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2010/2011 Monitoring Summary Report for the Technical Area 16 Permeable Reactive Barrier and Associated Corrective Measures Implementation Projects

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EXECUTIVE SUMMARY

This report summarizes corrective measures implementation (CMI) monitoring at Consolidated Unit 16-021(c)-99 within Technical Area 16 (TA-16) at Los Alamos National Laboratory (the Laboratory). It describes operations and maintenance activities, monitoring results (including data tables and graphs), and successes and problems with implementing corrective measures at Consolidated Unit 16-021(c)-99 from February 2010 to August 2011.

CMI activities reported herein focus on the performance of the pilot permeable reactive barrier (PRB) installed in Cañon de Valle. This report also discusses the effectiveness of the other corrective measures implemented, including the surge bed injection grouting, the low-permeability cap constructed on the 260 Outfall drainage, and the carbon filters installed in Cañon de Valle. The performance objectives of the corrective measures were to reduce concentrations of barium and the explosive compound hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in alluvial groundwater and to prevent their migration to recharge areas for deeper aquifers. Performance monitoring of corrective measures for the CMI was conducted between February 2010 and August 2011. Monitoring activities at the PRB consisted of water-level measurements, field-parameter measurements, and collection of samples for both on-site and off-site chemical analysis. The PRB alluvial wells were sampled and field parameters collected monthly for the first quarter and quarterly for the remaining quarters.

Analytical results from the PRB monitoring are reported in two operational periods: the first period was from April 2010 to July 2010 and the second was from September 2010 to February 2011. After the first month of operation, groundwater flow through the barrier became impeded, resulting in difficulty assessing concentrations of barium and RDX within the vessel. Subsequently, the PRB vessel was changed to bypass mode (i.e., water bypasses treatment media), pending evaluation of the filter media.

Filter media assessment revealed mineral precipitation and biological accumulation within the media beds. The zero-valent iron (ZVI) media became impenetrable by hand auger resulting from mineral precipitation. The sequence order of the filter media was changed in the PRB vessel to minimize chemical precipitation. Zeolite was moved to the first treatment cell, followed by ZVI. The intent was for the zeolite to remove the barium and possibly some of the carbonate minerals from the water before reaching the ZVI. Monitoring and maintenance of the PRB resumed in September 2010 and continued through February 2011. Analytical results from the second operational period indicated a reduction in barium and RDX by the treatment media. RDX was reduced from 16 µg/L to below detection, and barium was reduced from 4000 µg/L to 1000 µg/L. These results continued from October 2010 to February 2011, with approximately 140,000 L of groundwater treated. By mid-February 2011, flow through the barrier again declined, and the use of ZVI for removing RDX was deemed problematic. Substitute media were evaluated. The filter medium was changed from ZVI to granular activated carbon (GAC) in July 2011.

One week after the GAC filter media was installed, flash flooding in Cañon de Valle damaged alluvial wells and sampling ports associated with the PRB. More severe flash flooding occurred in late August, destroying or severely damaging the PRB cutoff wall, inflow plumbing, and several additional alluvial wells in Cañon de Valle. A summary of the flood damage is provided in this report.

During the monitoring period, site inspections were performed to evaluate the structural integrity and efficacy of the low-permeability cap and carbon filters. No degradations in materials were noted for either corrective measure, and the alluvial well installed to monitor for infiltration did not indicate water had breached either the cap or the injection grouting. The carbon filters installed in Cañon de Valle were not activated pending resolution of discharge-permit issues.

This report includes an appendix (Appendix C) that incorporates new information from the 2010 operational period to provide recommendations for potential changes and refinement for future monitoring and maintenance activities in terms of locations, analytes, and sampling frequencies of the various treatment systems. Appendix C reflects modifications in operation, maintenance, and sampling based on the damage sustained by flash flooding in the summer of 2011.

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Acronyms and Abbreviations

bgs	below ground surface
BMP	best management practice
CMI	corrective measures implementation
CMS	corrective measures study
COPC	chemical of potential concern
DNX	hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine
DO	dissolved oxygen
DOT	Department of Transportation (U.S.)
EES	Earth and Environmental Sciences Laboratory
EPA	Environmental Protection Agency (U.S.)
GAC	granular activated carbon
HE	high explosives
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
IDW	investigation-derived waste
IP	individual permit
LANL	Los Alamos National Laboratory
MNX	hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine
NMED	New Mexico Environmental Department
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
ORP	oxidation-reduction potential
PRB	permeable reactive barrier

PVC	polyvinyl chloride
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
SOP	standard operating procedure
TA	technical area
TAL	target analyte list
TDS	total dissolved solids
TNT	2,4,6-trinitrotoluene
TNX	hexahydro-1,3,5-trinitroso-1,3,5-triazine
TOC	total organic carbon
TSS	total suspended solids
ZVI	zero-valent iron

1.0 INTRODUCTION

This report summarizes the performance of the near-surface corrective measures implementation (CMI) at Consolidated Unit 16-021(c)-99, located in Technical Area 16 (TA-16) at the Los Alamos National Laboratory (Laboratory) (Figure 1.0-1).The activities reported in this document focus on measurements collected from the pilot permeable reactive barrier (PRB) installed in Cañon de Valle, the effectiveness of the low-permeability cap constructed on the former settling pond, and the monitoring of an alluvial well installed to measure performance of surge bed injection grouting within the former settling pond area.

Implementation of these corrective measures is documented in the long-term monitoring and maintenance plan for the corrective measures implementation at Consolidated Unit 16-021(c)-99 (the CMI plan) (LANL 2010, 109252). One additional corrective measure, treatment of spring water with carbon filters at SWSC, Burning Ground, and Martin Springs, was identified as a corrective measure under the CMI plan (LANL 2010, 109252). Although the carbon filters were installed in 2009 and are functional, a National Pollutant Discharge Elimination System (NPDES) permit has not been obtained from the U.S. Environmental Protection Agency (EPA); therefore, the spring treatment units are pending a permit to operate. No data were collected, and thus no results are reported for the three carbon filter units during the 2010/2011monitoring period.

Monitoring and maintenance activities, analytical parameters, and PRB performance are discussed in this report. Performance of the low-permeability cap and injection grouting were measured using observations of structural integrity. Performance-monitoring activities at the PRB consisted of water-level measurements, field parameters, screening for on-site analysis (Earth and Environmental Sciences [EES] analytical suites), and sampling for off-site analysis of the PRB vessel and alluvial wells.

The report is organized into eight sections, including this introduction, and three supporting appendixes. Section 2 describes the performance criteria of the corrective measures. Section 3 describes the monitoring and maintenance performed and the general approach for determining the effectiveness of the remedial systems. Section 4 summarizes the data analysis, evaluation, and interpretation for each of the treatment systems and their monitoring strategies. Section 5 describes damage to the PRB resulting from flash flooding in Cañon de Valle in July and August 2011 after the June 2011 Las Conchas fire. Section 6 describes management of the investigation-derived wastes (IDW). Section 7 presents conclusions and recommendations based on monitoring performed to date. Section 8 lists the references cited in this document.

Appendix A provides photographs of the CMI monitoring, PRB media configuration, and damage resulting from flash flooding. Appendix B presents both the field-screening and off-site analytical data collected during the CMI monitoring period. Appendix C presents the recommendations for design modification, operation, maintenance, and sampling, including the monitoring and sampling schedule, for the 2011/2012 CMI monitoring effort.

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the New Mexico Environment Department (NMED) in accordance with U.S. Department of Energy policy.

1.1 Project Background

Consolidated Unit 16-021(c)-99 consists of the high explosives– (HE-) machining building (16-260) and associated sumps, drainlines, and troughs that discharged into the 260 Outfall drainage channel. The 260 Outfall drainage channel consists of the outfall, a former settling pond, and the lower portion of the drainage channel leading to Cañon de Valle. Water contaminated with explosive compounds from the outfall entered the former settling pond and drained into the 260 Outfall drainage channel, providing a pathway for contamination identified in downgradient components of the Consolidated Unit 16-021(c)-99 hydrogeologic system, including the 260 Outfall drainage channel, SWSC, Burning Ground, Martin Springs, the Cañon de Valle alluvial system, and deeper groundwater systems (LANL 2003, 077965). Contaminants associated with Consolidated Unit 16-021(c)-99, particularly explosive compounds and barium, are present in shallow soil, springs, and shallow groundwater at several locations at TA-16 (LANL 2003, 077965).

In 2009, a remedial implementation was performed for contaminated structures and environmental media. Remediation activities included selective removal of soil and tuff from the 260 Outfall drainage channel, removal of the concrete trough, as well as injection grouting of a contaminated surge bed beneath the drainage channel (LANL 2010, 108868). Post remediation, the CMI at Consolidated Unit 16-021(c)-99, included installing three engineered systems: (1) a low-permeability cap on the former settling pond; (2) carbon filter treatment systems of spring waters at SWSC and Burning Ground Springs in Cañon de Valle and at Martin Spring in Martin Spring Canyon; and (3) a pilot PRB treatment system in Cañon de Valle (Figure 1.1-1). Contaminants have been identified in deeper groundwaters (i.e., deep perched and regional), and the intent of the CMI remediation strategies are to reduce potential contaminant migration from alluvial groundwater to these deeper aquifers.

1.2 Site Location and Description

TA-16, located in the southwest corner the Laboratory (Figure 1.0-1), is surrounded by a security fence, covers approximately 2410 acres (3.8 mi^2), and is on a portion of land acquired in 1943 by the U.S. Department of the Army for the Manhattan Project. TA-16 is bordered by Bandelier National Monument along NM 4 to the south and by the Santa Fe National Forest along NM 501 to the west. To the north and east, it is bordered by TA-08, TA-09, TA-11, TA-14, TA-15, TA-37, and TA-49 (Figure 1.0-1). Water Canyon, a 200-ft-deep ravine with steep walls, separates NM 4 from active sites at TA-16, and Cañon de Valle forms the northern boundary of TA-16. The 260 Outfall is located in the north-central portion of TA-16.

TA-16 was established to develop explosive formulations, cast and machine explosive charges, and assemble and test explosive components for the U.S. nuclear weapons program. Most work at TA-16 has been conducted in support of developing, testing, and producing explosive charges for the implosion method. Present-day use of TA-16 is essentially the same, although the facilities have been upgraded and expanded as the explosive and manufacturing technologies have advanced.

Consolidated Unit 16-021(c)-99 consists of two Solid Waste Management Units (SWMUs): 16-003(k) and 16-021(c). SWMU 16-003(k) consisted of 13 sumps and approximately 1200 ft of associated drainlines and troughs that led from the explosive compound–machining building (16-260) to the 260 Outfall drainage channel. Explosive compound–contaminated water flowed from the sumps into the concrete trough and ultimately to the 260 Outfall, located approximately 200 ft east of building 16-260.

SWMU 16-021(c) consists of three areas: an upper drainage channel fed directly by the 260 Outfall, a former settling pond, and a lower drainage channel leading to Cañon de Valle. The former settling pond was approximately 50 ft long and 20 ft wide and was located in the upper drainage channel, approximately 45 ft below the 260 Outfall. The drainage channel runs approximately 600 ft northeast from the 260 Outfall to the bottom of Cañon de Valle. A 15-ft near-vertical cliff is located approximately 400 ft from the 260 Outfall and marks the break between the upper and lower drainage channels.

Building 16-260 has been used since 1951 to process and machine explosive compounds. Water was used to machine the explosives (which are slightly water-soluble); wastewater from machining operations contained dissolved explosive compounds and possibly entrained explosive compound cuttings. Wastewater treatment consisted of routing the water to 13 settling sumps to recover entrained explosive compound cuttings. From 1951 to 1996, the water from these sumps was discharged to the 260 Outfall. In 1994, outfall discharge volumes were measured at several million gallons per year. The discharge volumes were probably higher during the 1950s when explosive compound production output from building 16-260 was substantially greater than it was in the 1990s (LANL 1994, 076858). In the past, barium had been a constituent of certain explosive compound formulations, and thus barium is also present in the outfall wastewater from building 16-260.

From the late 1970s to 1996, the 260 Outfall was permitted by EPA to operate as EPA Outfall No. 05A056 under the Laboratory’s 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 removed from the permit in January 1998. A 2000–2001 interim measure (IM) cleanup (LANL 2002, 073706) removed more than 1300 yd^3 of contaminated soil from the former settling pond and channel. Approximately 90% of the explosive compounds in the Consolidated Unit 16-021(c)-99 source area was removed (LANL 2002, 073706).

Explosive compound–contaminated water from the building 16-260 Outfall entered the former settling pond and drained into the 260 Outfall drainage channel, creating a significant pathway for contamination identified downgradient from Consolidated Unit 16-021(c)-99 hydrogeologic system, including three springs (SWSC, Burning Ground, and Martin Springs), the alluvial groundwater system, and deeper groundwater systems.

1.3 Site Contamination

Chemicals of potential concern (COPCs) associated with Consolidated Unit 16-021(c)-99 are detected in shallow soil, springs, and groundwater at several locations at TA-16. These COPCs include RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), TNT (2,4,6-trinitrotoluene), and barium. Another explosive compound, HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), is also present but less prevalent than other explosive compounds. A wide range of other contaminants, including volatile organic compounds, other metals, and high explosive byproducts and degradation products are associated with 260 Outfall discharges.

Bulk concentrations of explosive compounds and barium in the project area have been reduced by the soil remediation efforts described and summarized in Consolidated Unit 16-021(c)-99 CMI summary report (LANL 2010, 108868). The objectives of the current corrective measures are to (1) reduce or prevent contaminant migration from the alluvial aquifer to the intermediate and regional aquifers and (2) to reduce exposure concentrations of COPCs from groundwater and springs to below action levels.

2.0 CMI DESIGN AND IMPLEMENTATION

This section describes the design and implementation of the CMI at Consolidated Unit 16-021(c)-99. Each of the CMI projects is described, including its performance objectives and the types of data collected to evaluate performance.

The design and implementation of the corrective measures at Consolidated Unit 16-021(c)-99 followed the protocol of the CMI plan (LANL 2010, 109252). All corrective measures were designed to reduce the transport and uptake of explosive compounds and barium via alluvial groundwater (LANL 2007, 098192).

Complete descriptions of each corrective measure and specific information on design and construction are reported in the summary report (LANL 2010, 108868). Figure 1.0-1 presents a site map of the locations of Consolidated Unit 16-021(c)-99 CMI projects and Figure 2.0-1 provides a detailed map of the PRB installation location.

2.1 PRB

The PRB utilizes a cutoff wall to divert groundwater into a downgradient reactive cell. The cutoff wall is designed to dam and accumulate water on the upgradient side. The groundwater cutoff wall consists of impermeable polyvinyl chloride (PVC) sheet-piling. The PVC wall is placed in a 2-ft-wide linear trench, the bottom of which is tuff. The wall is sealed and keyed into the underlying tuff using a bentonite-soil mixture overlain with geotextile and 3/8-in. pea gravel. On the upgradient side of the wall is a 3/8-in. pea gravel collection gallery wrapped with a geotextile fabric. Within the pea gravel is a 4-in.-diameter perforated plastic pipe to collect water. Two penetrations slightly below the top of the subsurface cutoff wall allow accumulated water to overflow into a 2-in. flexible PVC line that delivers the collected water approximately 200 ft downgradient via gravity to the PRB treatment vessel.

The PRB is an enclosed, baffled polypropylene vessel containing four cells for the reactive media (Figures 2.1-1 and 2.1-2). The system is baffled to control the water flow path and residence time. Water flows into the four cells sequentially. After treatment through the four-stage reactive cell, the groundwater is directed to an infiltration gallery (LANL 2010, 108648). Figure 2.1-1 presents a schematic of the PRB vessel and lists the filter media configuration by operational periods. Water sampling ports were installed in three of the filter media cells (cells 2, 3, and 4), as well as the inflow and outflow ports (Figures 2.1-1 and 2.1-2), to evaluate barrier performance.

The PRB installation activities began on December 14, 2009, and were completed on January 19, 2010. Appendix A presents photographs of the PRB system, including the four-stage reactive cells.

From January 26 to January 31, 2010, 20 monitoring points (16 alluvial wells and 4 piezometers) were installed to measure water levels and groundwater chemistry of the barrier’s inflow and outflow (Figure 2.0-1). Monitoring included the collection of water-level data, as well as on- and off-site analytical chemistry of groundwater samples.

Upgradient and downgradient wells were monitored for explosive compounds, explosive compound degradation products, and barium to evaluate trends in concentrations that may have been affected by the PRB treatment system.

The performance objectives for the PRB were to reduce the occurrence and concentration of explosive compounds (namely RDX) and barium in alluvial groundwater to concentrations below the groundwater screening levels, thereby decreasing potential contributions to underlying and downgradient intermediate and regional groundwater zones. In addition, the PRB was constructed as a test-case for other permeable reactive vessels. Functionality was measured in terms of contaminant reduction as well as water-quality measurements, maintenance of flow, physical durability, and treatment media life.

2.2 Other CMI Projects

In addition to the installation of the PRB, three other projects were implemented as corrective measures for the CMI plan. These projects are discussed below.

Injection grouting was the selected remedy for the surge bed underlying the former settling pond. The grout material and injection technique were dictated by the site conditions. The surge bed site is a relatively small area (approximately 1250 ft^2). The contaminant levels are moderate to high and are primarily explosive compound–contamination with RDX concentrations up to 4500 mg/kg. The contamination was identified as residing within the surge bed material primarily to a depth of approximately 17 ft below ground surface (bgs). Because of the depth of the overburden overlaying the relatively small area of contamination, it was determined that grout injection was preferred over site excavation.

These activities were designed to prevent the contaminated upper surge bed within the former settling pond area from making contact with groundwater by isolating the contaminated horizon and preventing contaminants from leaching into groundwater, migrating off-site, and threatening groundwater quality. The decision to treat the surge bed using in situ injection grouting was based on the areal extent, depth, and volume of contamination, type and concentration of contaminants present, soil characteristics, and site hydrogeology (LANL 2009, 107452). The selection was described in the CMI plan (LANL 2007, 098192) and approved by NMED (2007, 098449). Injection-grouting activities began on November 3, 2009, and were completed on January 31, 2010.

A low-permeability cap constructed of soil and bentonite was placed over the former settling pond to prevent surface and groundwater from infiltrating and contacting potentially contaminated underlying tuff. During the cap installation, on-site field tests were conducted to verify the materials (e.g., water and soil-bentonite backfill mixture) met the engineering design requirements for moisture and compaction density (LANL 2009, 107452). Field activities were completed on January 30 and 31, 2010. Stormwater controls were erected to prevent run-on onto the cap.

The alluvial well in the vicinity of the former settling pond is monitored for the presence of water. If present, the water is analyzed for explosive compounds. The monitoring approach is designed to test the success of the low-permeability cap and surge bed injection grouting underlying the former settling pond. The measure of performance success of the cap and injection grouting is that no water is detected in the alluvial well (LANL 2007, 098192, p. 16).

Carbon filters were constructed at Burning Ground, SWSC, and Martin Springs in January 2010 to treat stormwater. After the filters had been installed, EPA determined an NPDES permit was required for their operation. The filters would not be able to meet discharge limits for aluminum, however, because of high background concentrations of aluminum in the spring water. The filters have remained in bypass mode pending resolution of permitting issues by EPA and NMED. Because the filters were not set to operate, no monitoring or sampling took place at the carbon filters at Burning Ground, SWSC, or Martin Springs in Cañon de Valle in 2010/2011. EPA issued a draft NPDES permit on August 27, 2011 that may help address the aluminum issue, but which raises additional issues with other inorganic constituents (e.g., silver, thallium).

3.0 OPERATION, MONITORING, AND MAINTENANCE ACTIVITIES

This section describes the monitoring and maintenance activities performed to evaluate the effectiveness of the PRB and associated CMI projects. A timeline of key activities associated with the PRB and CMI projects is presented in Table 3.0-1.

3.1 PRB Operation, Monitoring, and Maintenance

Installation of the PRB cutoff wall and vessel was complete in January 2010, and no flow was observed until spring snowmelt began in March 2010. The initial flow during the first 2 to 3 wk in March flushed the piping and collection systems. The preoperational or baseline sampling event of the upgradient and downgradient alluvial wells was completed before the vessel began to fill. The plumbing was turned on to fill the vessel beginning on April 2, 2010. Discharge from the vessel into the post-treatment sample port was first observed on April 8, 2010.

Monitoring activities at the PRB consisted of water-level measurements, field-parameter determination, and sampling for off-site analysis of the PRB vessel and alluvial wells as well as sampling for on-site analyses performed at the EES analytical laboratory to assess the functionality of the vessel. Water levels at the alluvial wells were recorded to assess the ability of the cutoff wall to divert groundwater flow through the PRB vessel and monitor the status of the groundwater potentiometric surface above and below the cutoff wall. Sampling and groundwater field parameters of the alluvial wells gave insight into the baseline groundwater geochemistry and contaminants passing through the PRB vessel, specifically the concentrations of explosive compounds, explosive compound degradation products, and barium. The sampling and field parameters measured in the vessel were used to assess whether the vessel media were successfully lowering the concentrations of COPCs (primarily RDX and barium) in the water. Water flow was measured at the inlet and outlet sampling ports to estimate the PRB vessel flow rate. Additionally, the structural integrity of the piping, U-joints, valves, vessel, piezometers, and manholes were monitored to check for damage or malfunction.

Operation, monitoring, and maintenance of the PRB included the monitoring of three upgradient alluvial wells (CDV-16-611921, CDV-16-611923, and CDV-16-611934); three downgradient alluvial wells (CDV-16-611938, CDV-16-611936, and CDV-16-611937); and the inflow (16-612215), outflow (16-612220); and the treatment chambers (16-612217, 16-612218, 16-612219) of the PRB vessel (Figure 2.0-1).

Sample collection dates for field parameters and analytical chemistry suites for alluvial monitoring wells and the PRB vessel are summarized in Tables 3.1-1 and 3.1-2. On-site field parameters and off-site chemical analyses performed are identified in Tables 3.1-3 and 3.1-4, respectively.

3.1.1 Water Levels

Water levels were measured in the PRB reactor vessel, as well as in the upstream and downstream alluvial monitoring wells. Water-level measurements included both manual and automated readings. Three wells upstream and three wells downstream of the cutoff wall were instrumented with pressure transducers to collect water level data on 1-h intervals.

