ROCKY MOUNTAIN ARSENAL

Final
2015 Five Year Review Report
for
Rocky Mountain Arsenal
Commerce City
Adams County, Colorado

Review Period: April 1, 2010 – March 31, 2015

Volume II of II

Five-Year Summary Report for
Groundwater and Surface Water

Revision 0

September 26, 2016

U.S. Department of the Army

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APPENDICES

ACRONYMS

AMA	Army Maintained Area
ARAR	Applicable or Relevant and Appropriate Requirement
ARDL	Applied Research and Development Laboratory
ASR	Annual Summary Report
BANS	Basin A Neck System
BRES	Bedrock Ridge Extraction System
CADT	Complex (Army) Disposal Trenches
CAMU	Corrective Action Management Unit
CBSG	Colorado Basic Standard for Groundwater
CBSMSW	Colorado Basic Standards and Methodologies for Surface Water
CCR	Construction Completion Report
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cfs	cubic feet per second
CFS	Confined Flow System
CLC6H5	Chlorobenzene
COC	Contaminant of Concern
CQAP	Chemical Quality Assurance Plan
CSRG	Containment System Remediation Goal
CWTF	CERCLA Wastewater Treatment Facility
CWQCC	Colorado Water Quality Control Commission
DBCP	Dibromochloropropane
DCN	Design Change Notice
DCPD	Dicyclopentadiene
11DCLE	1,1-Dichloroethane
DDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DITH	Dithiane
DIMP	Diisopropylmethyl phosphonate
DNAPL	Dense Non-Aqueous Phase Liquid
DOC	Dissolved Organic Carbon
DSR	Data Summary Report

ELF	Enhanced Hazardous Waste Landfill
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
FCS	First Creek System
FS	Feasibility Study
ft	Foot or Feet
ft/ft	Feet per Foot
FY	Fiscal Year
FYR	Five-Year Review
FYRR	Five-Year Review Report
FYSR	Five-Year Summary Report
FWENC	Foster Wheeler Environmental Corporation
GAC	Granular Activated Carbon
gal	Gallons
GWMR	Groundwater Mass Removal
GWMRP	Groundwater Mass Removal Project
gpm	Gallons per Minute
HBSF	Hydrazine Blending and Storage Facility
HLA	Harding Lawson Associates
HRC	Hydrogen Release Compound®
HWL	On-Post Hazardous Waste Landfill
IC	Indicator Compounds
ICS	Irondale Containment System
IRA	Interim Response Action
kg	Kilogram
kg/year	Kilograms per Year
lbs	Pounds
lbs/year	Pounds per Year
LCS	Leachate Collection System
LDS	Leak Detection System
LNAPL	Light Non-Aqueous Phase Liquid
LTCP	Long-Term Care Plan
LTMP	Long-Term Monitoring Plan
LWTS	Landfill Wastewater Treatment System

MCL	Maximum Contaminant Level
MCR	Monitoring Completion Report
mg/L	Milligrams per Liter
MOA	Memorandum of Agreement
MRL	Method Reporting Limit
NBCS	North Boundary Containment System
NBE	North Boundary Enhancement
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NEE	Northeast Extension
NDMA	n-Nitrosodimethylamine
NPL	National Priorities List
NPS	Northern Pathway System
NRAP	Non-Routine Action Plan
NWBCS	Northwest Boundary Containment System
OCN	Operations and Maintenance Change Notice
OCP	Organochlorine Pesticide
O&M	Operations and Maintenance
OGITS	Off-Post Groundwater Intercept and Treatment System
OGMP	Operational Groundwater Monitoring Plan
OU	Operable Unit
PCE	Tetrachloroethylene
PCGMP	Post-Closure Groundwater Monitoring Plan
PMRMA	Program Manager Rocky Mountain Arsenal
PQL	Practical Quantitation Limit
PRAS	Percent of Relative Aqueous Solubility
PT	Principal Threat (wells)
Railyard	Rail Classification Yard
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RMA	Rocky Mountain Arsenal
RMAED	RMA Environmental Database
RMANWR	Rocky Mountain Arsenal National Wildlife Refuge
ROD	Record of Decision
RS/S	Remediation Scope and Schedule
RVO	Remediation Venture Office

