that could not be injected via gravity flow.

On 11/23/15, attempted to inject 60 gal. of potable (chase) water to complete the injection but the hose was frozen. The hose was removed from the manifold and the wellhead and spread out in the sunlight to defrost during the day. After defrosting the ice that was in the hose the hose was rolled up and stored in the tracer trailer to use for the chase water injection the next day. At 10:37 am the Well 16-1i GW elevation was at 6798 ft (2 ft above the initial elevation).

On 11/24/15, at 10:26 am the Well GW elevation at 6798 ft. At 10:28 am started the 60 gal. chase water injection into 16-1i and finished at 10:35 am to complete the CdV-16-1i 6000 gal. tracer injection. The final GW elevation reading was 6835 ft.

# Appendix B

*Analytical Results for Tracer Tests*
*(on CD included with this document)*