The water levels of the alluvial wells were measured weekly from February to mid-June 2010, except for one missed event resulting from conflicts with site access requirements (the week of May 10, 2010), semimonthly from mid-June to July 2010, and monthly from August 2010 to March 2011. When water levels were measured at the PRB, field work included manually measuring water levels at each alluvial well, piezometer, and sample port as well as visually inspecting all visible plumbing and valves inside the two manholes. When the discharge ports before and after the vessel were not submerged, a discharge rate was taken. The discharge ports in the manholes were often submerged and a discharge rate could not be measured for most of the monitoring period.

Water levels at the PRB alluvial monitoring wells followed seasonal hydrologic variations with wet periods in the spring and summer rainy period in 2010. In 2011, there was very little snow accumulation in the canyon so spring runoff was minimal, and the summer rains did not begin until late July. Basically the canyon alluvium remained dry from fall 2010 through summer 2011. The wells downgradient of the PRB cutoff wall showed that groundwater was not leaking through the wall, while water levels in the piezometers and wells just upstream from the cutoff wall showed the water had successfully mounded behind the wall up to the elevation of the outflow points in the wall. Wells CDV-16-611928, CDV-16-611932, and CDV-16-611927 were dry during the whole course of monitoring. Wells CDV-16-611931, CDV-16-611921, CDV-16-611935, and CDV-16-611933 were dry as of June 19, 2011. Manual water-level measurements are discussed in section 4.1-1.

3.1.2 Field Parameters and On-Site Analytical Sample Collection

The PRB alluvial wells were sampled and field parameters were collected monthly for the first quarter and quarterly for the remaining three quarters. Field parameter measurements include water level, pH, temperature, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen (DO), and turbidity. Field parameters were measured using an YSI multiparameter water-quality probe and industry-standard water-level tape.

Wells were sampled according to Standard Operating Procedure (SOP) 5232, Groundwater Sampling, specific to alluvial wells using a peristaltic pump and synthetic tubing. Depending on the number of field personnel deployed, sampling for the alluvial wells (six representative wells) and the PRB vessel took 2 to 3 d to complete. The six representative wells include wells CDV-16-611931, CDV-16-611921, CDV-16-611934 upstream from the vessel and CDV-16-611936, CDV-16-611937, and CDV-16-611938 downstream from the vessel. Well CDV-16-611931 was consistently the highest producing well, maintaining a steady water level. Well CDV-16-611921 was dry or purged dry. Samples for on-site analysis (i.e., EES laboratory analysis) were collected in early November 2010, late November 2010, January 2011, and February 2011 and submitted for analysis of anions, cations, alkalinity, and RDX.

3.1.3 Off-Site Analytical Sample Collection

Groundwater samples were collected from three upgradient alluvial wells (CDV-16-611921, CDV-16-611923, and CDV-16-611934), three downgradient alluvial wells (CDV-16-611938, CDV-16-611936, and CDV-16-611937), and the inflow (16-612215), outflow (16-612220), and treatment chambers (16-612217, 16-612218, and 16-612219) of the PRB vessel. Samples for off-site analysis were collected in May, June, and July 2010. Following media replacement and reconfiguration of the PRB in September 2010, samples were collected and submitted for off-site analysis in November 2010 and February 2011. Groundwater samples were collected in accordance with SOP-5232 and were submitted for explosive compounds, explosive compound breakdown products, target analyte list (TAL) metals, cations, and anions.

3.1.4 Vessel Inspection and Maintenance

Physical inspection of the PRB vessel was performed concurrently with sampling events. The structural integrity of the piping, U-joints, valves, vessel, piezometers, and manholes were checked for damage or malfunction. Review of field parameter and off-site analytical data were also used to assess PRB performance and identify shortcomings in functionality.

3.2 Other CMI Monitoring and Maintenance

Monitoring and maintenance for the other CMI projects included visual inspection of the low-permeability cap and monitoring for water in the newly installed alluvial monitoring well CDV-16-612309 to evaluate the performance of the grout injections. The low-permeability cap was inspected for cracks and subsidence as well as for the presence of standing water or runoff as the result of run-on by or retention of stormwater or snowmelt. A summary of monitoring frequency for the other CMI projects is presented in Table 3.2-1.

3.3 Deviations from CMI Monitoring Plan

The CMI monitoring plan called for operation and monitoring of carbon water filters at Martin, Burning Ground, and SWSC Springs. The carbon water filters were installed but remained inactive pending resolution of NPDES discharge permit issues with EPA and NMED. The suspension of operation and monitoring of the spring carbon water filters was a deviation from the monitoring plan (LANL 2010, 109252).

The planned frequency of sampling at the PRB was affected by filter media performance troubleshooting and media replacement. Media replacement was planned for when outflow water measurements from the PRB exceeded standards for barium and RDX. However, the time elapsed between sample collection and receipt of analytical results was too great to ensure continued performance of the filter media, and water quality criteria were exceeded during more than one sampling event.

4.0 DATA ANALYSIS, EVALUATION, AND INTERPRETATION

This section discusses the findings, results, evaluation, and interpretation of data collected from the PRB and other CMI projects for the period of operation. Two separate configurations of the PRB media were evaluated during the past year. Configuration 1 consisted of gravel-ZVI-gravel-zeolite, which operated from April 2010 to June 2010. Configuration 2 rearranged the sequence of media with gravel-zeolite-gravel-ZVI and operated from September 2010 to February 2011. A third configuration was implemented in July 2011 and consisted of removing the ZVI media altogether and substituting granular activated carbon (GAC). NMED was consulted concerning the reconfiguration of PRB vessel media before each media change.

4.1 Configuration 1: Gravel-ZVI-Gravel-Zeolite

The initial operation of the PRB vessel began on April 2, 2010. Initial sampling was completed on May 6, June 3, and July 1, 2010. Results from the May 2010 sampling event were received in mid-July and indicated potential problems with PRB operation. Consequently, sampling was suspended to assess the functionality of the PRB. The results showed similar concentrations of RDX and HMX in the pretreatment and post-treatment ports. On August 3, 2010, the lid of the vessel was removed to inspect the media, and observations included the following.

- Water was not flowing through the vessel.
- Water was bypassing the vessel top and the vertical baffles despite the gaskets.
- Microorganisms were growing and a slight anaerobic smell was noted.
- The interface where the groundwater encounters the ZVI media was very hard and difficult to progress a hand auger through.
- The zeolite chamber of the PRB contained gas vapor.

The primary cause of the impeded water flow was attributed to mineral precipitation at the ZVI cell. This reduced flow and caused the water to back up and eventually bypass through the gasket at the top of the baffle. A secondary feature was the vapor lock from gas trapped in the PRB vessel. The vessel was designed with gas relief and vent ports; however, when the vessel was completely filled with water to the roof, this precluded proper gas venting. Off-gassing is normal within a ZVI PRB (the typical gases formed are hydrogen (H_2) from the ZVI corrosion process; methane and possibly nitrogen (N_2) from the biological activity); however, when water flow is impeded, water rises to the vessel top and blocks the exit path for gas.

Geochemical analysis across the media indicated the ZVI was creating a desirable reducing environment for RDX breakdown. This was apparent because of an increase in pH and a decrease in the ORP (redox potential) across the ZVI (Tables 4.1-1 and 4.1-2). The solubility of carbonate minerals decrease significantly at higher pH, resulting in precipitation or coprecipitation with other minerals. The initial interpretation was that barium carbonate was precipitating and plugging the ZVI. Because of the loss of porosity in the ZVI from excess precipitation, a decision was made to switch the location of the ZVI and zeolite cells since the zeolite, which was designed to remove the barium, would remove the barium before the water pH increases from contacting the ZVI. Removal of the barium before contact with the ZVI should help eliminate the precipitation of barium and its complexes within the ZVI (Figure 2.1-1, configuration 2).

4.2 Configuration 2: Gravel-Zeolite-Gravel-ZVI

The media configuration was changed on September 10, 2010, by shoveling out the media and changing locations of the ZVI and zeolite. To assess the vessel functionality earlier and more rapidly, additional monitoring was performed after the media modification and included increased frequency of water levels for the remainder of September and October 2010, vessel field parameters, and sampling of vessel ports for on-site analysis at the EES analytical laboratory. The results from four EES sampling events and one off-site analytical event from October 2010 to February 2011 showed improved operation of the system compared with the original setup (Figure 4.2-1; Tables 4.2-1 through 4.2-4). The four sampling events from October 2011 to January 2011 showed complete removal of RDX within the PRB treatment vessel. Barium concentrations decreased from as much as 4.30 ppm to a minimum of 0.80 ppm before and after treatment through the vessel. One unexpected result revealed by the EES analyses was that silica was also being removed by the vessel media, decreasing from 47 µg/L to 0.3 µg/L during the November 2010 sample round (Figure 4.2-2). The vessel media was functioning properly during this time, but results of the last sample event on February 14, 2011, showed an increase of RDX and barium from the ZVI port to the post-treatment port, indicating the vessel was no longer removing the COPCs as designed.

Extremely low temperatures during the first week of February 2011 (–5 to 2 degrees Fahrenheit in Cañon de Valle on February 2, 2011) caused multiple vessel ports to freeze, including the upper and middle vapor ports only 0.2 and 0.8 ft from the top of the casing. The cold temperatures made it difficult to distinguish whether the mounding was from mineral precipitation or freezing water within the vessel. Once again silica and barium were being removed across the ZVI media, lending evidence to plugging from excess mineral precipitation. The pH increase from the ZVI that created the reducing zone is still problematic despite removing most of the barium in the zeolite cell. Declines in silica, barium, calcium, and magnesium across the ZVI indicated the formation of mineral precipitates that impeded flow.

On March 23, 2011, PRB vessel water levels and field-monitoring parameters were measured at all vent and sampling ports. Water levels in the sample ports indicated mounding in each chamber upstream from the ZVI cell. Next, the PRB vessel lid was removed. During removal of the lid, it was noted water in the vessel was under pressure. When the vessel top bolts were loosened, water began flowing. During normal operation, the water flows between cells about 7 in. below the vessel lid. This pressurization provided further indication that flow was plugged and water was mounding behind the ZVI media. Upon removal of the vessel lid, water was observed near the top of cells 2 and 3 (zeolite and gravel), separated by the bottom baffle (see Figure 4.2-3) and was overtopping in the first gravel cell.

The ZVI cell was saturated but the water level was only slightly above the media surface (~0.75 in.) and was flowing out the discharge port. Small amounts of light- and dark-colored biological accumulation were noted on the gravel surface of cell 1 (Figure 4.2-4). Some dark reddish microorganism growth, also directly on top of the zeolite media, was found in cell 2 (zeolite) (Figure 4.2-5). None of the biological growth penetrated the media, and growth was limited to the water zone above the media surfaces. Cell 4 (ZVI) has a thin 1- to 2- in. layer of 3/8-in. gravel (as per the design) on top of the ZVI. The gravels showed a rust-colored coating, as expected, from iron rusting and oxidation (Figure 4.2-6). Hand excavation of the gravel showed a whitish coating on the ZVI media, probably from mineral precipitation. Also red streaking was visible on the ZVI vertical baffle wall, indicating leakage of water over the top of the baffle between the vessel lid and baffle seal. Flow over the top of a baffle that is sealed against the vessel lid could only occur from pressure forcing the water through the seal. ZVI permeability was tested using a stainless-steel rod about 0.5 in. in diameter to penetrate the media in each chamber. Cells 1 through 3 (gravel, zeolite, gravel) were easily penetrated from top to bottom with the exception of the bottom few inches of cell 3, the second gravel cell (just before the ZVI). The last few inches seemed much harder than the rest of the gravel. The ZVI was very difficult to penetrate. Although it appeared the ZVI had a very low permeability, a sample of the upper ZVI was removed and water was easily poured through it. Most of the blockage was probably at the interface between the gravel and ZVI media, which is typical for ZVI reactive media (i.e., the majority of the precipitation occurs within the first 12 in. of media). In most applications with ZVI worldwide, this effect is expected and acceptable; however, the solute mineral composition of the Cañon de Valle alluvial groundwater is such that the induced precipitation restricts flow through the media, making the media ineffective for a low-maintenance application. In June 2011, the project decided to remove the ZVI and substitute GAC, after NMED was consulted about the reconfiguration.

4.3 Configuration 3: Zeolite-Zeolite-GAC-GAC

In July 2011, the third configuration of the PRB vessel was implemented. The gravel cells were removed, and only zeolite and GAC were installed for filter material in the vessel. The first two cells contained zeolite, and the next two cells contained GAC. The additional volume of zeolite is intended to increase contact time and increase barium removal efficiency. GAC has been demonstrated to effectively remove high explosive compounds at the Laboratory (LANL 2003, 077965). Performance data for configuration 3 will be collected and reported in a future report.

4.4 Field Parameter and Contaminant Analysis

Water-level measurements for the period of operation of the PRB and alluvial wells are presented in Table 4.4-1 and Figures 4.4-1 through 4.4-5. As treatment progresses, downgradient water levels should decline to near dry conditions as subsurface water is captured and diverted to the vessel. It is not expected that all downgradient wells will become dry because portions of the subsurface flow infiltrates laterally from the slopes of the canyon or from surface water (Figures 4.4-1 through 4.4-5).

Results of on-site field parameter analysis are presented in Table 4.1-1. Table 4.1-2 presents water quality parameter results from off-site laboratory analysis.

The PRB was designed with multiple filter media because no single medium can simultaneously remove barium and RDX. The zeolite removes barium by physical adsorption, whereas the ZVI removes RDX by chemical and/or biological degradation into benign byproducts. The indicator that the zeolite media is working is measurement of pre- and post-zeolite–barium concentrations. In contrast, the ZVI media is working as designed when the pH increases, the DO decreases, and the ORP decreases (Tables 4.1-1 and 4.1-2). These field parameters show that geochemically reducing conditions are in place for degradation of nitrosamine compounds such as RDX. The completeness of the RDX breakdown must be checked by analyzing post-treatment samples for RDX and the common degradation byproducts. Common degradation products are hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine (MNX), hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine (DNX) and hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX) and further breakdown components that include nitrate, nitrite, and nitrous oxide. Ultimate degradation results in carbon dioxide, hydrogen and nitrogen gases (Tables 4.1-1 and 4.1-2).

Plates 1 and 2 show removal of barium and RDX across the vessel flow path. When the vessel was flowing properly, the pH, ORP, and DO values changed as expected (Tables 4.1-1 and 4.1-2). The ZVI sample port showed a reduction in RDX concentrations even when flow was bypassing the treatment cells because the sample was stagnant water pulled from a ZVI matrix. Evaluation of proper function of a PRB includes sampling analysis and hydraulic flow measurement. Both conditions must be within design specifications to have continued successful contaminant removal.

On-site analytical results for metals and RDX are presented in Tables 4.2-1 and 4.2-3. Tables 4.1-1 and 4.1-2 present off-site laboratory analytical results for metals and explosive compounds.

Table 4.4-2 summarizes the PRB design basis for RDX and barium. Table 4.4-3 presents the contaminant-removal residence time for RDX and barium to meet treatment goals.

Tables 4.4-4 and 4.4-5 present comparisons of RDX and barium concentrations to applicable NMED screening levels for configurations 1 and 2, respectively.

4.5 PRB Functionality Summary

As a pilot implementation of PRB technology in Cañon de Valle, various media have been evaluated for the removal of RDX and barium. The literature indicates the majority of PRBs installed worldwide use ZVI as a principal filter medium for removal of explosive compounds (ITRC 2005, 109019). The Laboratory conducted treatability studies before this pilot PRB was installed. The results were limited in scope; however, ZVI was selected as the media for removal of RDX, and clinoptilolite zeolite was identified for removal of barium. ZVI was selected for its ability at the laboratory scale to completely degrade RDX into benign byproducts. Barium is typically removed by precipitation with sulfate; however, this removal method is more effective for batch treatment rather than continuous-flow operations. The large molecule size of barium sulfate impedes flow through the barrier. Consequently, zeolite, which adsorbs the barium within the zeolite matrix, was selected for the pilot treatment.

The initial PRB operation was only moderately successful because of the rapid decline in the hydraulic flow through the vessel. The production of hydroxyl radicals from the ZVI corrosion resulted in an increase in pH, a shift in the solubility of certain carbonate and other compounds, and a reduction in porosity of the media (ITRC 2005, 109019, p. 11). More specifically, the Cañon de Valle PRB experienced significant decreases in solubility of silica and barium, resulting in precipitation of minerals containing free ions. Table 4.5-1 shows the pH shift across the PRB. The solubility of silica is lowest at pH levels between 7 and 8. Additionally, the solubility is affected by temperature according to the following formula:

$$\log C = \left(-\frac{731}{T}\right) + 4.52$$

Table 4.5-2 shows the effect of temperature on solubility.

Numerous laboratory studies have shown that, under a range of geochemical conditions, reduction in porosity from mineral precipitation can occur near the upgradient edge of ZVI zones because of both abiotic and biotic reactions (Gavaskar et al. 2002, 206425). In 2004, an iron PRB was installed at the Cornhusker Army Ammunition Plant by the U.S. Department of Defense. The PRB was an in-situ ZVI wall designed to remediate HE in the groundwater. After 20 mo of treatment, flow through the PRB wall was 20 times less than the surrounding aquifer. Core samples indicated the interface between the soil and the ZVI media had excessive sulfate precipitation and led to a decrease in porosity of the media. Precipitates containing iron and sulfide were present at much higher concentrations in native aquifer materials just upgradient of the PRB than in the PRB itself (Johnson et al. 2008, 206413); consequently, groundwater was primarily flowing around and beneath the PRB.

Precipitation of native inorganic constituents such as silica, barium, and carbonates in groundwater are the primary cause of loss of reactivity and porosity in an iron PRB. Considering the geochemical composition of the alluvial groundwater in Cañon de Valle and the poor hydraulic performance of the ZVI media, GAC was identified as a substitute for ZVI for removing RDX for the third media configuration. Problems caused by precipitation are not expected with GAC because no ORP or pH changes will occur inside the PRB vessel. The RDX will simply be adsorbed onto the GAC.

4.6 Other CMI Project Performance Summary

Mitigation measures employed to prevent the run-on of stormwater onto the low-permeable cap remained functional throughout the monitoring period. No water was observed in monitoring well CDV-16-612309, indicating the injection grouting and low-permeable cap were effective at preventing infiltration of contaminants into the vadose zone.

5.0 SUMMARY OF FIRE/FLOODING EVENTS IN CAÑON DE VALLE

Between June 26 and August 3, 2011, the Las Conchas fire consumed more than 156,000 acres and destroyed 49 structures across the Santa Fe National Forest in Sandoval, Los Alamos, and Rio Arriba Counties; Santa Clara Pueblo; Jemez Pueblo; Cochiti Pueblo; Santo Domingo Pueblo; Bandelier National Monument; Valles Caldera National Preserve; and state and private in-holdings. The Cañon de Valle watershed and large areas upgradient of the PRB and CMI projects sustained moderate to severe fire damage as the Las Conchas fire moved east and north. While Laboratory property and the PRB and CMI projects were not directly impacted by the Las Conchas fire, the subsequent burn scar left the watershed vulnerable to flash flooding and severe erosion.

Between July 28 and August 3, 2011, a series of storms produced 4.1 in. of rain measured within the Cañon de Valle watershed. On August 3, 2011, a single storm precipitation total was 1.73 in., with a 30-min maximum intensity of 1.37 in. This event produced moderate to severe flooding, erosion, and debris flow.

On August 9, a site visit was conducted to evaluate the extent of flood damage to the PRB vessel, spring carbon filters, and adjacent alluvial groundwater monitoring wells and equipment. The cover of the PRB was removed to inspect for infiltration by floodwater, sediment, and ash. Some infiltration of floodwater, sediment, and ash was observed in the first and second PRB vessel chambers where the vertical vapor-sampling ports had broken off and been washed away during the flood event. The third and fourth vessel chambers were relatively unaffected.

Sedimentation and ash in the PRB were removed to a depth of approximately 5 in. from the first cell (zeolite) and to a depth of less than 1 in. from the second cell (also zeolite) (Appendix A). Removed materials were packaged for off-site disposal. The PRB cover was replaced and locked, with the inflow line set to "bypass" mode pending additional action to structurally shore up the vessel to prevent additional erosion and damage and to clean the intake and outlet lines.

Observed damage to the stream channel and equipment following the August 3, 2011, flooding event included the following:

- A 4-ft-deep × 9-ft-wide × 20-ft-long headcut had formed in the Cañon de Valle channel just east (downgradient) of the PRB cutoff wall.
- Channel cut and erosion exposed the piping that leads from the cutoff wall to the PRB.
- Two vapor-sampling ports were broken from the cover of the PRB.
- Broken ports probably led to infiltration of floodwater and sediment/ash into the first two chambers of the PRB.
- The pre-treatment vapor port to the PRB (location 16-612215) was damaged by the floodwaters, lodging debris inside the intake piping.
- Two alluvial monitoring wells (CDV-16-611938 and CDV-16-611934) and their concrete footings were dislodged from the canyon floor.
- Casing for alluvial well CDV-16-611934 was carried downstream and lodged against the manhole next to the PRB.
- Casing/foundation for alluvial well CDV-16-611938 was uprooted from canyon floor and bent in downstream direction. The well was filled with debris. Its transducer was recovered.
- One piezometer location (CDV-16-611924) was damaged by floodwaters and debris.
- Carbon filters at upstream spring locations were unaffected by flooding events.

On August 21, 2011, a larger rain event occurred over the recent burn scar in the watershed draining into Cañon de Valle. The rain gauge in the area recorded a total of 12.3 in. during the day and a 30-min maximum intensity of 6.8 in. Although these measurements are abnormally high and subject to doubt, the storm was unquestionably destructive, flooding both NM 501 with debris and the area upstream from the PRB.

The site was thoroughly inspected on August 26, 2011. Additional damage to the channel and equipment following the August 21, 2011, flooding event included the following:

- The flood incised through the PRB cutoff wall down to bedrock about 10 ft wide and about 5 ft deep.
- The cutoff wall was broken and splayed open downstream.
- Sediment was eroded from the channel bed and adjacent stream banks and sediment and rocks as large as 2 to 3 ft in diameter were deposited on top of the PRB vessel and throughout the canyon.
- All monitoring tubes and plumbing around the vessel were either transported downstream or buried.
- The tube connecting the cutoff wall to the vessel was ripped out of the vessel and the cutoff wall.