RYCS	Railyard Containment System
SAP	Sampling and Analysis Plan
SEO	State Engineer's Office
Shell	Shell Oil Company
SOM	Supplemental Operational Monitoring
SQAPP	Sampling Quality Assurance Project Plan
SSI	Statistically Significant Increase
STF	South Tank Farm
TBC	To Be Considered
TCHD	Tri-County Health Department
TOC	Total Organic Carbon
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
TtEC	Tetra Tech EC, Inc.
TtFW	Tetra Tech FW, Inc.
UFS	Unconfined Flow System
µg/L	Micrograms per Liter
UPL	Upper Prediction Limit
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UV	Ultraviolet
VOC	Volatile Organic Compound
WP	Wastepile (wells)

Executive Summary

This Five-Year Summary Report (FYSR) for Groundwater and Surface Water evaluates the on-post and off-post Rocky Mountain Arsenal (RMA) groundwater remedies and the monitoring results for groundwater and surface water for the fiscal year 2010 (FY10) through FY14 Five-Year Review (FYR) period. It also provides a summary of how the water-related issues identified in the previous 2010 Five-Year Review Report (FYRR) (TtEC 2011a) have been addressed. The FYSR does not include assessments of the results against the FYR criteria and does not identify FYR issues as these assessments are performed as part of the FYRR.

The data used for this FYSR were collected pursuant to the 2010 Long-Term Monitoring Plan for Groundwater and Surface Water (LTMP) (TtEC and URS 2010), the Sampling and Analysis Plans (SAPs) issued as part of the Operations and Maintenance (O&M) Plans for the respective extraction and treatment systems, SAPs issued as part of the Post-Closure Plans, and the Rocky Mountain Arsenal Sampling Quality Assurance Project Plan (SQAPP) (Navarro 2014a) in accordance with Resource Conservation and Recovery Act (RCRA) requirements.

The long-term groundwater monitoring program described in the 2010 LTMP satisfies the requirements of the On-Post and Off-Post Records of Decision (RODs) (FWENC 1996; HLA 1995). The main objectives, as stated in the RODs, are to evaluate the effectiveness of the remedies, to verify the effectiveness of existing on-post and off-post groundwater treatment systems, to satisfy Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requirements for waste left in place, and to provide data for FYRs. The main component of the remedy related to groundwater is continued operation of the groundwater extraction and treatment systems.

2010 FYR Issues

The water-related FYR issues identified in the 2010 FYRR provided the basis for many of the groundwater program changes that were made during the FYR period, and status evaluations and descriptions of the follow-up actions are therefore included in this report. All the follow-up actions associated with the 2010 water-related issues either have been or are in the process of being addressed in accordance with the recommendations made in the 2010 FYRR.

On-Post Operable Unit (OU) Monitoring Program Evaluation

The following **on-post groundwater extraction systems** were evaluated against compliance requirements and performance criteria:

- Northwest Boundary Containment System (NWBCS)
- North Boundary Containment System (NBCS)
- Railyard Containment System (RYCS)
- Basin A Neck System (BANS)
- Bedrock Ridge Extraction System (BRES)

All the on-post groundwater extraction and treatment systems were found to be functioning as intended by the Decision Documents during the FYR period, with a few qualifications. The system performance evaluation resulted in the following conclusions.

- NWBCS treatment plant effluent contaminant concentrations were below Containment System Remediation Goals (CSRGs)/Practical Quantitation Limits (PQLs), except for detection of dieldrin above the PQL in the third quarter of FY12. Based on the results of an RMA PQL study, the dieldrin PQL was lowered from 0.05 µg/L to 0.013 µg/L in April 2012. The plant effluent was below the PQL for dieldrin in the four-quarter moving averages, which is the compliance requirement, for the entire FYR period. Changes in the treatment plant operation were made in 2012 immediately after dieldrin was detected above the PQL, and were successful in lowering the concentrations to be equal to or below the PQL. Additional steps may be needed to further reduce the effluent concentrations. The potential treatment changes include more frequent pulsing of carbon, using virgin carbon instead of regenerated carbon, evaluation of desorption of dieldrin from carbon fines during sample extraction and analysis, and removing carbon fines (defining) throughout the system.

  The NWBCS has three extraction/recharge components: Original System, Northeast Extension, and Southwest Extension. Each component is discussed below.

  Original System. In addition to the treatment requirements, the effectiveness of the NWBCS in intercepting the groundwater contamination migrating toward the system is based on meeting primary and secondary performance criteria. The NWBCS Original System primary performance criteria were met during the FYR period; the reverse hydraulic gradient and plume capture were maintained. According to the NWBCS decision rules in the LTMP, if the primary performance criteria are met, the secondary criteria do not normally apply. There is a discrepancy between the NWBCS decision rules and trigger table, which requires notification of the Regulatory Agencies if the downgradient well concentrations are increasing while the primary criteria are met. Due to a combination of the effluent concentrations of dieldrin being at or near the new PQL, and higher water levels potentially mobilizing dieldrin from the aquifer sediments downgradient of the NWBCS slurry wall, the dieldrin concentrations were above the PQL in some of the downgradient performance wells. The secondary performance criteria are to show that the downgradient performance well concentrations are below the CSRGs/PQLs or show decreasing concentration trends. The concentration trend is determined over a minimum of five years, based on annual evaluations. Prior to 2012, dieldrin was not detected in the downgradient wells and the long-term trend cannot be determined because the method reporting limit was higher. Monitoring data collected during the next FYR period will be used to evaluate the concentration trends in the downgradient wells and determine whether the secondary performance criteria are being met.

  Northeast and Southwest Extensions. The primary and secondary performance criteria were met for both systems.

- NBCS treatment plant effluent contaminant concentrations were below CSRGs/PQLs, except for single detections of aldrin and dieldrin above the PQLs in the third quarter of FY12. The plant effluent was below the PQL for aldrin and dieldrin in the four-quarter moving averages, which is the compliance requirement, for the entire FYR period. The reverse hydraulic gradient was maintained. The contaminant concentrations are decreasing or are below CSRGs/PQLs in the downgradient performance wells that are representative of system performance. Replacing five downgradient performance wells with alternate wells is recommended.
- RYCS treatment plant effluent contaminant concentrations were below CSRGs, plume capture was maintained, and the contaminant concentrations were below the CSRGs in the downgradient wells. Pre-shut-off monitoring was successfully conducted in 2014, and the shut-off process will proceed during the next FYR period. The Draft RYCS Shut-Off SAP was issued in November 2015.
- BANS treatment plant effluent contaminant concentrations were below CSRGs/PQLs, the mass removal performance goal was met, and the contaminant concentrations of most analytes were stable, decreasing, or below CSRGs/PQLs in the downgradient performance wells. In FY14, the extent of the reverse hydraulic gradient was reduced for part of the year because historically high water levels occurred after the unprecedented September 2013 storm/flood event. The BANS does not have reverse gradient performance criteria, but the FY14 concentrations of a few contaminants increased in two of the four downgradient performance wells, likely because of the reduced extent of the reverse gradient. This was a first-time occurrence. The long-term concentration trends are not increasing in these wells, thus, the downgradient well performance criterion is being met. System operations were modified in early FY15 and returned the reverse gradient to its historical extent. Establishing reverse gradient performance criteria in the LTMP will be considered when the LTMP is revised, possibly in 2017.

  The 2010 LTMP stated that the 75 percent mass removal goal would be re-evaluated after five years of data collection. Based on the performance during this FYR period, increasing the goal to greater than 75 percent was considered. However, as contaminant concentrations decline in the future, the concentrations in the upgradient wells may approach the CRSGs/PQLs. Meeting the 75 percent mass removal goal could then become more difficult because of limitations in the calculations when the dewatering well and influent concentrations approach the CSRGs/PQLs, and may also be unnecessary to meet ROD compliance requirements. Consequently, as concentrations decline in the future, lowering the mass removal goal may be appropriate to be consistent with ROD compliance. Additionally, as contaminant concentrations decline, the treatment efficiencies may also decline, which may make attainment of 75 percent mass removal more difficult. Army and Shell will continue to optimize the system operation for mass removal, and proposes to retain the 75 percent mass removal goal.
- BRES maintained plume capture, and the contaminant concentrations are decreasing in most of the downgradient wells. One of the four downgradient performance wells had decreasing concentrations of some analytes and increasing concentrations of others,

which may indicate that the well is located in a zone where the hydraulic gradient and permeability of the formation are low, and the divergent trends are not indicative of system effectiveness. Continued performance-well monitoring should help clarify the situation. Quarterly sampling of the downgradient performance well and an additional well for one year is proposed.