- Wells at locations CDV-16-611919, CDV-16-611934, CDV-16-611936, and CDV-16-611938 were washed away by flood waters, and the surface completion and well housing at location CDV-16-611931 was stripped away, leaving only PVC well casing.
- The piezometers at each of the cutoff wall's discharge points were broken off as well at locations CDV-16-611929 and CDV-16-611930.
- Debris from the PRB was found approximately 1 mi downstream and most likely traveled further downstream.

Appendix A presents photographs of post-flooding conditions in Cañon de Valle. Interim actions recommended as a result of field observations of flood damage include plugging and abandoning damaged wells and monitoring extant wells to measure post-flood baseline conditions. Appendix C presents the interim-monitoring actions proposed for the remaining CMI projects and baseline monitoring of alluvial groundwater. The Laboratory proposes to prepare a detailed flood recovery plan within 60 d of NMED's approval of this summary report. The plan will document the action(s) selected to ensure continued implementation of corrective measures for the remediation of barium and RDX in alluvial groundwater in Cañon de Valle.

6.0 WASTE MANAGEMENT

The IDW generated as a result of implementing corrective measures, investigation activities, and remediation activities includes purge water, spent filter media (gravel, zeolite, and ZVI), municipal solid waste, and contact waste. All IDW was containerized, characterized, and managed as specified in the project's waste characterization strategy form, which was prepared in accordance with SOP-5023, Characterization and Management of Environmental Program Waste.

In September 2010, approximately 0.75 yd^3 of spent filter media recovered from the first PRB configuration was packaged in wrangler bags and characterized for volatile organic compounds, semivolatile organic compounds, explosive compounds, TAL metals, and tritium. The spent filter media was determined to be nonhazardous and transported to the Rio Rancho disposal facility in Rio Rancho, New Mexico, on March 15, 2011. An excess of stormwater purged from the CMI and 90s Line Pond following a significant precipitation event was containerized and stored in three aboveground polyethylene tanks (two 2500-gal. and one 1200-gal. tank) with removable 12-in. lids. The purged stormwater was disposed of at Clean Harbors, in Denver, Colorado, on July 22, 2011.

Spent filter media recovered from the PRB on July 22, 2011, is staged in wrangler bags at the TA-16 field trailers, with disposal pending waste characterization results. Any additional waste generated as a result of post-flood cleanup and repairs will be managed in accordance with SOP-5023.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Installation of the PRB was completed in January 2010. During the initial operational period from April 2010 to July 2010, treatment was not successful because of mineral precipitation and subsequent plugging of the ZVI cell. In September 2010, the sequencing of the media was rearranged so the water passed through zeolite first, followed by ZVI. Under this configuration, the PRB successfully treated approximately 140,000 gal. of water from September 2010 to February 2011. Concentrations of RDX were reduced from 16 µg/L to below detection limits, and barium concentrations were reduced from approximately 4000 µg/L to approximately 1000 µg/L.

The performance goal of the PRB is to be a passive, low-maintenance treatment system. Because the ZVI had a limited operational period of 4 mo, the medium was replaced with GAC in July 2011. Although GAC does not degrade HE, it has been used previously at the Laboratory to successfully remove HE from groundwater, and it is well documented as useful for removing HE from numerous sites within the U.S. (http://docs.serdp-estcp.org). To further reduce the barium concentration so the post-treatment concentrations of barium will be less than the 1000 µg/L tap water standard, a greater volume of zeolite was added to the vessel. However, because of the substantial flash-flooding damage to the PRB system, the PRB will be remain nonoperational until repairs to the equipment or a modification to the corrective measure approach has been addressed.

Other CMI projects will continue to be monitored during the 2011/2012 monitoring period. A flood recovery plan will document the PRB repair approach or other action(s) selected to ensure continued implementation of corrective measures for the remediation of barium and RDX in alluvial groundwater in Cañon de Valle.

8.0 REFERENCES

The following list includes all documents cited in this report. 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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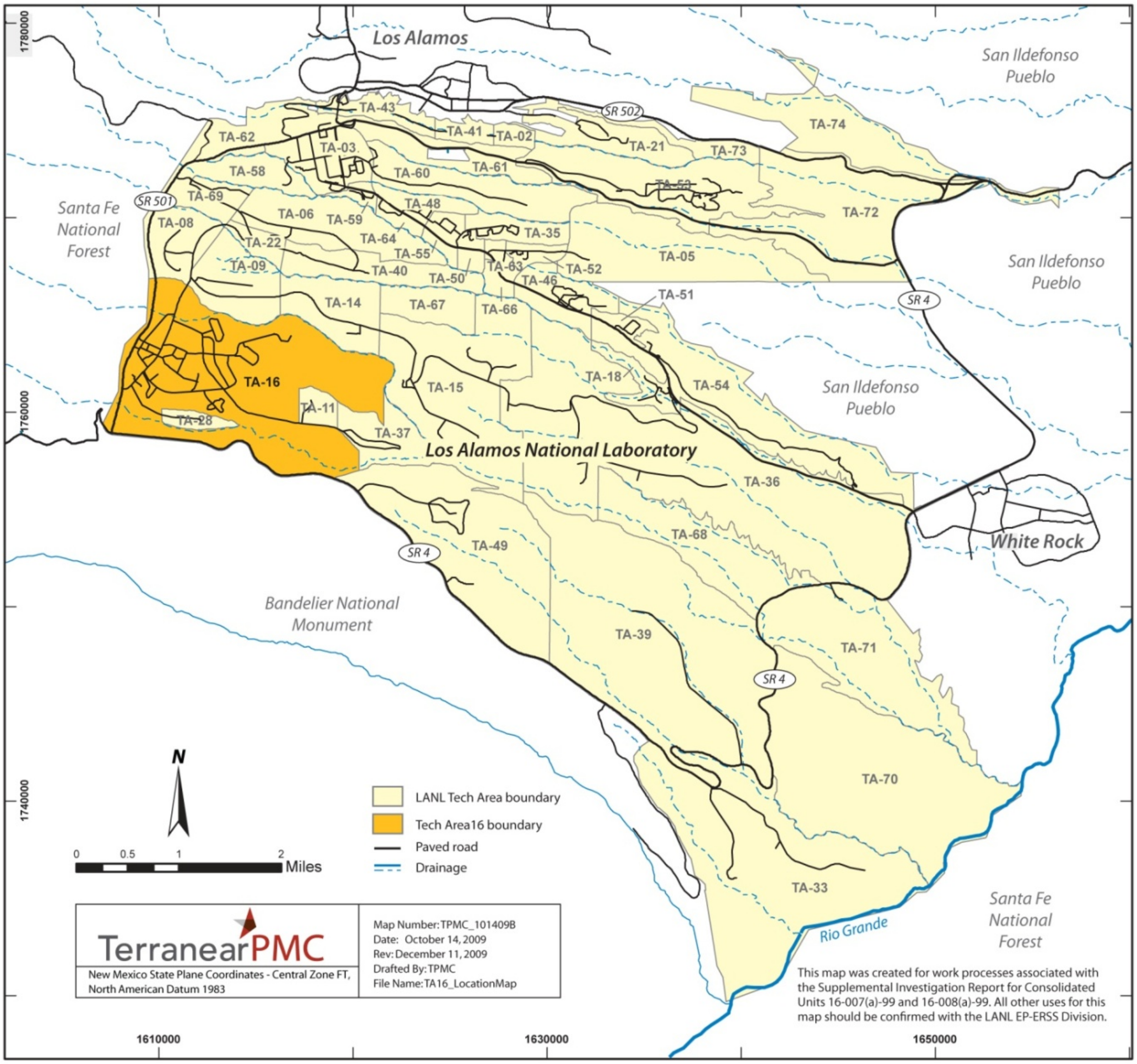


Figure 1.0-1 Location of TA-16 with respect to Laboratory TAs and surrounding areas

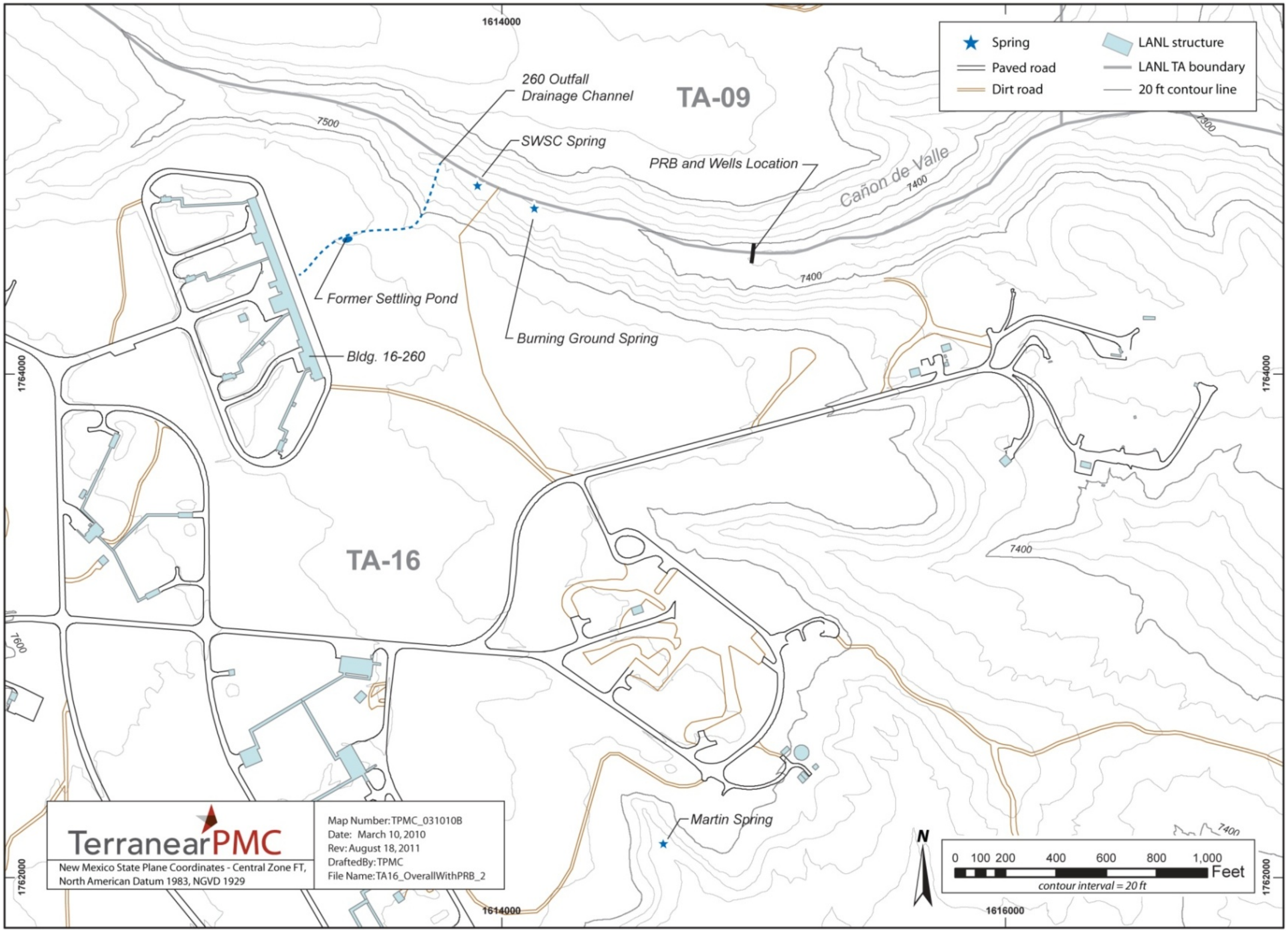


Figure 1.1-1 Location of Consolidated Unit 16-021(c)-99, including 260 Outfall drainage; former settling pond area; SWSC, Burning Ground, and Martin Springs; and PRB treatment system

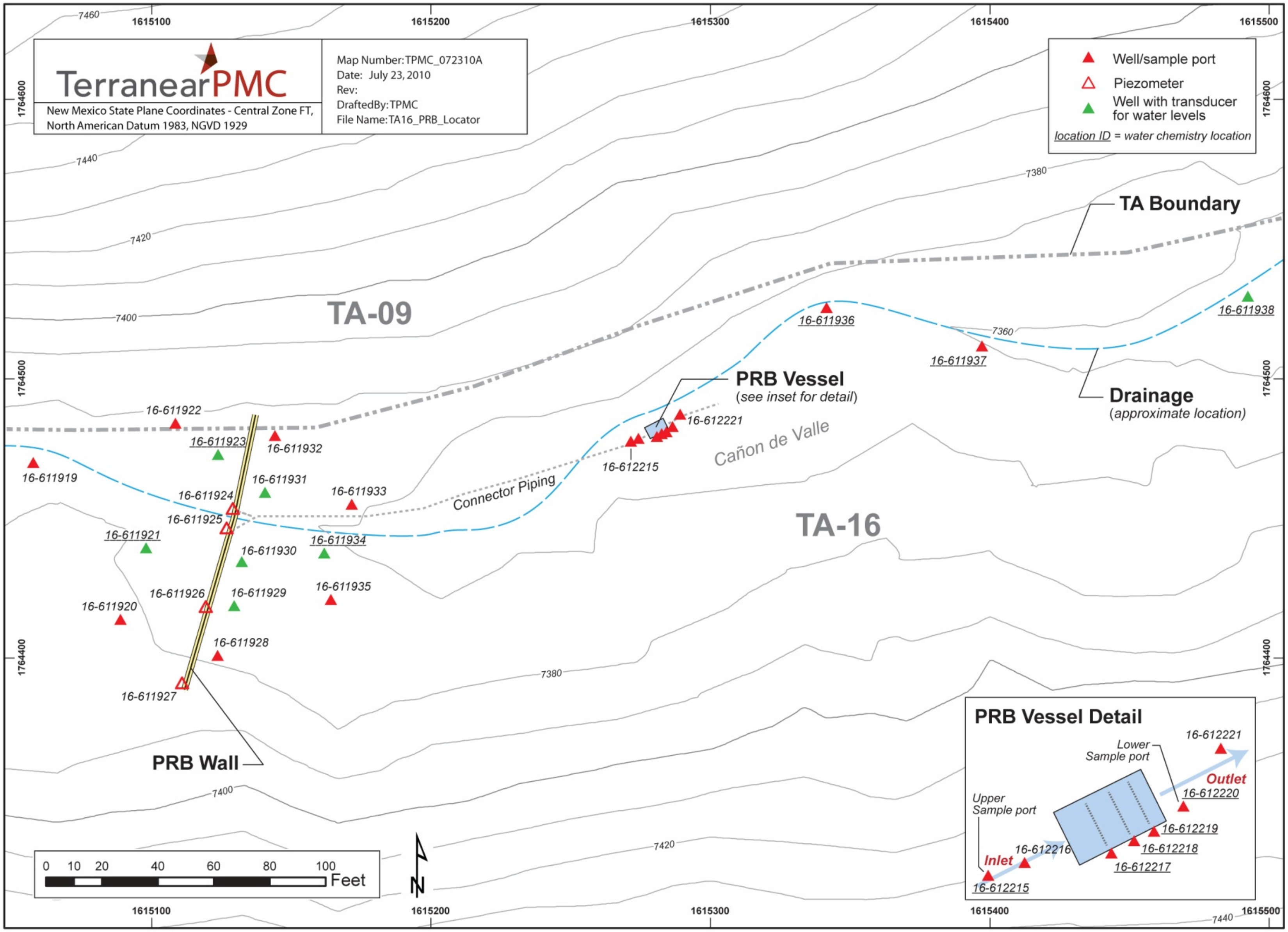
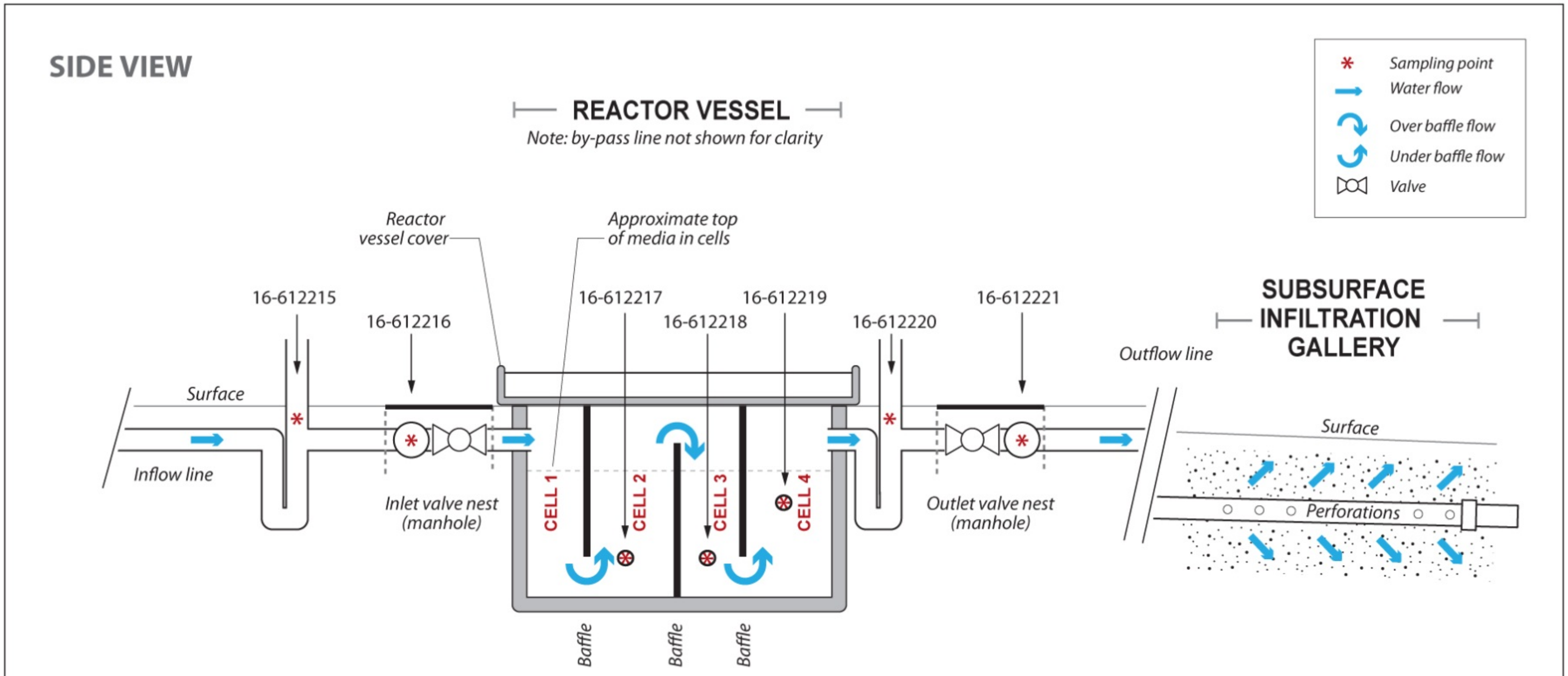


Figure 2.0-1 TA-16 CMI site map showing locations of the alluvial network, piezometers, and PRB



MEDIA CONFIGURATIONS FOR OPERATIONAL PERIODS

CONFIGURATION	OPERATIONAL PERIOD	CELL MEDIA			
		CELL 1	CELL 2	CELL 3	CELL 4
Config 1	April 2010 – September 2010	Gravel	ZVI	Gravel	Zeolite
Config 2	September 2010 – July 2011	Gravel	Zeolite	Gravel	ZVI
Config 3	July 2011 – August 2011	Zeolite	Zeolite	GAC	GAC

ZVI - Zero Valence Iron
GAC - Granular Activated Carbon

TerranearPMC

Drafted By: TPMC
Project Number:

Date: September 8, 2011
Filename: PRB_Vessel_MediaGeneral

GENERAL CONFIGURATION OF PERMEABLE REACTIVE BARRIER VESSEL

Los Alamos National Laboratory, Los Alamos, New Mexico

Not to scale

Figure 2.1-1 General configuration of the PRB vessel (side view)

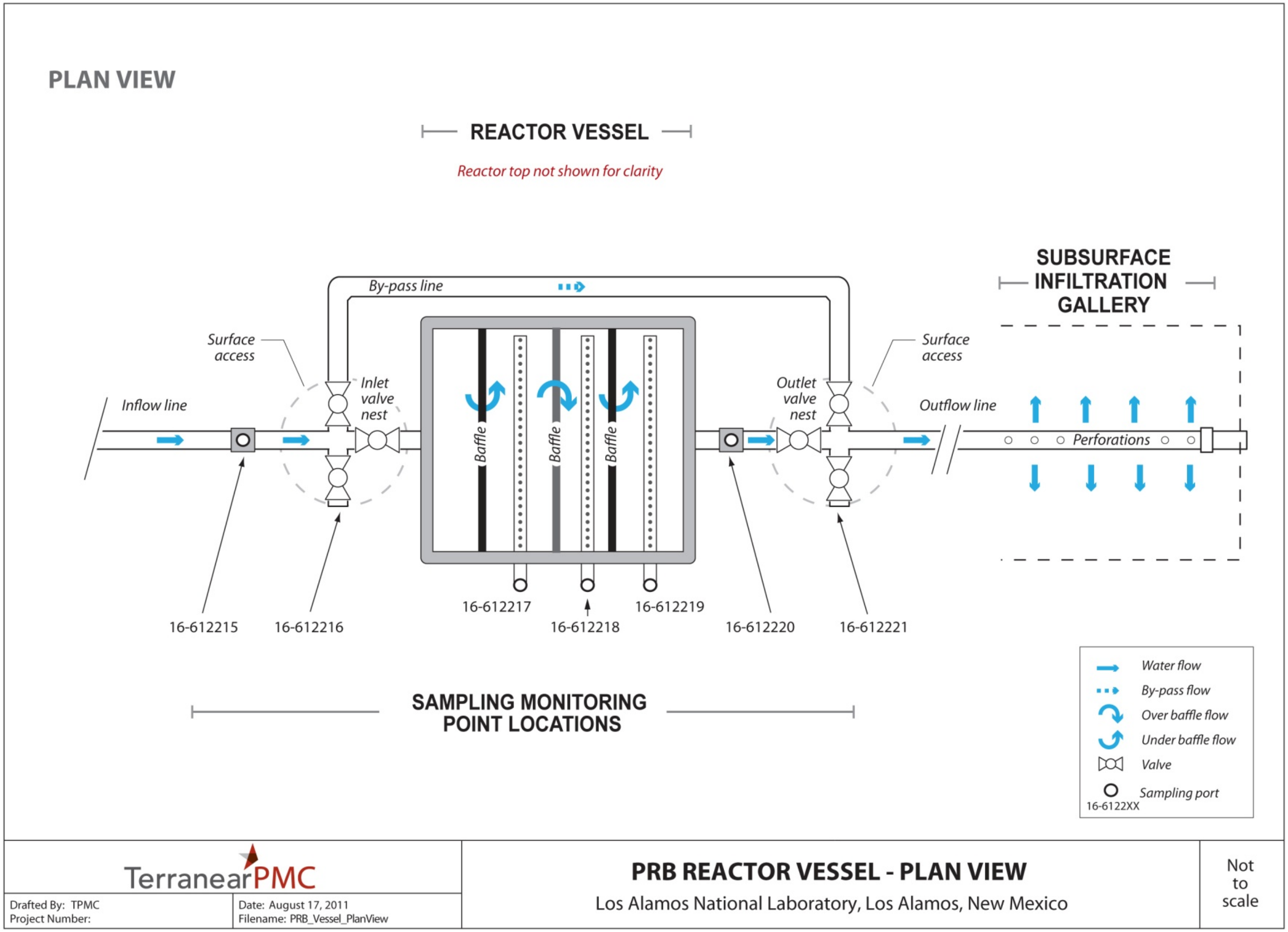
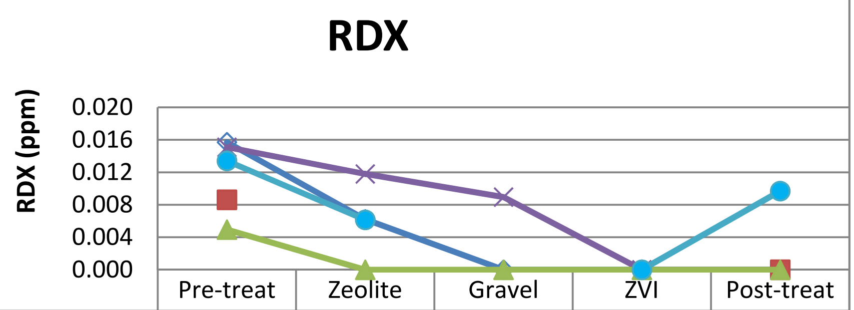
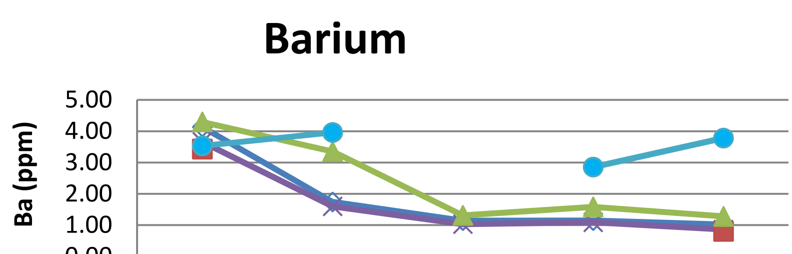


Figure 2.1-2 General configuration of the PRB vessel (top view)

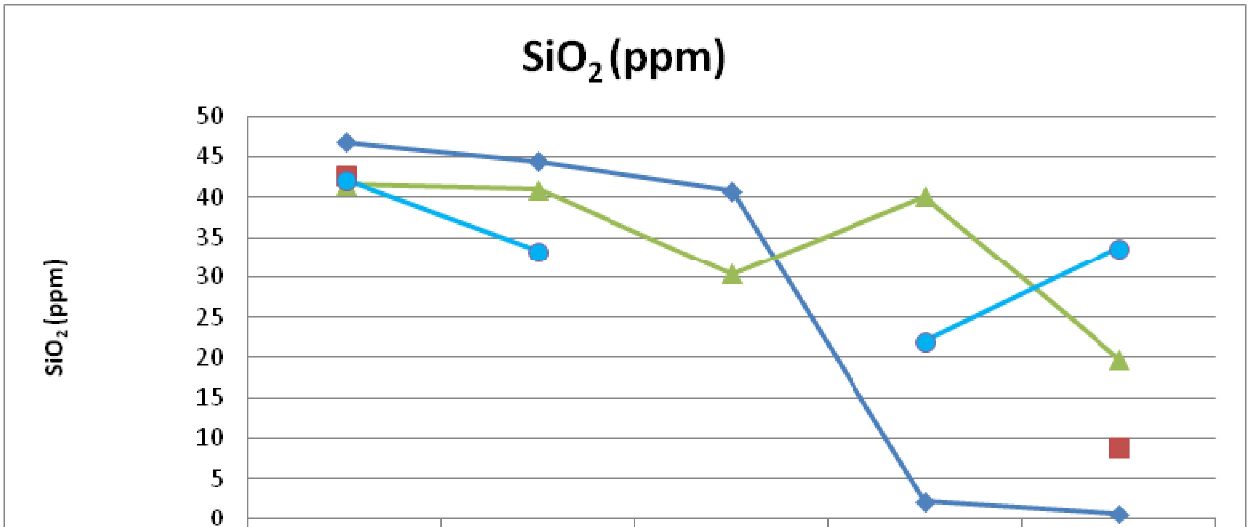


	Pre-treat	Zeolite	Gravel	ZVI	Post-treat
10/28/2010	0.016	0.006	0.000	0.000	0.000
11/1/10 Offsite Analytical	0.015	0.012	0.009	0.000	0.000
11/29/2010	0.009				0.000
1/6/2011	0.005	0.000	0.000	0.000	0.000
2/14/2011	0.013	0.006		0.000	0.010



	Pre-treat	Zeolite	Gravel	ZVI	Post-treat
10/28/2010	4.14	1.74	1.14	1.15	1.02
11/1/10 Offsite Analytical	3.66	1.6	1.03	1.09	0.86
11/29/2010	3.43				0.80
1/6/2011	4.30	3.35	1.31	1.58	1.28
2/14/2011	3.53	3.96		2.86	3.78

Figure 4.2-1 Removal of RDX and barium across treatment cells by sampling date



	Pre-treat	Zeolite	Gravel	ZVI	Post-treat
10/28/2010	47	44	41	2	1
11/29/2010	43				9
1/6/2011	42	41	30	40	20
2/14/2011	42	33		22	34

Figure 4.2-2 Removal of silica across the treatment cells by sampling date

Figure 4.2-3 Equilibration of water levels inside PRB vessel

Figure 4.2-4 Water accumulation in the gravel and zeolite cells (March 23, 2011)

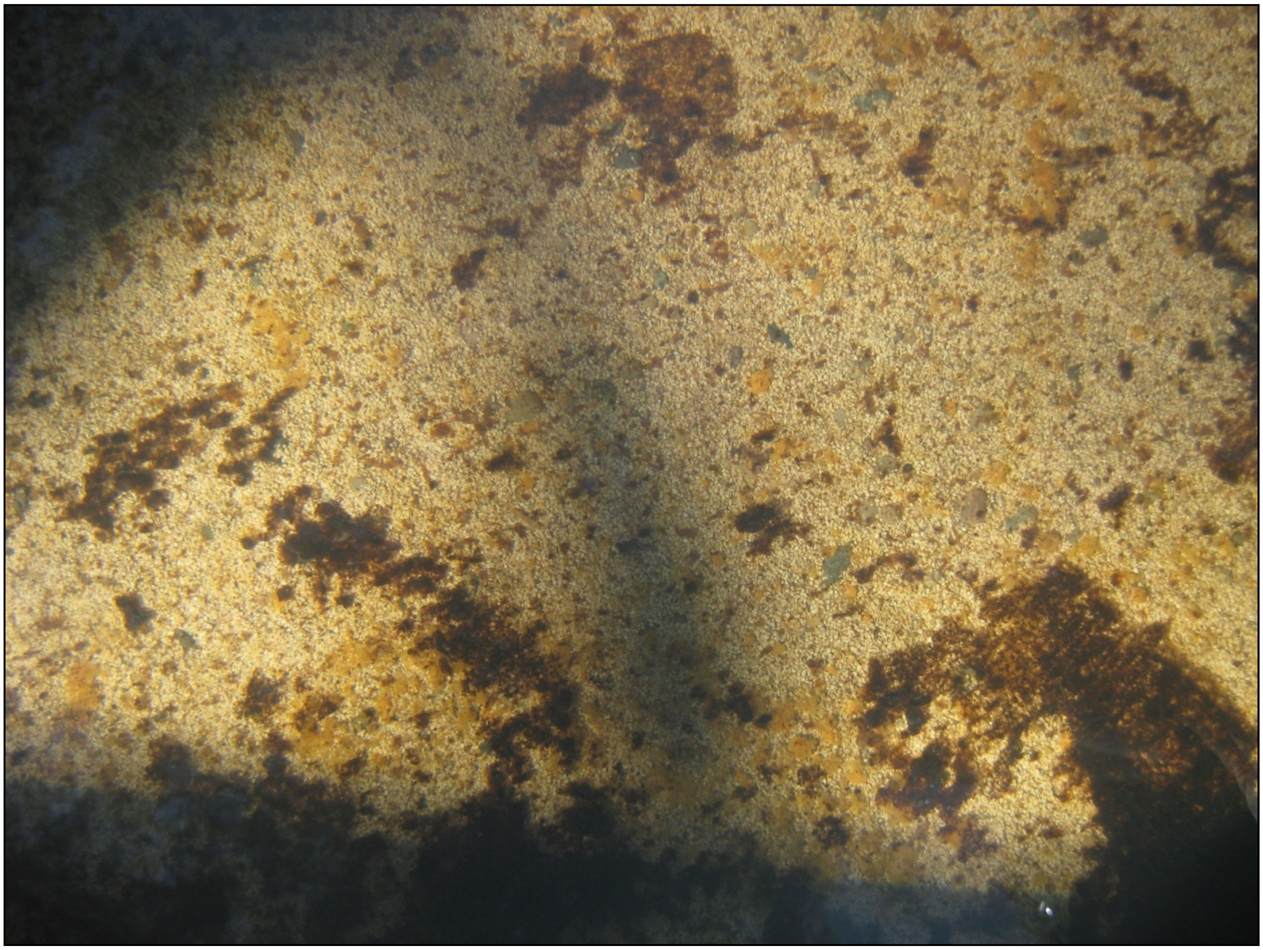


Figure 4.2-5 Biological accumulation in the zeolite cell (March 23, 2011)

Figure 4.2-6 Impermeable ZVI material reduces flow/causes groundwater mounding in upgradient gravel cell

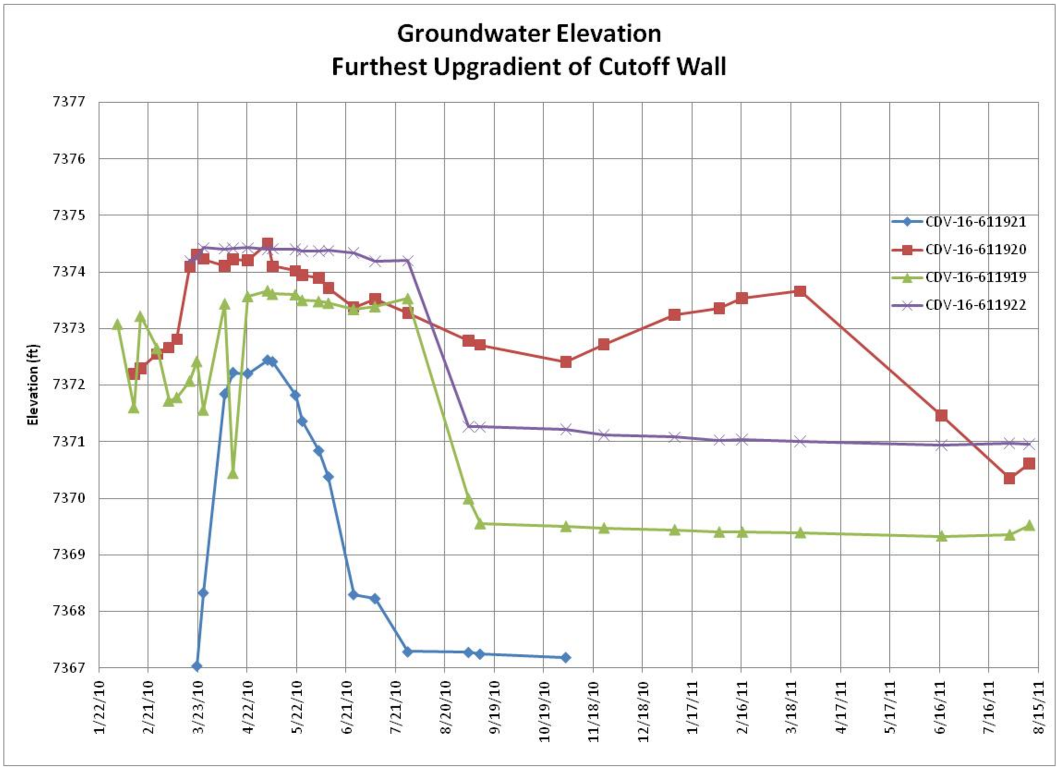


Figure 4.4-1 Water levels measured in wells located upgradient and away from the PRB cutoff wall

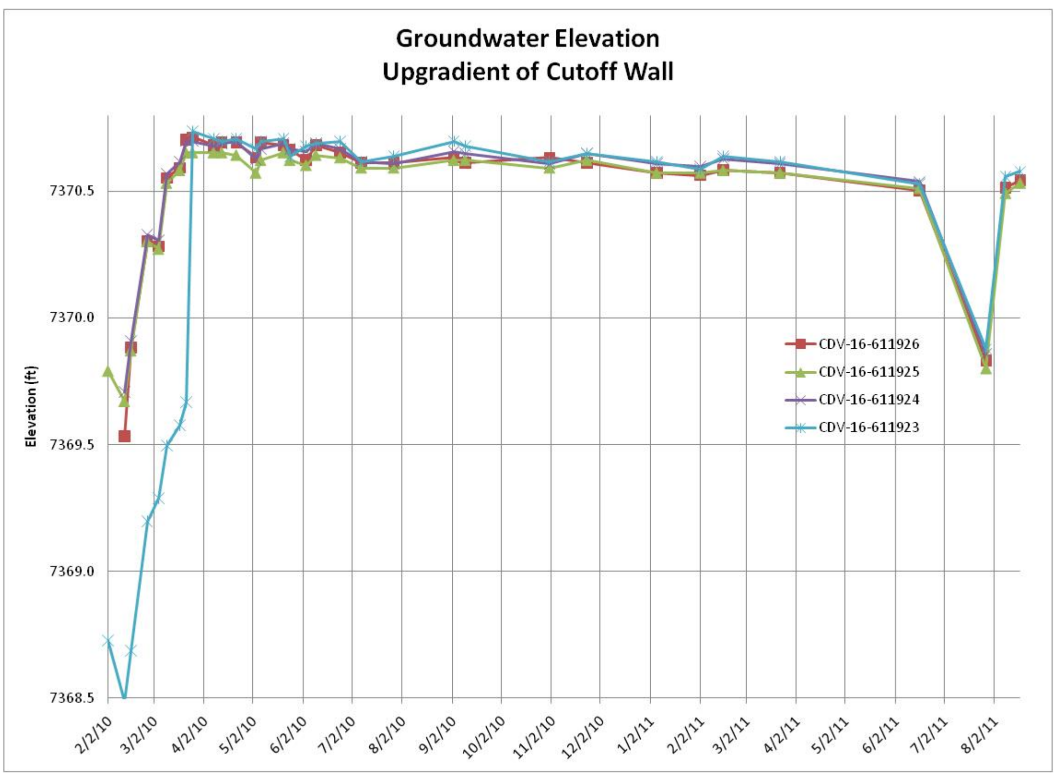


Figure 4.4-2 Water levels measured in wells located at the PRB cutoff wall

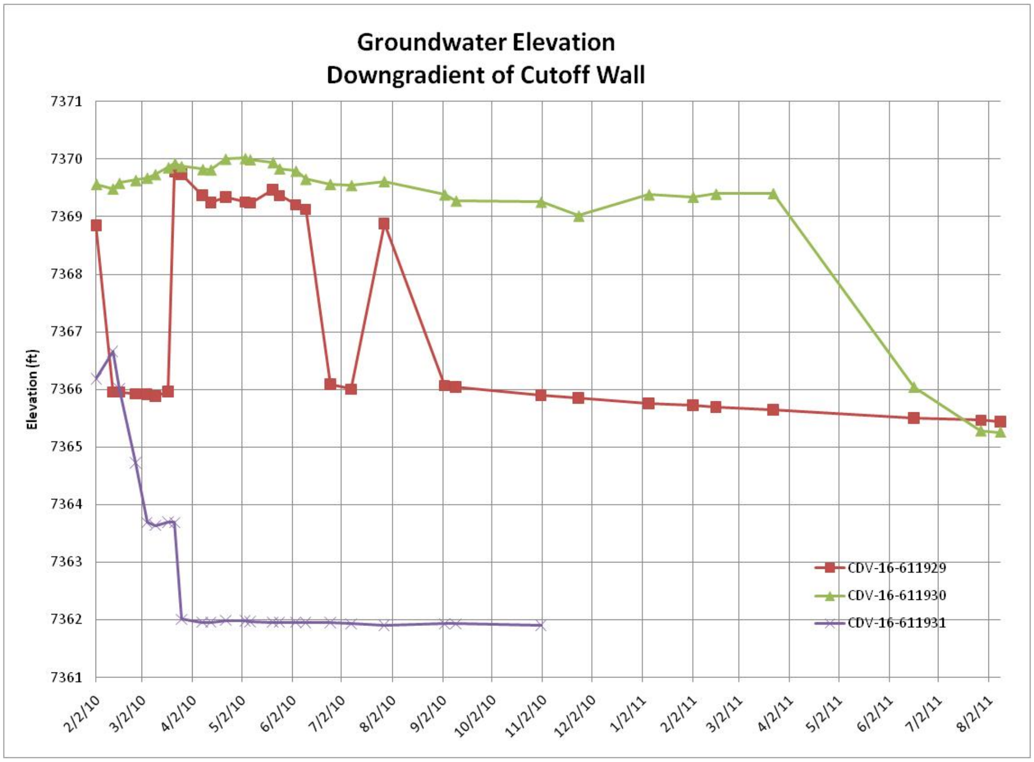


Figure 4.4-3 Water levels measured in wells located immediately downgradient of the PRB cutoff wall

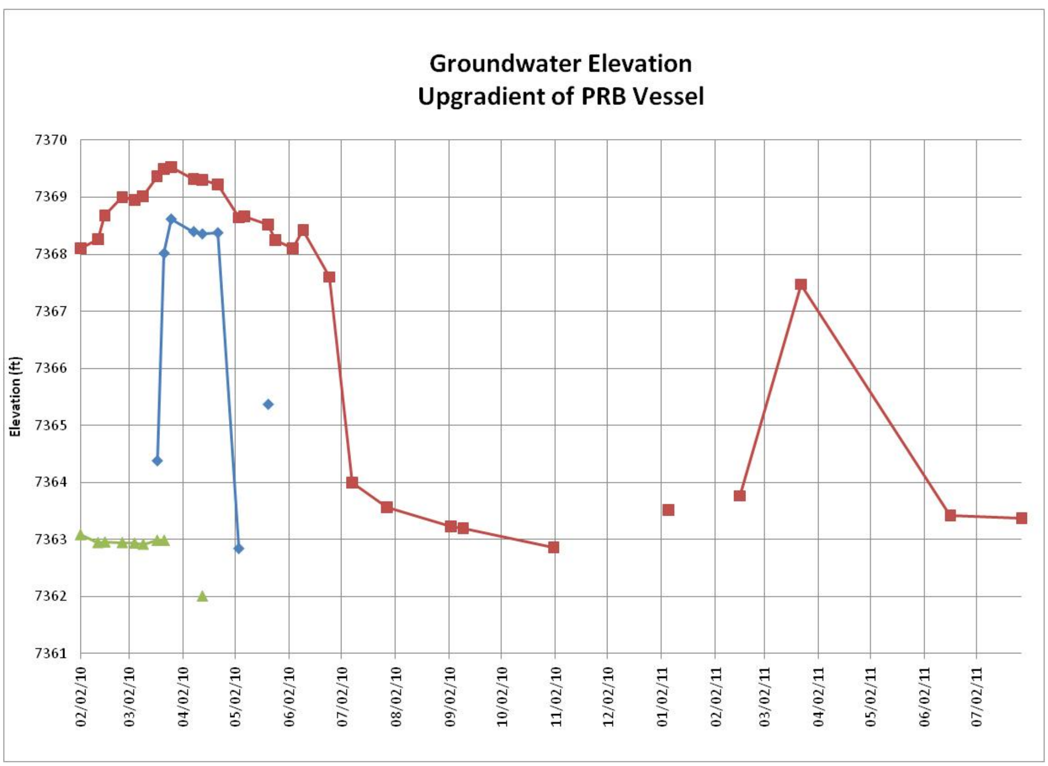


Figure 4.4-4 Water levels measured in wells located downgradient and away from the PRB cutoff wall