The **Groundwater Mass Removal (GWMR) Project** involved the installation of mass removal wells in the South Tank Farm (STF) and Lime Basins areas. The GWMR project was in operation during a portion of the FYR period. The STF mass removal system that was installed to remove contaminant mass from the South Plants STF area and enhance in-situ biodegradation operated successfully from 2006 through 2010, when it was decommissioned. The STF system had removed 2,863.5 kilograms (kg) (6,312.9 pounds [lbs]) of contaminant mass by the end of July, 2010. The Lime Basins System had removed 1059.8 kg (2,336.5 lbs) of contaminant mass by the end of July, 2010

The **Light Non-Aqueous Phase Liquid (LNAPL) Pilot System** was installed to remove LNAPL found in the North Plants area and the pilot study was initiated in February 2009. Since 2009, weekly, monthly, and quarterly monitoring showed that LNAPL did not accumulate in the wells in sufficient thickness for removal. Additionally, LNAPL typically has not been detected or measured. Annual monitoring during the next FYR period is proposed to continue to demonstrate that no further actions are needed. However, if LNAPL is found in sufficient thickness for removal, Army and Shell have an ongoing commitment for additional action, and LNAPL removal operations will commence.

The **Complex (Army) Disposal Trenches (CADT) and Shell Disposal Trenches** containment remedies rely on water level monitoring to assess performance. The Complex Disposal Trenches dewatering system had not attained the dewatering goal of lowering the water levels below the bottom of the disposal trenches in one of the two compliance wells by the end of the FYR period, and the dewatering goal had not been attained by September 9, 2014, which was the target date established in the 2010 LTMP. The September 2013 500- to 1000-year storm event (NOAA 2013) followed by heavy rains in May 2014 caused water levels inside the CADT slurry wall to rise. However, the long-term and short-term trends show falling water levels in the compliance well. Therefore, progress is being made toward meeting the goal. In the meantime, the groundwater contamination is contained within the slurry wall, and significant contaminant mass removal is occurring because of continued operation of the dewatering trench and treatment of the groundwater at BANS to meet CSRGs. A cost-benefit evaluation for installing dewatering wells to supplement the CADT dewatering system will be conducted in 2016.

The Shell Disposal Trenches containment remedy includes a slurry wall encircling the disposal trenches in addition to the cover. Water levels are to drop below the bottoms of the disposal trenches. The water-level goal was not attained by the October 2, 2012 date established in the 2010 LTMP, but the goal was attained in July 2013. The September 2013 500- to 1000-year storm event followed by heavy rains in May 2014 caused water levels inside the Shell Disposal Trenches slurry wall to rise above the target water elevation in one of the six compliance borehole locations during part of FY14. After the effects of the 2013/2014 storms have dissipated, the water levels are expected to fall and the water-level goal will be re-attained. In the meantime, the protectiveness of the remedy is not adversely affected because much of the groundwater contamination is contained within the dual slurry walls. Additionally, downgradient of the Shell Disposal Trenches, the groundwater is extracted by the BRES and BANS, and treated to meet CSRGs. Thus, the remedy contains multiple layers of protectiveness. A cost-benefit evaluation for installing dewatering wells in the Shell Disposal Trenches will be conducted in 2016.

Lime Basins Slurry Wall Dewatering and DNAPL Remediation Projects commenced during 2009 and 2012, respectively. The dewatering goals are to lower the water levels inside the Lime Basins slurry wall to below the waste, and to maintain an inward hydraulic gradient from outside to inside the slurry wall. Shortly after startup of the dewatering wells, dense non-aqueous phase liquid (DNAPL) was detected in one of the dewatering wells. A Remedial Investigation/ Feasibility Study (RI/FS) was conducted and a DNAPL remedy was selected, which consists of operating the dewatering system to meet the dewatering goals, removing DNAPL to the extent practicable, and monitoring to confirm that the integrity of the slurry wall is not adversely affected by DNAPL

At the end of the FYR period, the Lime Basins dewatering system had not attained the dewatering goals, and the dewatering goals were not attained by September 9, 2014, which was the target date established in the 2010 LTMP. However, significant progress has been made toward meeting the dewatering goals. An inward gradient has been established in the south-side well pairs, and the water levels are expected to decrease to below the waste elevation during the next FYR period. More continuous operation of the dewatering and treatment systems has been implemented and may help reduce the time frame for meeting all of the dewatering goals. In the meantime, the protectiveness of the remedy is not adversely affected because the Lime Basins contamination is contained within the slurry wall and significant mass removal and treatment are occurring. Progress toward meeting the dewatering goals will be evaluated further during the next FYR period and revised compliance dates will be developed.