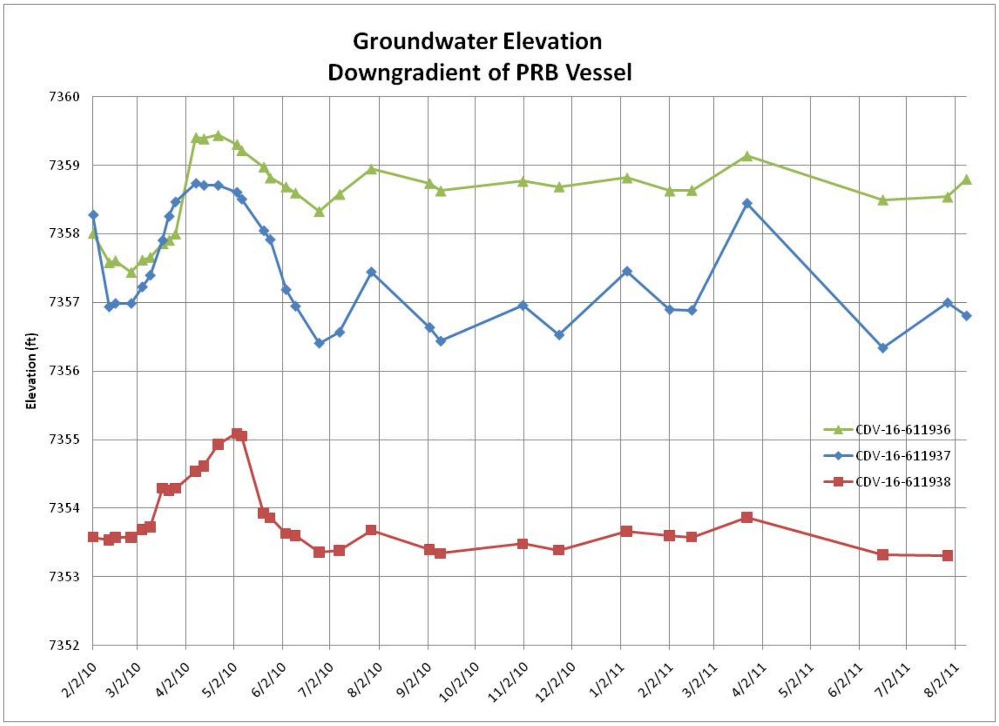


Figure 4.4-5 Water levels measured in wells located downgradient of the PRB vessel

Table 3.0-1
Timeline of Key Field Activities and Observations at the TA-16 Pilot PRB and CMI Projects

Date	Field Activity
10/12/09–11/12/09	Prepare for installation of the PRB (remove show and mobilize equipment and supplies)
12/14/2009	Begin installation of the PRB
1/14/2010	Complete installation of PRB (all vessel, plumbing wall, infiltration gallery)
1/19/2010	Install erosion control and complete site restoration on PRB-disturbed soil (erosion blankets, seeding)
1/26/2010	Begin drilling and installing 16 PRB monitoring alluvial wells (total of 20 monitoring points but 4 are piezometers that are a part of the piping of the PRB installation)
1/31/2010	Complete drilling and installation of PRB monitoring alluvial wells
3/22/2010	Begin 1 week countdown to fill up vessel
3/24/2010	Begin well development of PRB monitoring alluvial wells
3/29/2010	Complete alluvial well development
4/1/2010	First round of PRB monitoring alluvial wells begins
4/2/2010	Complete baseline alluvial well sampling, and PRB vessel plumbed to begin filling the vessel since baseline sample complete
4/8/2010	First confirmation of water discharging from vessel into post-treatment port
6/10/2010	Install transducers in selected alluvial wells
7/19/2010–7/20/2010	Demolish and rebuild ungrounded well pads of PRB
8/3/2010	Removed vessel lid because vessel believed not to be working. Water not flowing through vessel, water bypassing baffles, bacteria or algae was growing on open surfaces, could not hand auger to bottom of ZVI because of so much precipitated minerals, vapor lock in zeolite chamber
9/10/2010	Undertook media reconfiguration and replacement. Changed from gravel-ZVI-gravel-zeolite to gravel-zeolite-gravel-ZVI. The bottom 4–6 in of ZVI chamber very compact/cemented with precipitated products.
2/2/2011	Inspected vessel.
2/14/2011–2/16/2011	Observed possible signs of blockage within the vessel. Ponding behind the ZVI cell in the vapor ports and other sample ports. Frozen ports.
3/23/2011	Opened vessel to check functionality
6/17/2011	Inspected alluvial well water levels, switched vessel to bypass mode to drain water before filter media replacement
7/22/2011	Disposed of 5200 gal. of stored stormwater to Clean Harbors, Denver, CO
7/26/2011	Staged new PRB filter media (zeolite, GAC) at PRB study site
7/28/2011	Removed spent filter media from PRB and stored in wrangler bags at work site. Installed zeolite and GAC filter media in PRB vessel. Opened PRB inlet valve to fill vessel. Collected water level measurements. Collected and analyzed spent filter media waste samples.
8/3/2011	Severe storm event. Potential occurrence of flash flooding in Cañon de Valle.
8/4/2011	Observed flash flooding damage, including channel erosion, exposed piping, broken vessel sampling ports, missing piezometers, alluvial well damage. Postponed waste relocation due to threat of additional flooding.
8/5/2011	Moved wrangler bags of spent filter media from PRB site to TA-16 field trailer for disposal pending waste characterization sampling results.

Table 3.0-1 (continued)

Date	Field Activity
8/7/2011	Severe storm event. Flash flooding observed in Cañon de Valle.
8/9/2011	Performed field inspection to determine extent of flash flooding damage to CMI projects. Observed significant damage to alluvial wells and PRB sampling ports. Removed PRB vessel lid to check for infiltration. Observed sediment/ash infiltration in the first two cells. Collected water-level measurements at intact alluvial wells.
8/18/2011	Additional field assessment of damage performed at PRB. Maintenance and repair activities included securing the PRB vessel lid, shortening sampling port tubes to reduce resistance to flow of flood water and debris. Observed sediment/debris in PRB intake line.
8/21/2011	Severe storm event. Flash flooding observed in Cañon de Valle.
8/26/2011	Reevaluated CMI projects for flash flooding damage following 8/21/2011 storm. Observed damage was more severe and widespread than previous flooding: four alluvial wells completely destroyed; three alluvial wells compromised by flooding. PRB cutoff wall and connector piping destroyed and washed downstream; stream channel scoured to bedrock. Rerecorded elevations of channel and PRB vessel.
9/2/2011	Removed damaged debris from cutoff wall, tubing, and alluvial wells from channel. Collected stream flow measurements. Measured water levels from functional wells. Packaged debris waste in 1 yd^3 wrangler bag and staged at TA-16 field trailer.

Table 3.1-1
2010/2011 Sampling Dates for On-Site Field-Parameter Measurements

Sampling Date	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
	CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 Zeolite	16-612218 Gravel	16-612219 ZVI	16-612220 Post-Treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
On-Site Field Parameters (EES)											
11/1/2010	—[a]	—	—	X[b]	X	X	X	X	—	—	—
11/29/2010	—	—	—	X	X	X	X	X	—	—	—
1/6/2011	—	—	—	X	X	X	X	X	—	—	—
2/14/2011	—	—	—	X	X	X	X	X	—	—	—

[a] — = Parameters not measured.

[b] X = Parameters measured.

Table 3.1-2
2010/2011 Sampling Dates for Off-Site Chemical Analysis

	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
Sampling Date	CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Field Parameters and General Inorganics											
4/1/2010–4/2/2010	X[c]	X	X	*Preoperational Period*[d]					X	X	X
5/5/2010–5/6/2010	X	X	X	X	X	X	X	X	X	X	X
6/2/2010–6/30/2010	X	X	X	X	X	X	X	X	X	X	X
6/30/2010–7/1/2010	X	X	X	X	X	X	X	X	X	X	X
11/1/2010–11/2/2010	D[e]	X	D	X	X	X	X	X	X	X	X
2/14/2011–2/15/2011	D	X	D	X	X	F[f]	X	X	X	X	X
Metals											
4/1/2010–4/2/2010	X	X	X	*Preoperational Period*					X	X	X
5/5/2010–5/6/2010	X	X	X	X	X	X	X	X	X	X	X
6/2/2010–6/30/2010	X	X	X	X	X	X	X	X	X	X	X
6/30/2010–7/1/2010	—[g]	X	X	X	X	X	X	X	X	X	X
11/1/2010–11/2/2010	D	X	D	X	X	X	X	X	X	X	X
2/14/2011–2/15/2011	D	X	D	X	X	F	X	X	X	X	X

Table 3.1-2 (continued)

Sampling Date	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
	CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Explosive Compounds											
4/1/2010–4/2/2010	X	X	X	*Preoperational Period*					X	X	X
5/5/2010–5/6/2010	X	X	X	X	X	X	X	X	X	X	X
6/2/2010–6/30/2010	X	X	X	X	X	X	X	X	X	X	X
6/30/2010–7/1/2010	X	X	X	X	X	X	X	X	X	X	X
11/1/2010–11/2/2010	D	X	D	X	X	X	X	X	X	X	X
2/14/2011–2/15/2011	D	X	D	X	X	F	X	X	X	X	X

[a] ZVI was installed from April 2010 to September 2010. Zeolite was installed September 2010 to July 2011.

[b] Zeolite was installed from April 2010 to September 2010. ZVI was installed September 2010 to July 2011.

[c] X = Sample collected.

[d] April sampling period re-dates operation of the PRB.

[e] D = Well dry.

[f] F = Sampling port frozen.

[g] — = Sample not collected.

Table 3.1-3
Summary of Field Parameters Measured at the PRB Vessel Monitoring Points and Alluvial Wells

Monitoring Point	Monitoring Point Description	Water Level	Flow Rate (L/s)	pH (standard units)	Temp (deg C)	Oxidation Reduction Potential (mV)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU[a])
PRB Vessel									
16-612215	Upgradient sampling port	X[b]	—[c]	X	X	X	X	X	X
16-612216	Upgradient valve	—	X	—	—	—	—	—	—
16-612217	Vessel zeolite port	X	—	X	X	X	X	X	X
16-612218	Vessel gravel port	X	—	X	X	X	X	X	X
16-612219	Vessel ZVI port	X	—	X	X	X	X	X	X
16-612221	Downgradient valve	—	X	—	—	—	—	—	—
16-612220	Downgradient sampling port	X	—	X	X	X	X	X	X
Alluvial Wells									
CDV-16-611938	Monitoring well	X	—	X	X	X	X	X	X
CDV-16-611921	Monitoring well	X	—	X	X	X	X	X	X
CDV-16-611923	Monitoring well	X	—	X	X	X	X	X	X
CDV-16-611934	Monitoring well	X	—	X	X	X	X	X	X
CDV-16-611936	Monitoring well	X	—	X	X	X	X	X	X
CDV-16-611937	Monitoring well	X	—	X	X	X	X	X	X

[a] NTU = Nephelometric turbidity unit.

[b] X = Parameters measured.

[c] — = Parameters not measured.

Table 3.1-4
Summary of Chemical Analyses Requested at the PRB Vessel Monitoring Points and Alluvial Wells

Monitoring Point	Monitoring Point Description	Alkalinity	Cations (Filtered and Unfiltered)	Anions	Nitrogen Species	TDS[a]	TSS[b]	TOC[c]	Explosive Compounds	HE Breakdown Products	TAL Metals
PRB Vessel											
16-612215	Upgradient sampling port	X[d]	X	X	X	X	X	X	X	X	X
16-612216	Upgradient Valve	—[e]	—	—	—	—	—	—	—	—	—
16-612217	Vessel Zeolite Port	X	X	X	X	X	X	X	X	X	X
16-612218	Vessel Gravel Port	X	X	X	X	X	X	X	X	X	X
16-612219	Vessel ZVI Port	X	X	X	X	X	X	X	X	X	X
16-612221	Downgradient Valve	—	—	—	—	—	—	—	—	—	—
16-612220	Downgradient sampling port	X	X	X	X	X	X	X	X	X	X
Alluvial Wells											
CDV-16-611938	Monitoring well	—	X	X	—	—	—	—	—	X	X
CDV-16-611921	Monitoring well	—	X	X	—	—	—	—	—	X	X
CDV-16-611923	Monitoring well	—	X	X	—	—	—	—	—	X	X
CDV-16-611934	Monitoring well	—	X	X	—	—	—	—	—	X	X
CDV-16-611936	Monitoring well	—	X	X	—	—	—	—	—	X	X
CDV-16-611937	Monitoring well	—	X	X	—	—	—	—	—	X	X

[a] TDS = Total dissolved solids.
[b] TSS = Total suspended solids.
[c] TOC = Total organic carbon.
[d] X = Parameters measured.
[e] — = Parameters not measured.

Table 3.2-1
Summary of Monitoring and Maintenance Parameters and Frequencies for the Former Settling Pond Injection Grouting and Low-Permeability Cap

Sampling Media	Monitoring/ Maintenance Parameter	Sampling Point/ Location	Monitoring Event Frequency	Number of Maintenance Events in 1 yr	Explosive Compounds (EPA SW-846:8330)	Comments
Low-Permeability Cap						
Cap	Stability	n/a[a]	March/April August	1 1	—[b]	Inspections followed spring snowmelt and summer rains
Run-on/ runoff controls	Stability	n/a	March/April August	1 1	—	Inspections followed snowmelt and summer rains
Groundwater Well						
Groundwater	Chemical analysis	Well	Year 1–Quarterly	4	—	No groundwater present

[a] n/a = Not applicable.

[b] — = Analysis was not requested.

Table 4.1-1
PRB On-Site Water-Quality Parameter Measurements by Date and Location

Analyte	Sample Date	PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
		Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
Alk-CO_{3-}	11/1/2010	0.8 U	0.8 U	0.8 U	10.1	11.1
	11/29/2010	0.8 U	*Sampling ports frozen – No sample*			0.8 U
	1/6/2011	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
	2/14/2011	0.8 U	0.8 U	*Port frozen*	0.8 U	0.8 U
Alk-CO_3+HCO_3	11/1/2010	216	269	302	249	130
	11/29/2010	216	*Sampling ports frozen – No sample*			247
	1/6/2011	168	200	180	170	203
	2/14/2011	124	162	*Port frozen*	223	145
Anions	11/1/2010	4.84	5.66	6.24	5.52	4.56
	11/29/2010	4.55	*Sampling ports frozen – No sample*			5.13
	1/6/2011	3.66	4.32	3.85	3.69	4.32
	2/14/2011	2.88	3.32	*Port frozen*	4.47	3.16
Balance	11/1/2010	-0.0617	-0.0441	-0.0454	-0.0506	-0.203
	11/29/2010	-0.0739	*Sampling ports frozen – No sample*			-0.0927
	1/6/2011	-0.0545	-0.107	-0.0445	-0.0454	-0.0941
	2/14/2011	-0.0492	-0.0817	*Port frozen*	-0.0517	-0.0737
C_2O_4	11/1/2010	0.01 U	0.01 U	0.01 U	0	0.01 U
	11/29/2010	0.01 U	*Sampling ports frozen – No sample*			0.01 U
	1/6/2011	0.01 U	0.01 U	0.01 U	0.01 U	0.0103
	2/14/2011	0.01 U	0.01 U	*Port frozen*	0.01 U	0.01 U
Cations	11/1/2010	4.28	5.18	5.69	4.99	3.02
	11/29/2010	3.92	*Sampling ports frozen – No sample*			4.26
	1/6/2011	3.28	3.48	3.52	3.37	3.57
	2/14/2011	2.61	2.82	*Port frozen*	4.03	2.73
Cl^-	11/1/2010	30.1	29.4	29.9	29.4	57.1
	11/29/2010	24.9	*Sampling ports frozen – No sample*			30.3
	1/6/2011	23.6	30	23.4	23.5	29.5
	2/14/2011	20.8	20.6	*Port frozen*	21	20.6
F^-	11/1/2010	0.23	0.25	0.29	0.16	0.27
	11/29/2010	0.123	*Sampling ports frozen – No sample*			0.241
	1/6/2011	0.155	0.394	0.146	0.193	0.372
	2/14/2011	0.233	0.222	*Port frozen*	0.316	0.256
NO_2	11/1/2010	0.01	0.01	0.01	0.01	0.01
	11/29/2010	0.01	*Sampling ports frozen – No sample*			0.01
	1/6/2011	0.01	0.0845	0.01	0.01	0.123
	2/14/2011	0.01	0.01	*Port frozen*	0.01	0.01

Table 4.1-1 (continued)

Analyte	Sample Date	PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
		Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
NO_2-N	11/1/2010	0.00304 U	0.00304 U	0.00304 U	0.00304 U	0.00304 U
	11/29/2010	0.00304 U	*Sampling ports frozen – No sample*			0.00304 U
	1/6/2011	0.00304 U	0.0257	0.00304 U	0.00304 U	0.0374
	2/14/2011	0.00304 U	0.00304 U	*Port frozen*	0.00304 U	0.00304 U
NO_3	11/1/2010	1.28	0.93	0.39	0.01	0.19
	11/29/2010	0.345	*Sampling ports frozen – No sample*			0.164
	1/6/2011	0.348	0.213	0.318	0.365	0.996
	2/14/2011	0.577	0.0969	*Port frozen*	0.02	0.317
NO_3-N	11/1/2010	0.289	0.21	0.0881	0.002258 U	0.0429
	11/29/2010	0.078	*Sampling ports frozen – No sample*			0.0371
	1/6/2011	0.0786	0.0481	0.0719	0.0824	0.225
	2/14/2011	0.13	0.0219	*Port frozen*	0.00452	0.0716
$PO_4^{(3-)}$	11/1/2010	0.25	0.01 U	0.01 U	0.01 U	0.01 U
	11/29/2010	0.0916	*Sampling ports frozen – No sample*			0.01 U
	1/6/2011	0.0994	0.01 U	0.0648	0.0884	0.01 U
	2/14/2011	0.0841	0.01 U		0.062	0.01 U
SiO_2	11/1/2010	46.8	44.4	40.8	2.21	0.708
	11/29/2010	42.7	*Sampling ports frozen – No sample*			8.75
	1/6/2011	41.5	40.1	30.5	41	19.8
	2/14/2011	42.2	22	*Port frozen*	33.2	33.7
$SO_4^{(-2)}$	11/1/2010	18.6	17.4	18.4	12.1	20.3
	11/29/2010	12.3	*Sampling ports frozen – No sample*			8.83
	1/6/2011	9.41	6.25	9.45	9.49	4.48
	2/14/2011	9.98	2.07	*Port frozen*	8.34	7.53
TDS	11/1/2010	403	468	507	405	279
	11/29/2010	379	*Sampling ports frozen – No sample*			392
	1/6/2011	313	350	335	316	348
	2/14/2011	255	282	*Port frozen*	370	270
pH	11/1/2010	6.58	6.84	7.03	8.13	8.78
	11/29/2010	6.32	*Sampling ports frozen – No sample*			7.44
	1/6/2011	6.96	6.78	6.67	6.73	7.1
	2/14/2011	6.79	6.78	*Port frozen*	7.04	6.63

Notes: Units in ppm unless otherwise noted. U = The analyte was analyzed for but was not detected.

Table 4.1-2
Detected Results for Off-Site Laboratory
Water-Quality Parameter Measurements in Upgradient Wells, PRB Vessel, and Downgradient Wells

Analyte	Sample Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Alkalinity-CO_3	Nov 2010	*Dry*	—[c]	*Dry*	—	—	—	4.04	7.08	—	—	—
Alkalinity-CO_3+HCO_3	Nov 2010	*Dry*	442	*Dry*	148	184	207	178	113	142	113	120
	Feb 2011	*Dry*	—	*Dry*	85.2	157	*Port frozen*	104	97.8	—	—	—
Ammonia as Nitrogen	Feb 2011	*Dry*	—	*Dry*	0.051	—	*Port frozen*	0.074	0.037 J	—	—	—
Bromide	Apr 2010	—	0.07 J	0.048 J	*Preoperational Period*					0.082 J	0.062 J	0.049 J
	June 2010	0.078 J	0.15 J	0.082 J	0.095 J	0.11 J	0.096 J	0.092 J	0.088 J	0.089 J	0.096 J	0.094 J
	July 2010	—	0.33	0.22 J	0.11 J	0.091 J	0.1 J	0.074 J	0.077 J	0.13 J	0.11 J	0.11 J
	Nov 2010	*Dry*	0.759	*Dry*	—	0.122 J	0.118 J	—	—	0.192 J	0.135 J	0.123 J
	Feb 2011	*Dry*	0.292	*Dry*	0.0979 J	0.181 J	*Port frozen*	0.193 J	0.0951 J	0.138 J	0.117 J	0.097 J
Calcium	Apr 2010	18	24.6	21.1	*Preoperational Period*					24.4	25.1	25.7
	May 2010	23.1	21.2	19.5	31.1	9.7	30.5	29.8	30.8	23.4	21.8	21.3
	June 2010	20.9	30.5	20.2	28.6	10.5	34.7	36.4	32.8	26.1	19.4	20.4
	July 2010	—	51.8	29.3	27.5	10.1	40.4	41.4	43.9	23.8	23.4	17.9
	Nov 2010	*Dry*	98.7	*Dry*	47.3	66.8	71.1	62.3	26.1	33	28.1	30.3
	Feb 2011	*Dry*	41.5	*Dry*	24.1	48.3	*Port frozen*	31.1	27.2	28.1	26.8	15.2
Chloride	Apr 2010	8.5	41.7	47.1	*Preoperational Period*					24.9	33.6	30.5
	May 2010	30.6	29.4	22.1	31	32.2	30.3	30.6	30.1	28.3	34.2	23.1
	June 2010	26.4	27.9	16.5	26	26.9	25.3	24.5	26.1	29.3	23.1	24
	July 2010	—	28.1	16.5	23.7	24.3	22.8	23.8	23.7	26.9	25.7	23
	Nov 2010	*Dry*	24.8 J+	*Dry*	20	19.9	20 J+	20	19.9	19.8 J+	19.4 J+	18.5 J+
	Feb 2011	*Dry*	19.7	*Dry*	19.1 J+	19.2 J+	*Port frozen*	19.6 J+	19.7 J+	17.5	19.8	19.6

Table 4.1-2 (continued)

Analyte	Sample Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215	16-612217	16-612218	16-612219	16-612220	CDV-16-611936	CDV-16-611937	CDV-16-611938
					Pretreatment	ZVI/ Zeolite[a]	Gravel	Zeolite/ ZVI[b]	Post-treatment			
Dissolved Oxygen	May 2010	—	—	—	—	—	3.76	—	5.53	—	—	—
	June 2010	8.95	0.44	3.65	6.57	1.02	5.71	6.41	6.15	0.56	0.46	1.13
	July 2010	6.98	0.63	3.03	6.7	0.75	6.06	5.83	6.18	0.5	3.81	5.49
	Nov 2010	*Dry*	2.29	*Dry*	3	2.15	0.67	0.35	3.17	5.68	0.67	1.23
	Feb 2011	*Dry*	0.95	*Dry*	6.42	0.49	*Port frozen*	0.4	0.4	1.24	1.09	—
Fluoride	Apr 2010	0.13	0.16	0.12	*Preoperational Period*					0.18	0.13	0.078 J
	May 2010	0.13	0.19	0.13	0.14	0.3	0.12	0.13	0.12	0.19	0.12	0.18
	June 2010	0.11	0.17	0.18	0.11	0.26	0.13	0.12	0.12	0.23	0.14	0.11
	July 2010	—	0.17	0.11	0.096 J	0.22	0.1	0.08 J	0.083 J	0.2	0.13	0.11
	Nov 2010	*Dry*	0.262	*Dry*	0.177	0.187	0.172	0.18	0.164	0.237	0.176	0.174
	Feb 2011	*Dry*	0.279	*Dry*	0.2	0.258	*Port frozen*	0.204	0.206	0.182	0.146	0.124
Hardness	Nov 2010	*Dry*	370	*Dry*	145	194	216	188	113	117	97.5	107
	Feb 2011	*Dry*	169	*Dry*	80.4	151	*Port frozen*	101	92.4	97.6	99.7	53.5
Magnesium	Apr 2010	4.75	6.89	5.93	*Preoperational Period*					6.68	5.94	5.65
	May 2010	5.96	6.18	5.47	6.15	1.58	6.48	6.3	6.36	7	5.44	4.79
	June 2010	6.56	8.37	5.75	6.33	0.548	6.42	6.76	6.52	6.99	4.71	4.19
	July 2010	—	15	8.54	6.21	0.432	6.24	6.66	7.16	6.79	5.83	4.06
	Nov 2010	*Dry*	29.8	*Dry*	6.66	6.72	8.68	9.04	10.4	9.07	7.07	7.5
	Feb 2011	*Dry*	12.1	*Dry*	5.01	7.26	*Port frozen*	5.35	5.31	7.48	6.58	3.83
Nitrate-Nitrite as Nitrogen	Nov 2010	*Dry*	—	*Dry*	0.1 J	0.0945 J	—	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	0.098 J	—	*Port frozen*	—	—	—	—	—

Table 4.1-2 (continued)

Analyte	Sample Period	Upgradient Wells: CDV-16-611921	Upgradient Wells: CDV-16-611923	Upgradient Wells: CDV-16-611934	PRB Vessel Sampling Port: 16-612215 Pretreatment	PRB Vessel Sampling Port: 16-612217 ZVI/ Zeolite[a]	PRB Vessel Sampling Port: 16-612218 Gravel	PRB Vessel Sampling Port: 16-612219 Zeolite/ ZVI[b]	PRB Vessel Sampling Port: 16-612220 Post-treatment	Downgradient Wells: CDV-16-611936	Downgradient Wells: CDV-16-611937	Downgradient Wells: CDV-16-611938
Oxidation Reduction Potential (mV)	May 2010	—	—	—	—	—	610	—	341	—	—	—
	June 2010	81	-1.9	144.7	132.5	112.2	168.2	191	147.2	10.7	-40.2	67.8
	July 2010	155.8	70.3	165.1	151.4	76.3	100.9	271.3	224.3	-68.2	-68	303.5
	Nov 2010	*Dry*	-43	*Dry*	333.5	288.9	76.2	—	-277.4	-18	-35.1	69.3
	Feb 2011	*Dry*	-78.6	*Dry*	104.6	77.3	*Port frozen*	-284.3	-284.3	-89.2	-106.9	—
pH	May 2010	—	—	—	—	—	6.7	—	6.74	—	—	—
	June 2010	7.5	6.79	6.28	6.7	8.94	6.7	6.36	6.34	6.79	7.25	6.56
	July 2010	6.6	6.78	6.55	6.71	10.11	6.79	6.73	6.8	6.42	6.29	
	Nov 2010	*Dry*	6.79	*Dry*	6.52	6.82	6.97	8.37	8.49	6.67	6.59	6.32
	Feb 2011	*Dry*	7.09	*Dry*	7.12	7.25	*Port frozen*	7.97	6.93	7.01	7.08	—
Potassium	Apr 2010	4.72	3.58	3.36	*Preoperational Period*					3.29	3.76	3.51
	May 2010	4.06	3.05	3.5	3.48	3.4	3.7	3.71	3.71	3.27	3.38	2.93
	June 2010	3.89	3.71	3.82	3.47	4.2	3.56	3.65	3.56	3.81	3.25	3.32
	July 2010	—	5.53	4.67	3.6	4.34	3.4	3.96	4.19	3.91	3.8	3.76
	Nov 2010	*Dry*	7.84	*Dry*	3.95	3.64	3.52	3.49	3.55	4.29	4.57	4.15
	Feb 2011	*Dry*	3.67 J	*Dry*	3	3.43	*Port frozen*	2.93	2.87	3.21 J	3.55	2.73
Sodium	Apr 2010	10.4 J-	24.7 J-	21.7 J-	*Preoperational Period*					17.6 J-	18.9 J-	28.3 J-
	May 2010	18.3	22.6	18.7	19.5	22.3	21	20.3	20.3	17.9	20	21.5
	June 2010	19.3	24.2	17.4	18.7	20.7	19.2	19	19.1	19	18.2	17.4
	July 2010	—	32.4	18.1	18.5	20	17.9	18.8	19.2	19.1	20.4	18.8
	Nov 2010	*Dry*	41.2	*Dry*	20.7	21.5	20.7	20.1	20.2	21.9	19.4	20
	Feb 2011	*Dry*	22.6	*Dry*	17.3	20.3	*Port frozen*	18.4	17.8	19	16.8	15.2

Table 4.1-2 (continued)

Analyte	Sample Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Specific Conductance (µS/cm)	May 2010	—	—	—	—	—	319	—	324	—	—	—
	June 2010	280	370	253	294	202	328	336	315	320	276	259
	July 2010	264	542	276	289	185	345	355	366	313	306	209
	Nov 2010	*Dry*	854	*Dry*	381	460	488	450	300	393	366	339
	Feb 2011	*Dry*	404	*Dry*	264	389	*Port frozen*	325	325	367	408	—
Sulfate	Apr 2010	5.1	7.7	14.5	*Preoperational Period*					4	10.5	15
	May 2010	11.7	9.9	13.7	12.4	15.9	12.6	12.9	12.9	4	11.6	15.4
	June 2010	11.8	4.9	9.2	12.1	22.2	13	12.5	12.7	2.7	8.3	4.8
	July 2010	—	5.2	5.7	11.8	19.4	11.7	11.8	11.8		4.5	2.4
	Nov 2010	*Dry*	1.94	*Dry*	10.1	10.4	9.74	6.11	4.66	1.54	5.48	7.68
	Feb 2011	*Dry*	1.29	*Dry*	8.3	7.08	*Port frozen*	2.02	6.25	3.12	4.24	9.98
Temperature (deg C)	May 2010	—	—	—	—	—	7.15	—	7.47	—	—	—
	June 2010	7.83	8.72	12.01	8.97	9.9	9.14	8.98	10.69	9.31	8.33	9.85
	July 2010	10.83	12.24	14.35	13.2	13.29	13.04	13.3	15.32	11.69	9.9	
	Nov 2010	*Dry*	11.98	*Dry*	7.3	7.31	6.63	6.84	6.18	9.79	10.15	9.68
	Feb 2011	*Dry*	5.68	*Dry*	3.25	2.38	*Port frozen*	2.62	2.79	3.63	5.04	—
Total Kjeldahl Nitrogen	Nov 2010	*Dry*	—	*Dry*	0.051 J	0.085 J	0.037 J	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	0.149 J-	0.335 J-	*Port frozen*	0.163 J-	0.243 J-	—	—	—

Table 4.1-2 (continued)

Analyte	Sample Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Turbidity (nephelometric turbidity unit)	May 2010	*Dry*	—	*Dry*	—	—	3.1	—	3.5	—	—	—
	June 2010	22.1	19.4	—	3	2.65	2.6	3.3	2.9	17	18.3	46.3
	July 2010	34.7	1.41	52.5	15.3	2.13	2.52	3.36	2.19	17.1	1.42	—
	Nov 2010	*Dry*	9.51	*Dry*	1.54	0.52	0.35	9.17	4.27	24.4	3.9	12
	Feb 2011	*Dry*	11	*Dry*	4.6	94	*Port frozen*	0	0	45.4	55.4	—

Notes: Units in ppm unless otherwise noted. J = Result was qualified as estimated. J+ = Result was qualified as estimated and biased high. J- = Result was qualified as estimated and biased low.

[a] ZVI was installed from April 2010 to September 2010. Zeolite was installed September 2010 to July 2011.

[b] Zeolite was installed from April 2010 to September 2010. ZVI was installed September 2010 to July 2011.

[c] — = Not analyzed or not detected.

Table 4.2-1
Metals Detected in On-Site (EES) Alluvial Groundwater Samples by Date and Location

		PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
Analyte	Sample Date	Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
Aluminum	11/1/2010	13.9	3.67	2	2	2.58
	11/29/2010	142	*Sampling Ports Frozen*			2.5
	1/6/2011	62.9	29.7	4.7	34.9	2.37
	2/14/2011	500	2	*Port frozen*	9.83	75.6
Antimony	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Arsenic	11/1/2010	0.791	0.433	0.318	0.225	0.2
	11/29/2010	1.14	*Sampling Ports Frozen*			0.266
	1/6/2011	1.12	0.749	0.243	0.795	0.253
	2/14/2011	1.45	0.322	*Port frozen*	0.967	0.899
Barium	11/1/2010	4140	1740	1140	1150	1020
	11/29/2010	3430	*Sampling Ports Frozen*			797
	1/6/2011	4300	1580	1310	3350	1280
	2/14/2011	3530	2860	*Port frozen*	3960	3780
Beryllium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Boron	11/1/2010	38.8	38	62.5	62.5	68.9
	11/29/2010	39.6	*Sampling Ports Frozen*			48.1
	1/6/2011	49.5	37	34.5	32.6	42
	2/14/2011	59.8	30.2	*Port frozen*	25.5	40
Bromine	11/1/2010	110	110	110	120	260
	11/29/2010	253	*Sampling Ports Frozen*			242
	1/6/2011	104	98.2	91	97.5	99.3
	2/14/2011	293	298	*Port frozen*	210	63.2
Cadmium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Calcium	11/1/2010	50900	70800	76300	62000	20900
	11/29/2010	43600	*Sampling Ports Frozen*			53500
	1/6/2011	33700	40100	41300	37200	41500
	2/14/2011	24800	29700	*Port frozen*	47900	27000

Table 4.2-1 (continued)

		PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
Analyte	Sample Date	Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
Cesium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Chromium	11/1/2010	2.26	2.11	1.8	1.85	1.43
	11/29/2010	1.91	*Sampling Ports Frozen*			1.44
	1/6/2011	1.78	1.66	1.44	1.49	1.23
	2/14/2011	2.68	1.57	*Port frozen*	1.92	1.73
Cobalt	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Copper	11/1/2010	1	1	1	1	1
	11/29/2010	1.2	*Sampling Ports Frozen*			1.41
	1/6/2011	2.48	1.95	1	1.65	1.2
	2/14/2011	1.22	1		2.99	1
Iron	11/1/2010	18.8	10.2	170	2400	18.5
	11/29/2010	136	*Sampling Ports Frozen*			8640
	1/6/2011	219	54.1	18700	61.8	16300
	2/14/2011	339	16000	*Port frozen*	23.8	3970
Lead	11/1/2010	0.2	0.2	0.2	0.2	0.2
	11/29/2010	0.2	*Sampling Ports Frozen*			0.2
	1/6/2011	0.2	0.2	0.2	0.2	0.2
	2/14/2011	0.2	0.2	*Port frozen*	0.2	0.2
Lithium	11/1/2010	7.65	7.98	8.27	8.32	7.57
	11/29/2010	6.49	*Sampling Ports Frozen*			5.06
	1/6/2011	5.33	5.51	5.49	5.52	5.67
	2/14/2011	10.5	6.33	*Port frozen*	6.8	6.64
Magnesium	11/1/2010	7200	6850	10000	10300	11500
	11/29/2010	7180	*Sampling Ports Frozen*			6320
	1/6/2011	6710	6190	6180	6330	6340
	2/14/2011	5360	5350	*Port frozen*	7580	5450
Manganese	11/1/2010	59.2	44.8	60.3	130	37.4
	11/29/2010	471	*Sampling Ports Frozen*			551
	1/6/2011	662	6.97	189	5.11	235
	2/14/2011	245	178	*Port frozen*	1.73	437

Table 4.2-1 (continued)

		PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
Analyte	Sample Date	Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
Mercury	11/1/2010	0.05	0.05	0.05	0.05	0.05
	11/29/2010	0.05	*Sampling Ports Frozen*			0.05
	1/6/2011	0.05	0.05	0.05	0.05	0.05
	2/14/2011	0.05	0.05	*Port frozen*	0.05	0.05
Molybdenum	11/1/2010	1	2.89	4.48	28.1	78.4
	11/29/2010	1	*Sampling Ports Frozen*			9.4
	1/6/2011	1.7	1.46	7.94	1.22	11.3
	2/14/2011	1	7.25	*Port frozen*	4.64	3.09
Nickel	11/1/2010	1.11	2.46	1.58	4.23	1
	11/29/2010	1	*Sampling Ports Frozen*			2.32
	1/6/2011	1.14	1.49	1	1.52	1
	2/14/2011	1.33	1	*Port frozen*	1	1
Potassium	11/1/2010	3950	3620	3740	3560	3500
	11/29/2010	3530	*Sampling Ports Frozen*			3120
	1/6/2011	3350	3040	2960	3240	3050
	2/14/2011	3220	2830	*Port frozen*	3260	2910
Rubidium	11/1/2010	2.4	8.05	1.55	2.05	2.16
	11/29/2010	3.78	*Sampling Ports Frozen*			5.48
	1/6/2011	3.22	8.82	7.52	8.82	7.46
	2/14/2011	4.4	5.18	*Port frozen*	8.79	3.51
Selenium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	2.21	1.08	*Port frozen*	1	1.01
Silicon	11/1/2010	21900	20700	19100	1030	331
	11/29/2010	19900	*Sampling Ports Frozen*			4090
	1/6/2011	19400	18700	14200	19100	9270
	2/14/2011	19700	10300	*Port frozen*	15500	15800
Silver	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Sodium	11/1/2010	22400	22000	21600	21300	21000
	11/29/2010	22800	*Sampling Ports Frozen*			22000
	1/6/2011	20000	19800	19400	19700	20000
	2/14/2011	18100	17700	*Port frozen*	19900	18000

Table 4.2-1 (continued)

Analyte	Sample Date	PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
		Pretreatment	Zeolite	Gravel	ZVI	Post-treatment
Strontium	11/1/2010	284	329	349	332	316
	11/29/2010	275	*Sampling Ports Frozen*			261
	1/6/2011	252	249	254	247	257
	2/14/2011	195	202	*Port frozen*	308	204
Thorium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Tin	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Titanium	11/1/2010	2	2	2	2	2
	11/29/2010	2	*Sampling Ports Frozen*			2
	1/6/2011	2	2	2	2	2
	2/14/2011	11	2	*Port frozen*	2	2
Thallium	11/1/2010	1	1	1	1	1
	11/29/2010	1	*Sampling Ports Frozen*			1
	1/6/2011	1	1	1	1	1
	2/14/2011	1	1	*Port frozen*	1	1
Uranium	11/1/2010	0.749	0.712	0.706	0.2	0.2
	11/29/2010	1.24	*Sampling Ports Frozen*			0.2
	1/6/2011	0.611	0.655	0.2	0.603	0.2
	2/14/2011	0.392	0.2	*Port frozen*	1.46	0.253
Vanadium	11/1/2010	3.8	3.39	2.57	2.35	1.21
	11/29/2010	3.89	*Sampling Ports Frozen*			2.29
	1/6/2011	3.37	2.9	1.98	2.11	1.1
	2/14/2011	3.47	1.35	*Port frozen*	2.39	2.15
Zinc	11/1/2010	17.8	4.15	3.17	3.32	4.06
	11/29/2010	14.9	*Sampling Ports Frozen*			5.87
	1/6/2011	11.6	4.81	5.35	8.09	4.53
	2/14/2011	9.91	5.03	*Port frozen*	5.47	7.22

Note: Units in µg/L unless otherwise noted.

Table 4.2-2
RDX Concentrations Measured On-Site (EES) in Alluvial Groundwater by Date and Location for Post-Media Replacement/Reconfiguration 1

		PRB Vessel Sampling Port				
		16-612215	16-612217	16-612218	16-612219	16-612220
Analyte	**Sample Date**	**Pretreatment**	**Zeolite**	**Gravel**	**ZVI**	**Post-treatment**
RDX	11/1/2010	15.7	6.21	< 2	< 2	< 2
	11/29/2010	8.62	*Sampling Ports Frozen*			< 2
	1/6/2011	4.95	< 4	< 4	< 4	< 4
	2/14/2011	13.4	< 2	*Port Frozen*	6.15	9.69

Table 4.2-3
Metals Concentrations in Upgradient Wells, PRB Vessel, and Downgradient Wells

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Aluminum	April 2010	179	270	1130	*Preoperational Period*					31.1	20.6 J	94.6
	May 2010	77.7	366	1040	236	—[c]	106	190	265	12.1 J	28.4 J	1690
	June 2010	38.7	25.2 J	229	210	—	140	136	115	—	13.1 J	61.1
	July 2010	—	—	232	225	—	123	86.8	62.2	23.1 J	10.7 J	209
	Nov 2010	*Dry*	—	*Dry*	146 J	187 J	—	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	262	—	*Port Frozen*	—	—	—	—	—
Antimony	May 2010	—	1.4 J	1.1 J	—	—	—	—	—	—	—	—
Arsenic	Apr 2010	—	—	—	*Preoperational Period*					—	1.6 J	—
	May 2010	—	2.2 J	—	—	—	—	—	—	—	—	—
	June 2010	—	2.4 J	—	—	—	—	—	—	—	2.5 J	—
	July 2010	—	4 J	—	—	—	—	—	—	1.8 J	3.1 J	—
	Nov 2010	*Dry*	4.93 J	*Dry*	—	—	—	—	—	—	2.77 J	—
	Feb 2011	*Dry*	3.36 J	*Dry*	3.16 J	3.45 J	*Port Frozen*	2.78 J	3.4 J	—	1.89 J	—
Barium	Apr 2010	1580	11500	3300	*Preoperational Period*					10700	13500	3340
	May 2010	4090	11000	3260	4900	19.9	4950	4620	4010	10400	4670	1480
	June 2010	3740	18200	3940	3920	24.7	4410	4070	3980	13900	5350	2020
	July 2010	—	34000	6580	3880	32.2	4080	2470	2270	14100	8180	2730
	Nov 2010	*Dry*	49400	*Dry*	3660	1600	1030	1090	860	15000	7000	6460
	Feb 2011	*Dry*	18100	*Dry*	3310	3910	*Port Frozen*	2820	3650	12500	6180	4010
Boron	Nov 2010	—	46 J	—	34 J	36.2 J	36.6 J	44 J	54.8	41.8 J	40.8 J	38.8 J
	Feb 2011	—	22.8 J	—	22.5 J	20.2 J	*Port Frozen*	24.9 J	23.6 J	22.4 J	21.6 J	24.4 J

Table 4.2-3 (continued)

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Cadmium	May 2010	—	—	—	—	0.31 J	—	—	—	—	—	—
	June 2010	*Dry*	—	*Dry*	—	0.24 J	—	—	—	—	—	—
	July 2010	*Dry*	—	*Dry*	—	0.63	—	—	—	—	—	—
Cobalt	Apr 2010	2.5	3.6	2.3	*Preoperational Period*					6.2	3.8	2.7
	May 2010	0.72 J	3.3	1.6 J	0.82 J	—	1.1 J	1.7 J	0.73 J	5.6	3.2	2.9
	June 2010	1.7 J	5.5	1.1 J	1.4 J	1.7 J	1.4 J	1.1 J	—	6.7	5.3	1.3 J
	July 2010	—	6.1	1.7 J	0.26 J	—	—	0.3 J	—	5.8	4.8	2.1
	Nov 2010	*Dry*	33.3 J	*Dry*	1 J	—	—	—	—	—	—	—
	Feb 2011	*Dry*	5.18	*Dry*	—	—	*Port Frozen*	—	—	6.49	3.93 J	1.21 J
Copper	Apr 2010	0.92 J	0.75 J	1.5	*Preoperational Period*					—	—	1.3
	May 2010	1	1	2.6	1.2	0.59 J	1.2	1.3	1.2	—	—	2.9
	June 2010	0.58 J	0.64 J	1.7	0.78 J	—	1	0.98 J	0.78 J	—	—	0.92 J
	July 2010	—	0.48 J	1.9	0.74 J	—	1.7	1.1	0.88 J	—	—	1.5
	Feb 2011	*Dry*	—	*Dry*	—	3.53 J	*Port Frozen*	—	—	—	—	—
Iron	Apr 2010	114	815	546	*Preoperational Period*					3430	6320	68.3
	May 2010	57	1990	541	138	24.1 J	71.2	113	152	3550	5630	954
	June 2010	29.7 J	3610	130	111	—	92	81.9	70.8	4850	7990	126
	July 2010	—	7070	150	141	22.9 J	96.8	79.2	57.7	5940	8750	210
	Nov 2010	*Dry*	11400	*Dry*	—	—	390 J	4560		9580	12500	7560
	Feb 2011	*Dry*	5880	*Dry*	168	—	*Port Frozen*	16000	3920	12400	12400	5780
Lead	Apr 2010	—	—	0.57 J	*Preoperational Period*					—	—	—
	May 2010	—	—	0.75 J	—	—	—	—	—	—	—	2 J
	June 2010	0.7 J	—	—	—	—	—	—	—	—	—	—

Table 4.2-3 (continued)