The monitoring data indicate that the Lime Basins slurry wall has not been impacted by the presence of DNAPL, and based on criteria in the Decision Documents; the Lime Basins DNAPL Remediation Project is functioning as intended.

On-post water level and water quality tracking are conducted in areas upgradient from the containment systems to track changes in groundwater flow and contaminant migration within the unconfined flow system (UFS). Water level tracking wells are used to monitor water levels and track groundwater flowpaths between individual on-post remedies and the RMA boundary. The water quality monitoring focuses on tracking changes in indicator analyte concentrations at plume source areas, between the sources and the groundwater systems, along the edges of plumes, and across transects of major plumes. The monitoring results from the on-post water level tracking over the FYR period show that the flowpaths are consistent with the previous review period. Groundwater levels were generally higher in FY14 on-post in non-cover areas and off-post after the historic September 2013 flood event and heavy rains in May 2014, but the flow directions were unchanged. The groundwater levels in the cover areas were affected less by the storm events than in areas outside the covers. Water quality tracking results show that groundwater conditions remain consistent with the initial assumptions used at the time of remedy selection. Refer to the sections concerning 2014 on-post plume mapping for comparison of the groundwater contaminant plumes in 1994 and 2014, and observations about the longer term progress of the remedy.

Confined flow system (CFS) monitoring is required by the On-Post ROD to identify vertical or lateral migration of contaminants to or within the CFS in the Basin A**,** Basin F, and South Plants areas. The results show that there has been no significant organic contamination or increases in concentrations of organic contaminants during the FYR period. A few organic contaminants were detected at low concentrations in three CFS wells during the FYR period, but the affected wells either have questionable aquitards and the wells may be semi-confined, and/or the detections were within historical ranges.

The results indicate that migration to the CFS did not occur during the current FYR period; one potential exception is reflected in elevated chloride concentrations in one well. The adjacent UFS well was sampled in FY14 and the chloride concentration was more than an order-of-magnitude lower than the CFS well. Thus, the elevated chloride concentrations in the CFS well are not caused by vertical migration in the vicinity of the well, but may be caused by a combination of lateral and vertical migration from a different area. Adding two alternate CFS wells to the network has been proposed to monitor upgradient of this well.

The vertical hydraulic gradient reversed from downward to upward in one UFS/CFS well pair in South Plants in the latter part of the previous FYR period and remained upward during this FYR period prior to the September 2013 flood event. In South Plants UFS/CFS well pairs with downward gradients, the head differentials decreased significantly in the South Plants cover area because of reduced infiltration of precipitation and lower groundwater elevations in the UFS.

The vertical gradient head differentials in the Basin A UFS/CFS well pairs were more stable and the vertical gradients in the Basin F area well pairs were variable because some of the wells are located outside of cover areas where water levels in the UFS rose following the unusual rains in September 2013 and May 2014.

On-post surface water quality monitoring was conducted at RMA during this FYR period in order to determine whether surface water quality was impacted by cover soils during the establishment of cover vegetation, and that groundwater plumes are not migrating into the lakes. Four metals (copper, manganese, nickel, and zinc) were detected above Colorado aquatic life standards in one of two samples collected at the former Basin E Pond. The surface water concentrations for these metals are consistent with background soil concentrations measured in the shallow soil in Basin E during the RMA Remedial Investigation. Copper was detected above the chronic aquatic life standard at the former North Plants site. Additional sampling will be conducted during FY15 and FY16 to further assess these sites.

Post-Shut-Off monitoring was conducted for the Motor Pool System/Irondale Containment System (MPS/ICS) and the Groundwater Mass Removal (GWMR) Project. The MPS/ICS contaminant concentrations were below the CSRGs. Benzene was not detected during two of the three years of post-shut-off monitoring in the STF and the results confirm that the benzene plume continues to be stable or is receding and is not migrating toward the lakes.