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Manganese	Apr 2010	127	854	8.6	—	—	—	—	—	1900	3580	870
	May 2010	23.2	734	13.7	63.1	10.3	14.4	10.7	9.9	2020	3410	241
	June 2010	13.5	1260	39.8	9.8	11	10.3	3.4	19.4	2250	2860	484
	July 2010	—	3080	178	7.7	8.6	10.4	1 J	2.6	2390	3880	498
	Nov 2010	*Dry*	7510	*Dry*	51.3	17.2	206	147	53.3	3790	3780	1870
	Feb 2011	*Dry*	4110	*Dry*	223	2.56 J	*Port Frozen*	170	402	3360	3860	1100
Mercury	Apr 2010	0.095 J	—	—	*Preoperational Period*					—	—	—
	May 2010	—	0.13 J	—	—	—	—	—	—	—	—	—
	June 2010	—	—	0.11 J	—	0.1 J	—	—	—	0.098 J	0.11 J	—
	July 2010	—	0.1 J	—	—	—	—	—	—	—	0.18 J	—
Molybdenum	Nov 2010	*Dry*	6.61	*Dry*	0.49 J	2.98	4.23	24.9	70.3	—	2.53 J	—
	Feb 2011	*Dry*	7.95 J	*Dry*	1.05	5.06	*Port Frozen*	8.13	3.57	1.2 J	1.99 J	—
Nickel	Apr 2010	1.8 J	1.9 J	2.1 J	*Preoperational Period*					2.4 J	1.3 J	1.3 J
	May 2010	1.4 J	2.4 J	3.5 J	1.6 J	0.82 J	1.6 J	1.5 J	1.5 J	2.5 J	1.2 J	2.4 J
	June 2010	0.77 J	1.9 J	2.2 J	1.1 J	0.56 J	1.5 J	1.1 J	1 J	2.4 J	1.6 J	1.5 J
	July 2010	—	3.7 J	4 J	—	—	—	—	—	3.2 J	1.7 J	1.7 J
	Nov 2010	*Dry*	4.77	*Dry*	1.24 J	3.47	3.06	5.32	1.18 J	3.9	1.9 J	3.38
	Feb 2011	*Dry*	3.44	*Dry*	1.01 J	1.38 J	*Port Frozen*	0.729 J	1.06 J	3.31	1.63 J	1.84 J
Selenium	May 2010	—	—	—	—	—	—	—	0.57 J	—	—	—
	July 2010	—	—	—	—	—	0.5 J	0.51 J	0.51 J	—	—	—
Strontium	Nov 2010	*Dry*	1230	*Dry*	291	348	357	344	306	348	211	226
	Feb 2011	*Dry*	496	*Dry*	201	330	*Port Frozen*	226	220	284	204	114

Table 4.2-3 (continued)

		Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
					16-612215	16-612217	16-612218	16-612219	16-612220			
Analyte	Sampling Period	CDV-16-611921	CDV-16-611923	CDV-16-611934	Pretreatment	ZVI/ Zeolite[a]	Gravel	Zeolite/ ZVI[b]	Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
Thallium	July 2010	—	—	—	—	1.3 J	—	—	0.66 J	0.66 J	—	—
	Nov 2010	*Dry*		*Dry*	—	0.363 J	—	—	—	—	—	—
Tin	Nov 2010	*Dry*	10.5	*Dry*	4.43 J	12.1	10.6	7.65 J	3.45 J	—	—	—
Uranium	Nov 2010	*Dry*	4.69	*Dry*	0.709	0.854	0.697	—	—	—	—	—
	Feb 2011	*Dry*	0.797	*Dry*	0.195 J+	1.13 J+	*Port Frozen*	—	0.179 J+	0.101 J	—	—
Vanadium	May 2010	—	—	3.1 J	—	—	—	—	—	—	—	5.8 J
	June 2010	—	—	—	—	—	—	—	3 J	—	—	4.2 J
	July 2010	—	—	4.4 J	4.2 J	—	3 J	3.5 J	—	—	—	5.9 J
	Nov 2010	*Dry*	—	*Dry*	1.4 J	—	—	—	—	—	1.25 J	—
	Feb 2011	*Dry*	—	*Dry*	1.32 J	—	*Port Frozen*	—	—	—	—	—
Zinc	Apr 2010	10.1	13.1	8.7 J	*Preoperational Period*					14.7	6.9 J	7.6 J
	June 2010	7.5 J	18.9	5.6 J	7.8 J	5.1 J	6.2 J	6.1 J	8.2 J	13.4	7.6 J	5 J
	July 2010	—	30.6	8.7 J	19.7	—	8 J	5.5 J	4.5 J	15.6	9.3 J	7.9 J
	Nov 2010	*Dry*	15.4	*Dry*	26.3	22.7	15.2	13.3	11.2	—	—	4.26 J
	Feb 2011	*Dry*	—	*Dry*	4.18 J	—	*Port Frozen*	—	—	—	—	—

Notes: Units in µg/L unless otherwise noted. J = Result was qualified as estimated. J+ = Result was qualified as estimated and biased high.

[a] ZVI was installed from April 2010 to September 2010. Zeolite was installed September 2010 to July 2011.

[b] Zeolite was installed from April 2010 to September 2010. ZVI was installed September 2010 to July 2011.

[c] — = Not analyzed or not detected.

Table 4.2-4
Off-Site Laboratory Results for Explosive Compound Concentrations in Upgradient Wells, PRB Vessel, and Downgradient Wells

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
2,4-Diamino-6-nitrotoluene	Apr 2010	—[c]	1	—	*Preoperational Period*					0.21	—	—
	May 2010	—	1.9	0.041 J	0.27	—	0.22	0.24	0.17	0.33	—	—
	June 2010	—	1.2 J	—	—	—	0.036 J	0.038 J	—	0.29 J	—	—
	July 2010	—	3.2 J	0.048 J	0.036 J	—	0.035 J	0.052 J	0.032 J	0.27 J	—	0.026 J
	Feb 2011	—	—	—	—	0.464 J	*Port Frozen*	—	—	—	—	—
2,6-Diamino-4-nitrotoluene	Apr 2010	—	0.3	—	*Preoperational Period*					0.13	—	—
	May 2010	—	0.39	—	0.063	—	0.06	0.052	0.032 J	0.17	—	—
	June 2010	—	0.32 J	—	—	—	—	—	—	0.16 J	—	—
	July 2010	—	1.1 J	0.033 J	0.027 J	—	—	—	—	0.17 J	—	0.037 J
3,5-Dinitroaniline	Apr 2010	0.3	0.11	0.24	*Preoperational Period*					—	—	—
	May 2010	0.32	0.068	0.23	0.31	—	0.28	0.25	0.27	—	—	—
	June 2010	0.45	0.032 J	0.18 J-	0.34	—	0.32	0.28	0.3	—	—	—
	July 2010	0.45	—	0.18	0.37	—	0.33	0.37	0.34	—	—	—
Amino-2,6-dinitrotoluene[4-]	Apr 2010	3.9	2.9	1.8	*Preoperational Period*					—	—	—
	May 2010	2.9	1.5	1.7	4.4	—	4.5	4.4	4.2	—	—	—
	June 2010	4.6	1.3	1.7 J-	4.7	—	4.9	4.4	4.3	—	—	—
	July 2010	5.3	—	2.6	6.2	0.23	5.7	5.3	5.7	—	—	0.54
	Nov 2010	*Dry*	—	*Dry*	4.79	3.59	2.18	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	4.01	0.655	*Port Frozen*	—	2.57	—	—	—
Amino-4,6-dinitrotoluene[2-]	Apr 2010	3 J	2.2 J	1.3 J	*Preoperational Period*					—	—	—
	May 2010	2.4	1.2	1.4	3.3	—	3.1	3.4	3.4	—	—	—
	June 2010	3.3	0.84	1.4 J-	3.6	—	3.5	3.5	3.2	—	—	—
	July 2010	4 J	—	2 J	4.8 J	0.2 J	4.4 J	4.1 J	4 J	—	0.13 J+	0.5 J
	Nov 2010	*Dry*	—	*Dry*	4.12 J	2.98 J	1.72	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	3.78 J	0.688 J	*Port Frozen*	—	2.51 J	—	—	—
Dinitrobenzene[1,3-]	July 2010	—	—	—	0.13 J	0.1 J	—	0.088 J	—	—	0.088 J	—
	July 2010	—	—	—	—	—	—	—	—	—	—	0.32 J

Table 4.2-4 (continued)

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215	16-612217	16-612218	16-612219	16-612220	CDV-16-611936	CDV-16-611937	CDV-16-611938
					Pretreatment	ZVI/ Zeolite[a]	Gravel	Zeolite/ ZVI[b]	Post-treatment			
Dinitrotoluene[2,4-]	Apr 2010	0.18 J	0.084 J	0.041 J	*Preoperational Period*					—	—	—
	May 2010	0.16 J	0.051 J	0.062 J	0.23 J	—	0.22 J	0.22 J	0.23 J	—	—	—
	June 2010	0.29	—	0.08 J-	0.25	—	0.25	0.23	0.24	—	—	—
	July 2010	0.22	—	0.048 J	0.31	0.094 J	0.21	0.26	0.2	—	0.083 J	0.32
	Nov 2010	*Dry*	—	*Dry*	0.106 J	—	—	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	0.191 J	—	*Port Frozen*	—	—	—	—	—
Dinitrotoluene[2,6-]	July 2010	0.053 J	—	—	0.19 J	0.12 J	0.057 J	0.13 J	0.05 J	—	0.1 J	0.4 J
DNX	Apr 2010	—	0.51	0.52	*Preoperational Period*					—	—	—
	May 2010	—	1.5	1	0.55	—	0.51	0.62	0.56	—	—	—
	June 2010	0.3 J	—	0.61 J-	0.37 J	—	0.33 J	0.35 J	0.34 J	—	—	—
	July 2010	—	2.3	0.39 J	0.22 J	—	0.35 J	0.35 J	0.34 J	—	—	—
	Nov 2010	*Dry*	—	*Dry*	0.53	0.34 J	0.18 J	—	—	—	—	—
HMX	Apr 2010	15	25	54	*Preoperational Period*					2.2	0.17 J	4.6
	May 2010	29	19	30	30	0.1 J	31	36	31	2.3	1.9	18
	June 2010	26	11	30 J-	27	—	25	24	25	1.7	0.44	2.9
	July 2010	32 J	1.6 J+	12 J	25 J	0.41 J	25 J	24 J	26 J	1.8 J+	0.27 J+	1.8 J
	Nov 2010	*Dry*	—	*Dry*	19.2 J	15.4 J	10.9 J	—	—	1.44	—	0.912
	Feb 2011	*Dry*	0.204 J	*Dry*	14.8 J	12.2 J	*Port Frozen*	—	11.3 J	1.17	—	—
MNX	Apr 2010	—	0.81	2.3	*Preoperational Period*					—	—	—
	May 2010	0.92 J	2	2.2	1.3	—	1.2	1.4	1.4	—	—	1.4 J
	June 2010	1.1	2.2	1.4 J-	1.1	—	1	1.1	1.1	—	—	—
	July 2010	—	—	0.74	1	—	1	1.1	0.99	—	—	—
	Nov 2010	*Dry*	—	*Dry*	0.79	0.59	0.36 J	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	0.91	0.51	*Port Frozen*	—	0.75	—	—	—
Nitrobenzene	July 2010	—	—	—	0.11 J	0.082 J	—	0.099 J	—	—	0.11 J	0.31 J
Nitroglycerin	July 2010	—	—	—	0.43 J	0.42 J	—	0.27 J	—	—	0.22 J	0.72 J
Nitrotoluene[2-]	July 2010	—	—	—	0.13 J	—	—	—	—	—	—	0.33 J
Nitrotoluene[3-]	July 2010	—	—	—	—	—	—	—	—	—	—	0.28 J

Table 4.2-4 (continued)

Analyte	Sampling Period	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
		CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215 Pretreatment	16-612217 ZVI/ Zeolite[a]	16-612218 Gravel	16-612219 Zeolite/ ZVI[b]	16-612220 Post-treatment	CDV-16-611936	CDV-16-611937	CDV-16-611938
PETN	July 2010	0.076 J	—	—	0.36	0.28	0.082 J	0.2	—	—	0.16 J	0.59
RDX	Apr 2010	4.1	8.7	63	*Preoperational Period*					0.3	0.22	1.9
	May 2010	16	15	35	17	0.44	18	17	18	0.37	0.38	21
	June 2010	18	6.4	18 J-	22	—	20	21	20	0.54	—	0.48
	July 2010	19 J	1.4 J+	8.2 J	19 J	0.33 J	19 J	20 J	19 J	—	0.19 J+	0.65 J
	Nov 2010	*Dry*	—	*Dry*	15.1	11.8 J	8.95 J	—	—	0.42 J	—	—
	Feb 2011	*Dry*	—	*Dry*	11.4	7.77	*Port Frozen*	—	9.08	0.459 J	—	—
Tetryl	July 2010	0.055 J	—	—	0.29 J	0.25 J	0.058 J	0.16 J	—	—	0.11 J	0.57 J
TNX	Apr 2010	—	0.79	—	*Preoperational Period*					—	—	—
	June 2010	0.47 J	3.1	1.1 J-	0.49 J	—	0.6	0.67	0.54	—	—	—
	July 2010	—	8.2	0.97	—	—	0.45 J	—	0.45 J	—	—	—
	Nov 2010	*Dry*	0.69	*Dry*	0.72	0.51	0.27 J	—	—	—	—	—
Trinitrobenzene[1,3,5-]	July 2010	0.11 J	—	—	0.18 J	0.15 J	—	0.12 J	—	—	0.095 J	0.37 J
Trinitrotoluene[2,4,6-]	Apr 2010	0.22	—	0.3	*Preoperational Period*					—	—	—
	May 2010	0.13 J	—	—	0.1 J	—	0.091 J	0.085 J	0.086 J	—	—	—
	June 2010	0.25	—	—	0.17	—	0.098 J	0.087 J	0.12	—	—	—
	July 2010	0.4 J	—	—	0.49 J	0.19 J	0.22 J	0.31 J	0.16 J	—	0.13 J	0.49 J
	Nov 2010	*Dry*	—	*Dry*	0.162 J	—	—	—	—	—	—	—
	Feb 2011	*Dry*	—	*Dry*	0.119 J	—	*Port Frozen*	—	—	—	—	—

Notes: Units in µg/L unless otherwise noted. PETN = pentaerythritol tetranitrate. J = Result was qualified as estimated. J+ = Result was qualified as estimated and biased high. J− = Result was qualified as estimated and biased low.

[a] ZVI was installed from April 2010 to September 2010. Zeolite was installed September 2010 to July 2011.

[b] Zeolite was installed from April 2010 to September 2010. ZVI was installed September 2010 to July 2011.

[c] — = Not analyzed or not detected.

Table 4.4-1
Water-Level Measurements for Alluvial Wells and PRB

Sampling Date	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
	CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215	16-612217	16-612218	16-612219	16-612220	CDV-16-611936	CDV-16-611937	CDV-16-611938
Water Levels (depth to water [ft])											
2/2/2010	—[a]	7.70	5.41	*Preoperational Period* [b]					5.12	4.31	5.67
2/12/2010	Dry[c]	7.94	5.25						5.55	5.65	5.71
2/16/2010	Dry	7.74	4.83						5.52	5.60	5.68
2/26/2010	Dry	7.23	4.51						5.69	5.60	5.68
3/5/2010	Dry	7.14	4.56						5.51	5.36	5.56
3/10/2010	Dry	6.93	4.50						5.47	5.19	5.52
3/18/2010	Dry	6.85	4.14						5.27	4.68	4.96
3/22/2010	14.11	6.76	4.02						5.22	4.33	4.99
3/26/2010	12.82	5.69	3.99						5.13	4.12	4.96
4/8/2010	9.31	5.72	4.19						3.72	3.85	4.71
4/13/2010	8.93	5.73	4.21						3.74	3.88	6.64
4/22/2010	8.95	5.72	4.29						3.69	4.88	4.32
5/4/2010	8.71	5.76	4.87	2.81	2.09	2.43	2.47	3.71	3.82	3.98	4.16
5/7/2010	8.74	5.73	4.85	2.81	2.01	2.43	2.50	3.74	3.91	4.08	4.20
5/21/2010	9.33	5.72	4.99	2.30	1.52	2.51	2.51	3.80	4.15	4.54	5.32
5/25/2010	9.79	5.79	5.26	2.74	1.98	2.61	2.52	3.90	4.31	4.67	5.39
6/4/2010	10.31	5.75	5.41	2.86	2.08	2.62	2.53	3.63	4.44	5.40	5.62
6/10/2010	10.77	5.74	5.09	2.86	2.08	2.62	2.54	3.25	4.53	5.64	5.65
6/25/2010	12.85	5.73	5.91	2.85	2.28	2.69	2.55	3.39	4.80	6.18	5.89
7/8/2010	12.92	5.81	9.52	2.85	2.09	2.61	2.56	3.21	4.55	6.02	5.87
7/28/2010	13.86	5.79	9.95	2.87	2.10	2.67	2.56	3.66	4.18	5.14	5.57

Table 4.4-1 (continued)

Sampling Date	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
	CDV-16-611921	CDV-16-611923	CDV-16-611934	16-612215	16-612217	16-612218	16-612219	16-612220	CDV-16-611936	CDV-16-611937	CDV-16-611938
8/3/2010	—	—	—	2.81	2.10	2.67	2.57	3.32	—	—	—
9/3/2010	13.87	5.73	10.28	2.89	2.51	2.65	2.57	4.56	4.39	5.95	5.85
9/10/2010	13.90	5.75	10.32	2.93	2.73	3.00	2.89	4.78	4.50	6.15	5.91
9/16/2010	—	—	—	3.40	2.79	3.58	Dry	4.19	—	—	—
9/24/2010	—	—	—	3.43	2.74	2.74	2.63	3.78	—	—	—
10/1/2010	—	—	—	3.41	2.76	2.92	2.83	4.08	—	—	—
10/13/2010	—	—	—	3.43	2.69	2.69	2.59	4.33	—	—	—
10/15/2010	—	—	—	3.41	2.68	2.69	2.59	3.71	—	—	—
10/28/2010	—	—	—	3.72	2.69	2.68	2.59	4.07	—	—	—
11/1/2010	13.96	5.81	10.65	3.41	2.66	2.65	2.57	3.96	4.36	5.63	5.77
11/12/2010	—	—	—	3.44	2.70	2.70	2.61	4.07	—	—	—
11/24/2010	Dry	5.78	Dry	3.45	2.68	2.66	2.59	3.67	4.44	6.06	5.86
11/29/2010	—	—	—	4.23	Frozen[d]	Frozen	Frozen	3.30	—	—	—
1/6/2011	Dry	5.81	10.0	2.15	1.78	1.78	2.56	4.14	4.31	5.13	5.59
2/2/2011	Dry	5.84	Dry	Frozen	Frozen (slush)	Artesian[e]	2.60	4.10	4.5	5.69	5.65
2/16/2011	Dry	5.79	9.75	1.88	3.25 (with ice slush)	Frozen	2.55	3.94	4.49	5.7	5.67
2/23/2011	Dry	5.81	6.04	2.11	1.58	0.75	2.54	3.92	3.99	4.14	5.38
3/2/2011	—	—	—	3.55	Frozen	Frozen	Frozen	4.07	—	—	—
6/17/2011	Dry	5.9	10.09	—	—	—	—	—	4.63	6.25	5.93

[a] — = Measurement not collected.

[b] Dates precede operational period of the PRB.

[c] Dry indicates monitoring point was dry.

[d] Frozen indicates monitoring point was frozen

[e] Artesian indicates monitoring point was actively flowing.

Table 4.4-2
Design Basis for RDX and Barium Concentrations for the PRB

Concentration	RDX	Barium
Avg.	6.6	9,400
Min.	0.2	90
Max.	27.0	18,000
Target Cleanup Levels*	6.1	1,000

Note: Units in µg/L.
*Based on 10^{-5} cancer risk level.

Table 4.4-3
Contaminant Removal Residence Time

Contaminant	Max. Expected Conc. (µg/L)	Treatment Goal (µg/L)[a]	Half-Life (h)		Number of Half-Lives to Reach Goal	Min. Residence Time (Tr) (h)	Factor of Safety	Design Residence Time Tr (h)
			RDX	Barium				
RDX	27	6.1	1	—[b]	4.43	4.43	2	8.7
Barium	18,000	1,000	—	0.17	18	3.0	2	6.0

[a] Source: NMED guidance (NMED 2009, 108070).
[b] — = Not analyzed or not detected.

Table 4.4-4
Comparison of Off-Site Analytical RDX and Barium Results to Applicable Standards for PRB Configuration 1

	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
Sampling date	CDV-16-611921	CDV-16-611923	CDV-16-611934	Pre-treatment (16-612215)	ZVI (16-612217)	Gravel (16-612218)	Zeolite (16-612219)	Post-treatment (16-612220)	CDV-16-611936	CDV-16-611937	CDV-16-611938
Maximum Detected RDX Concentrations (µg/L) [a]											
April 2010	4.1	8.7	63	*Preoperational Period* [b]					0.3	0.22	1.9
May 2010	16	15	35	17	0.44	18	17	18	0.37	0.38	21
June 2010	18	6.4	18	22	0.2 U	20	21	20	0.54	0.2 U	0.48
July 2010	19	1.4	8.2	19	0.33	19	20	19	0.33 U	0.19	0.65
Maximum Detected Barium Concentrations (µg/L) [c]											
April 2010	1580	11500	3300	*Preoperational Period*					10700	13500	3340
May 2010	4090	11000	3260	4900	19.9	4950	4620	4010	10400	4670	1480
June 2010	3740	18200	3940	3920	24.7	4410	4070	3980	13900	5350	2020
July 2010	—[d]	34000	6580	3880	32.2	4080	2470	2270	14100	8180	2730

Note: Shaded cells indicate results exceeds applicable standard. U = The analyte was analyzed for but was not detected.

[a] RDX tap water screening level = 6.1 µg/L (NMED 2009, 108070).

[b] April 2010 sampling timeframe pre-dates operation of the PRB.

[c] Barium tap water standard = 1000 µg/L.

[d] — = Not analyzed or not detected.

Table 4.4-5
Comparison of Off-Site Analytical RDX and Barium Results to Applicable Standards for PRB Configuration 2

Sampling Date	Upgradient Wells			PRB Vessel Sampling Port					Downgradient Wells		
	CDV-16-611921	CDV-16-611923	CDV-16-611934	Pre-treatment (16-612215)	Zeolite(16-612217)	Gravel (16-612218)	ZVI (16-612219)	Post-treatment (16-612220)	CDV-16-611936	CDV-16-611937	CDV-16-611938
Maximum Detected RDX Concentrations (µg/L) [a]											
November 2010	*Dry* [b]	0.325 U	*Dry*	15.1	11.8	8.95	0.325 U	0.325 U	0.42	0.325 U	0.325 U
February 2011	*Dry*	0.325 U	*Dry*	11.4	7.77	*Frozen* [c]	0.325 U	9.08	0.459	0.325 U	0.325 U
Maximum Detected Barium Concentrations (µg/L) [d]											
November 2010	*Dry*	49400	*Dry*	3660	1600	1030	1090	860	15000	7000	6460
February 2011	*Dry*	18100	*Dry*	3310	3910	*Frozen*	2820	3650	12500	6180	4010

Note: Shaded cells indicate results exceeds applicable standard. U = The analyte was analyzed for but was not detected.

[a] RDX tap water screening level = 6.1 µg/L (NMED 2009, 108070).

[b] Dry = Well dry.

[c] Frozen = Sample port frozen.

[d] Barium tap water standard = 1000 µg/L.

Table 4.5-1
Trend in Increasing pH across the PRB Vessel

Sampling Date	pH				
	16-612215	16-612217	16-612218	16-612219	16-612220
11/1/2010	6.58	6.84	7.03	8.13	8.78
11/29/2010	6.32	*Sampling ports frozen – No sample*			7.44
1/6/2011	6.96	6.78	6.67	6.73	7.1
2/14/2011	6.79	6.78	*Port frozen*	7.04	6.63

Table 4.5-2
Correlation between Temperature and Solubility

Temperature (°C)	Solubility (mg/kg)
100	321
25	117
3	74

Appendix A

Photographs of the
Permeable Reactive Barrier at Technical Area 16

December 2009: Permeable reactive barrier (PRB) vessel before installation showing baffels and sample port locations.

December 18, 2009: Initial configuration: gravel zero-valent iron (ZVI), gravel, zeolite.

August 3, 2010: Reconfiguration: gravel, ZVI, gravel, zeolite. Bypass over baffles because of precipitation in ZVI chamber.

September 10, 2010: Second configuration: gravel, zeolite, gravel, ZVI. Reinforced baffles installed to prevent bypass.

March 23, 2011: Configuration 2 assessment: gravel, zeolite, gravel, ZVI. No flow through ZVI chamber. Flow to the vessel backed up and eventually forced through the gasket at top of baffle.

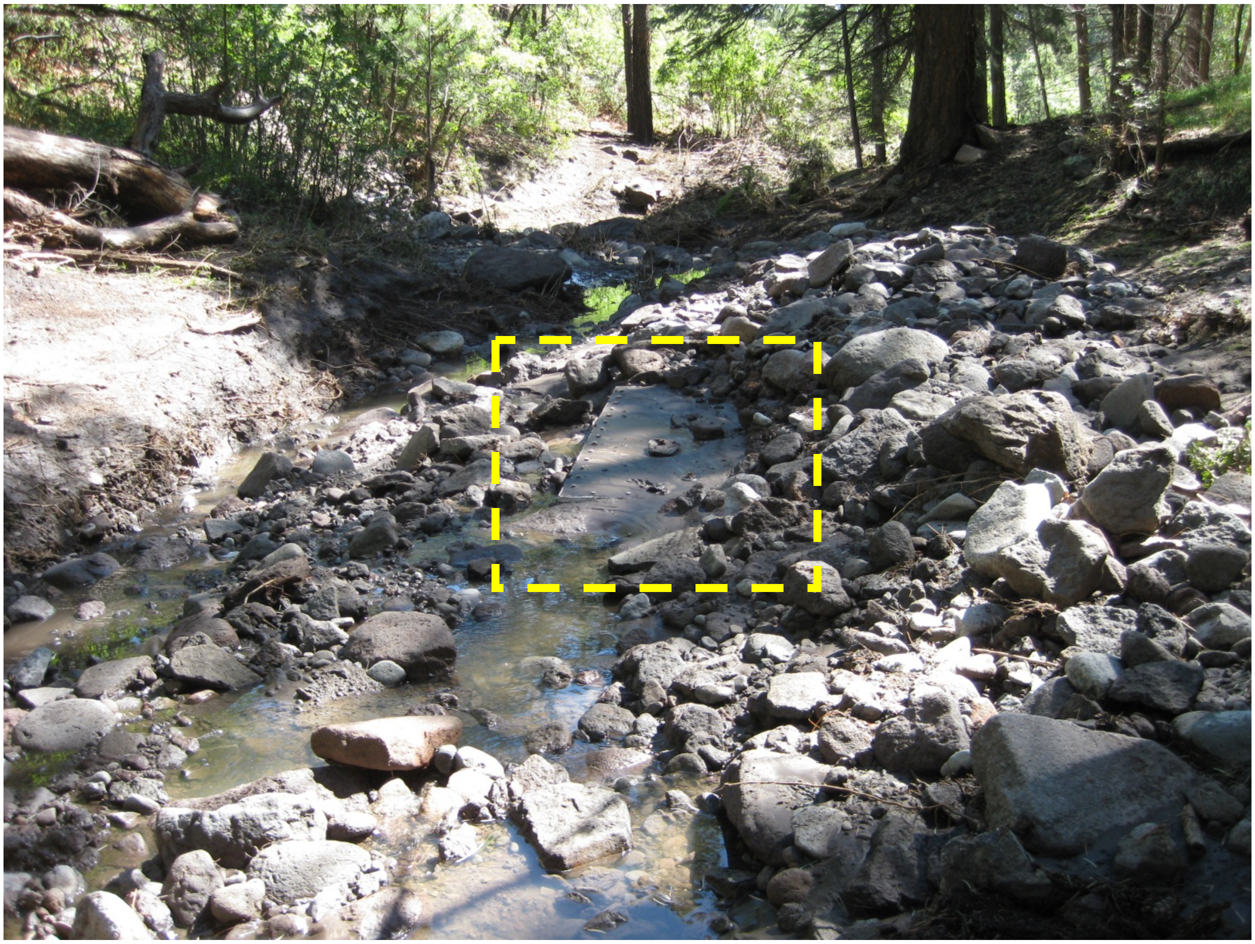
July 28, 2011: Third and current configuration: zeolite, granular activated carbon (GAC).

August 9, 2011: Post-8/3/11 flood damage. Input of stormwater and sediment to the vessel.

August 9, 2011: Post-8/3/11 flood. Cell 1, approximately 2 in. of ash and silt deposited on zeolite. Also note the high water mark of organic debris.

August 23, 2011: Post-8/21/11 flood. Cañon de Valle channel scoured to bedrock upgradient of PRB cutoff wall. Photograph shows remnants of PRB cutoff wall (geotextile, exposed piping in channel).

August 23, 2011: One of several upgradient alluvial wells compromised by flash flooding on 8/21/2011.



August 23, 2011: PRB vessel covered with sediment, rocks and debris in Cañon de Valle channel downgradient of PRB cutoff wall.

Appendix B

Field Screening and Analytical Data
(on CD included with this document)

Appendix C

Design Modifications and
Operation, Maintenance, and Sampling Schedule for
2011/2012 Corrective Measures Implementation Monitoring

C-1.0 INTRODUCTION

This appendix serves as an addendum to the Technical Area 16 (TA-16) Corrective Measures Implementation (CMI) Plan (LANL 2010, 109252). This appendix includes recommendations for corrective measure design modifications as well as the schedule for the operation, maintenance, and sampling for the corrective measures implemented in 2011 and 2012. Objectives of the corrective measures monitoring are reported in the summary report.

This appendix contains six sections, including this introduction. Section C-2 identifies the design modifications for the 2011/2012 monitoring period and rationale for any deviation from the original plan. Section C-3 identifies the operation, maintenance, and sampling activities for 2011/2012. Section C-4 presents the operation, maintenance, and sampling schedule for the TA-16 CMI projects. Section C-5 lists the reporting requirements and contingencies for monitoring and reporting. Section C-6 lists the references used throughout this appendix.

C-2.0 RECOMMENDED MODIFICATIONS TO CMI DESIGN AND PLAN IMPLEMENTATION

Because of the extensive damage caused in August 2011 by flash flooding in Cañon de Valle following the Las Conchas fire, recommendations for the implementation of the CMI plan during the 2011/2012 operational period are limited to baseline monitoring of alluvial groundwater from intact wells and continued monitoring of the well located at the 16-260 outfall. In the event that a discharge permit is obtained for operation of the carbon filters at Burning Ground, SWSC, and Martin Springs, the carbon filters will also be operated, maintained, and monitored in accordance with the schedule and frequencies presented in section C-4.0.

Interim actions recommended as a result of field observations of flood damage in Cañon de Valle include plugging and abandoning damaged wells and monitoring intact wells to measure post-flood baseline conditions. A detailed flood recovery plan is proposed for preparation within 60 d of New Mexico Environment Department (NMED) approval of the TA-16 permeable reactive barrier (PRB) and CMI summary report. The flood recovery plan will document the action(s) selected to ensure continued implementation of corrective measures for the remediation of barium and RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) in alluvial groundwater in Cañon de Valle.

C-3.0 DESCRIPTION OF OPERATION, MAINTENANCE, AND SAMPLING FOR 2011/2012 CMI ACTIVITIES

PRB

Repair and monitoring of the PRB system is suspended for the 2011/2012 CMI monitoring period, pending development and issuance of a flood recovery plan. The plan will identify and propose essential repairs, design configuration and modifications, performance terms for operation and maintenance, and sampling frequency to ensure continued implementation of corrective measures for the remediation of barium and RDX in alluvial groundwater in Cañon de Valle.

Alluvial Monitoring Wells

Alluvial wells that were not damaged from August 2011 flash flooding will continue to be monitored to assess post-flooding baseline conditions during the 2011/2012 monitoring period. Water levels, field parameters, geochemical parameters, and suite analyses for metals and explosive compounds will be monitored.

Table C-3.0-1 summarizes the field-parameter measurements to be collected at the intact alluvial wells in Cañon de Valle. Table C-3.0-2 summarizes the geochemical screening parameters to be collected. Table C-3.0-3 lists the suite analyses to be performed by an off-site analytical laboratory for samples from the alluvial monitoring wells and carbon filters.

Carbon Filters at Burning Ground, SWSC, and Martin Springs

In the event that a discharge permit is obtained from the U.S. Environmental Protection Agency (EPA) Region 6 for operation of the carbon filters, the stormwater units will be monitored on a monthly basis for on-site analyses and quarterly for off-site analysis. Final approval of the permit may dictate additional sampling and monitoring requirements. National Pollutant Discharge and Elimination System (NPDES) permit requests will be followed if they are more stringent than the design proposed in this monitoring plan.

Low-Permeability Cap

The low-permeability cap installed at the former settling pond is one of several best management practices (BMPs) installed at Consolidated Unit16-021(c)-99. This consolidated unit also contains berms, a check dam, and areas that have been stabilized with seed and mulch. This area is referenced as CDV-SMA 2.2 under the NPDES individual permit (IP) (available at http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-11-01554). The IP requires this area to be inspected following 0.25 in. of rainfall during a 30-min period. Future documentation of the low-permeability cap and other BMPs associated with the 260 Outfall will be documented as part of the inspections for CDV-SMA 2.2. No additional reporting will be included in subsequent CMI monitoring reports for Consolidated Unit 16-021(c)-99.

Former Settling Pond Injection Grouting

The alluvial groundwater well installed next to the injection grouting site will continue to be monitored for the presence of water twice a year for 1 yr or more: once in March and April during the spring snowmelt season and once in August and September following the summer rain season. If water is encountered, samples will be collected for analysis of explosive compounds.

C-4.0 OPERATION, MAINTENANCE, AND SAMPLING SCHEDULE

The operation, maintenance, and sampling schedule for the PRB is provided in Table C-4.0-1. The schedule accounts for a 1-yr operational and monitoring period, beginning in September 2011 and concluding in September 2012. Results from off-site analytical data proposed for collection in August 2012 may not be available for reporting in September.

The surveillance and monitoring schedule for the other CMI projects is presented in Table C-4.0-2.

C-5.0 CONTINGENCIES AND REPORTING

A 1-yr operational and monitoring period is proposed for the alluvial groundwater monitoring wells, carbon filters, and settling pond injection grouting, beginning in September 2011 and concluding in September 2012.

Any delays in operation and monitoring resulting from unanticipated repairs to or installation of replacement alluvial wells or resulting from delays in NPDES permit issuance for the operation of spring carbon filters are not accounted in the proposed sampling schedules and monitoring frequencies presented in section C-4.0. Significant delays or proposed alterations to the operation, monitoring, and maintenance schedule included in this schedule will be discussed with NMED.

C-6.0 REFERENCES

The following list includes all documents cited in this appendix. 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.

LANL (Los Alamos National Laboratory), April 2010. "Long-Term Monitoring and Maintenance Plan for the Corrective Measures Implementation at Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-10-2196, Los Alamos, New Mexico. (LANL 2010, 109252)

Table C-3.0-1
Summary of Field-Parameter Measurements at the PRB Vessel Monitoring Points, Alluvial Wells, and Carbon Filters

Monitoring Point	Water Level	Flow Rate (L/s)	pH (Standard Unit)	Temp (deg C)	Oxidation Reduction Potential (mV)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU[a])
PRB Vessel Monitoring Points								
n/a[b]	PRB vessel will remain offline until post-flooding system repairs have been addressed.							
PRB Alluvial Wells								
CDV-16-611921	X[c]	—[d]	X	X	X	X	X	X
CDV-16-611923[e]	X	—	X	X	X	X	X	X
CDV-16-611934[f]	—	—	—	—	—	—	—	—
CDV-16-611936[f]	—	—	—	—	—	—	—	—
CDV-16-611937[e]	X	—	X	X	X	X	X	X
CDV-16-611938[f]	—	—	—	—	—	—	—	—
Carbon Filters[g]								
Martin Spring: 16-06707	—	X	X	X	X	X	X	X
Burning Ground: 16-612308	—	X	X	X	X	X	X	X
SWSC: 16-612307	—	X	X	X	X	X	X	X

[a] NTU = Nephelometric turbidity units.
[b] n/a = Not applicable.
[c] X = Parameter will be measured.
[d] — = Parameter will not be measured.
[e] Monitoring well potentially damaged by flood water. Well will require additional development before sample collection.
[f] Monitoring well destroyed by flash flooding.
[g] Monitoring of carbon filters pending approval of discharge permit.

Table C-3.0-2
Summary of On-Site Geochemical Screening Parameters at the PRB Vessel Monitoring Points, Alluvial Wells, and Carbon Filters

Monitoring Point	Alkalinity	Filtered Cations	Filtered Anions	High Explosives Screening
PRB Vessel Monitoring Points				
n/a[a]	PRB vessel will remain offline until post-flooding system repairs have been addressed.			
PRB Alluvial Wells				
CDV-16-611921	X[b]	X	X	X
CDV-16-611923[c]	X	X	X	X
CDV-16-611934[d]	—[e]	—	—	—
CDV-16-611936[d]	—	—	—	—
CDV-16-611937[c]	X	X	X	X
CDV-16-611938[d]	—	—	—	—
Carbon Filters[f]				
Martin Spring: 16-06707	—	X	X	X
Burning Ground: 16-612308	—	X	X	X
SWSC: 16-612307	—	X	X	X

[a] n/a = Not applicable.
[b] X = Analysis will be requested.
[c] Monitoring well potentially damaged by flood water. Well will require additional development before sample collection.
[d] Monitoring well destroyed by flash flooding.
[e] — = Analysis will not be requested.
[f] Monitoring of carbon filters pending approval of discharge permit.

Table C-3.0-3
Summary of Off-Site Analyses for the PRB
Vessel Monitoring Points, Alluvial Wells, and Carbon Filters

Monitoring Well	Explosive Compounds (EPA SW-846:8330) and Breakdown Compounds (EPA SW-846:8321A_MOD)	TAL Metals (EPA SW-846:6010B/6020) (filtered/unfiltered)	Cations (calcium, magnesium, iron, manganese)	Anions (sulfate, chloride, nitrate, alkalinity)
PRB Vessel Monitoring Points				
n/a[a]	PRB vessel will remain offline until post-flooding system repairs have been addressed.			
PRB Alluvial Wells				
CDV-16-611921	X[b]	X	X	X
CDV-16-611923[c]	X	X	X	X
CDV-16-611934[d]	—[e]	—	—	—
CDV-16-611936[d]	—	—	—	—
CDV-16-611937[c]	X	X	X	X
CDV-16-611938[d]	—	—	—	—
Carbon Filters[f]				
Martin Spring: 16-06707	X	X	X	X
Burning Ground: 16-612308	X	X	X	X
SWSC: 16-612307	X	X	X	X

[a] n/a = Not applicable.

[b] X = Analysis will be requested.

[c] Monitoring well potentially damaged by flood water. Well will require additional development before sample collection.

[d] Monitoring well destroyed by flash flooding.

[e] — = Analysis will not be requested.

[f] Monitoring of carbon filters pending approval of discharge permit.

Table C-4.0-1
Summary of Monitoring and Maintenance Parameters and Frequencies at the PRB Vessel Monitoring Points, Cutoff Wall Monitoring Wells, Alluvial Groundwater Monitoring Wells, and Carbon Filters

Monitoring Locations	Monitoring Parameter[a]	Quarter	2011/2012 Monitoring Event Schedule[a]	Water Level	Flow Rate	Explosive Compounds and Breakdown Compounds (EPA SW-846:8321A_MOD)	TAL Metals (EPA SW-846:6010B/6020)	Cations (Ca, Mg, Fe, Mn)	Anions (sulfate, chloride, nitrate, alkalinity)	Field Chemistry (pH, temperature, ORP, specific conductivity, DO, turbidity)	EES Screen
PRB Vessel											
n/a[b]	PRB Vessel will remain offline until post-flooding system repairs have been addressed.										
Cutoff Wall Hydrology											
Upgradient wells CDV-16-611920 CDV-16-611921 CDV-16-611922 CDV-16-611923[c] Upgradient piezometers CDV-16-611926 CDV-16-611927 Downgradient wells CDV-16-611928 CDV-16-611929 CDV-16-611930 CDV-16-611932 CDV-16-611933 CDV-16-611935	Water level[d]	Q1	(Semimonthly) Sept, Oct, Nov 2011	X[e]	—[f]	—	—	—	—	—	—
		Q2	(Monthly) Dec 2010, Jan 2011, Feb 2011	X	—	—	—	—	—	—	—
		Q3	(Semimonthly) Mar, Apr, May 2012	X	—	—	—	—	—	—	—
		Q4	(Semimonthly) Jun, Jul, Aug 2012	X	—	—	—	—	—	—	—

Table C-4.0-1 (continued)

Monitoring Locations	Monitoring Parameter[a]	Quarter	2011/2012 Monitoring Event Schedule[a]	Water Level	Flow Rate	Explosive Compounds and Breakdown Compounds (EPA SW-846:8321A_MOD)	TAL Metals (EPA SW-846:6010B/6020)	Cations (Ca, Mg, Fe, Mn)	Anions (sulfate, chloride, nitrate, alkalinity)	Field Chemistry (pH, temperature, ORP, specific conductivity, DO, turbidity)	EES Screen
Cañon de Valle Alluvial Groundwater											
Monitoring wells CDV-16-611921 CDV-16-611923[c] CDV-16-611937[c]	Field-parameter analysis	Q1	Nov 2011	—	—	—	—	—	—	X	—
		Q2	Feb 2012	—	—	—	—	—	—	X	—
		Q3	May 2012	—	—	—	—	—	—	X	—
		Q4	Aug 2012	—	—	—	—	—	—	X	—
	Off-site chemical analysis	Q1	Nov 2011	—	—	X	X	X	X	X	X
		Q2	Feb 2012	—	—	X	X	X	X	X	X
		Q3	May 2012	—	—	X	X	X	X	X	X
		Q4	Aug 2012	—	—	X	X	X	X	X	X
	On-site chemical analysis (EES)	Q1–Q4	Optional as needed Sept 2011–Aug 2012	—	—	—	—	—	—	—	X

Table C-4.0-1 (continued)

Monitoring Locations	Monitoring Parameter[a]	Quarter	2011/2012 Monitoring Event Schedule[a]	Water Level	Flow Rate	Explosive Compounds and Breakdown Compounds (EPA SW-846:8321A_MOD)	TAL Metals (EPA SW-846:6010B/6020)	Cations (Ca, Mg, Fe, Mn)	Anions (sulfate, chloride, nitrate, alkalinity)	Field Chemistry (pH, temperature, ORP, specific conductivity, DO, turbidity)	EES Screen
Carbon Filters[g]											
Martin Spring: 16-06707 Burning Ground: 16-612308 SWSC: 16-612307	Flow rate	Q1–Q4	Monthly Sept 2011–Aug 2012	—	X	—	—	—	—	—	—
	Field-parameter analysis	Q1–Q4	Monthly Sept 2011–Aug 2012	—	—	—	—	—	—	X	—
	Off-site chemical analysis	Q1	Nov 2011	—	—	X	X	X	X	—	—
		Q2	Feb 2012	—	—	X	X	X	X	—	—
		Q3	May 2012	—	—	X	X	X	X	—	—
		Q4	Aug 2012	—	—	X	X	X	X	—	—
	On-site chemical analysis (EES)	Q1–Q4	Monthly Sept 2011–Aug 2012	—	—	—	—	—	—	—	X

Notes: TAL= Target analyte list; ORP = oxidation-reduction potential; DO = dissolved oxygen; EES = Earth and Environments Sciences.

[a] All monitoring/sampling is performed once during reporting period, unless stated otherwise.

[b] n/a = Not applicable.

[c] Monitoring well potentially damaged by flood water. Well will require additional development prior to sample collection.

[d] Water levels will be measured manually. Three upgradient and three downgradient wells will be instrumented with pressure transducers for automated monitoring, which will be downloaded quarterly.

[e] X = Analysis will be requested or parameter will be measured.

[f] — = Analysis will not be requested or parameter will not be measured.

[g] Monitoring of carbon filters pending approval of discharge permit.

Table C-4.0-2
Surveillance Schedule for Alluvial Well to Monitor Low-Permeability Cap and Injection Grouting

Sampling Media	Monitoring/ Maintenance Parameter	Sampling Point/ Location	Monitoring Event Frequency	Number of Maintenance Events in 1 yr	Explosive Compounds (EPA SW-846:8330)	Comments
Groundwater	Water level and chemical analysis	Well	Semiannual	2	2	Inspection to follow snowmelt and summer rains, well to be sampled if water is present.