On-post plume-extent mapping was conducted in 2014 to evaluate the long-term progress of the remedy. Nine indicator analytes were selected for mapping, which included diisopropylmethyl phosphonate (DIMP), dieldrin, chloroform, benzene, n-nitrosodimethylamine (NDMA), carbon tetrachloride, dithiane, arsenic, and dibromochloropropane (DBCP). The previous on-post plume mapping at RMA was conducted in 1994, and was intended to show the pre-ROD groundwater contaminant distributions. The 2014 plume maps are compared to the 1994 maps both qualitatively and quantitatively to show whether there have been changes in the plumes since the On-post ROD was issued in 1996.

The average concentrations for the wells sampled in 1994 and 2014 decreased for all the analytes, both for all wells sampled both times, and for the subset of wells with detections in 1994. The average decrease in the 2014 average concentrations in the wells with detections in 1994 ranged from 17 percent for benzene to 90 percent for arsenic, with an average decrease of 53 percent for the nine analytes.

The areal extents of the plumes for the concentration intervals above the CSRGs/PQLs were determined for 1994 and 2014 by computer calculation of the mapped plume areas. All of the plume areas above CSRGs/PQLs decreased when similar concentration intervals were compared. The decrease in the plume areas above CSRGs/PQLs ranged from 5 percent for carbon tetrachloride to 63 percent for DBCP and dithiane (Table 5.1.5.1-11). The average decrease in the on-post plume areas above CSRGs/PQLs for the nine analytes was 42 percent. The largest areas where the plume concentrations decreased to below the CSRGs/PQLs include former Basin F, between former Basin F and the NBCS, downgradient of BANS, and downgradient of BRES.

With decreasing contaminant concentrations upgradient of the boundary and on-post groundwater systems, the treatment plant influent concentrations for most of the analytes also decreased between 1994 and 2014. For example, at BANS the average DIMP concentration decreased from 980 µg/L in 1994 to 25.6 µg/L in 2014, and at NBCS the average DIMP concentration decreased from 95 µg/L to 3.1 µg/L, both of which are 97 percent reductions. DIMP was not detected in the NWBCS influent in either 1994 or 2014. Reducing the extent and concentrations of contaminant plumes upgradient of the boundary systems meets the Remedial Action Objective for on-post groundwater.

Characterization of the horizontal and vertical extent of 1,4-dioxane was conducted on-post and off-post during this FYR period. The investigative sample concentrations were above the method reporting limit (MRL) of 0.1 µg/L in the majority of groundwater samples for UFS wells, both on-post and off-post. The 1,4-dioxane concentrations in 60 on-post wells were above the CBSG of 0.35 µg/L, and the concentrations in nine off-post wells were above the CBSG, including two private wells. The two RMA water supply wells in Section 4 were above the

CBSG, but these wells are located in a plume with sources located upgradient of RMA. Twenty-two CFS were sampled on-post and 1,4-dioxane was not detected in any of the CFS wells. Therefore, based on these data, the 1,4-dioxane contamination is limited to the uppermost water-bearing zone.

The apparent sources of 1,4-dioxane include South Plants, North Plants, CADT, and Basin F, and are consistent with the known sources of 111TCE and TCE, which may be associated with 1,4-dioxane. The treatment plant effluent concentrations were below the CBSG of 0.35 µg/L, except at BANS, which is an internal mass removal system. The 1,4-dioxane concentrations were below the MRL of 0.1 µg/L at the surface water sites, except Lake Ladora site SW020009. Additional 1,4-dioxane sampling will be conducted in Lake Ladora. Evaluation of the 1,4-dioxane standard, effect on remedy protectiveness, and recommendation on whether to adopt the standard is ongoing and is identified as an issue in the FYRR.

Off-Post OU Monitoring Programs

The monitoring programs in the Off-Post OU are:

- Monitoring associated with Off-Post Groundwater Intercept and Treatment System (OGITS)
- CSRG exceedance monitoring
- Off-post private well monitoring
- Surface water monitoring

The **OGITS** is a mass removal system designed to treat off-post contaminated alluvial groundwater. The performance of the OGITS extraction and treatment systems was evaluated against its compliance requirements and performance criteria. The system consists of two separate extraction systems, the First Creek System (FCS) and the Northern Pathway System (NPS). Chloride and sulfate concentrations exceeded CSRGs in the OGITS effluent for most of the FYR period, but these analytes are not treated by OGITS and will meet CSRGs in the effluent by attenuation, consistent with the on-post remedy. The chloride and sulfate concentrations decreased during the FYR period and were below the CSRGs in FY14. The other CSRG analyte concentrations were below CSRGs/PQLs in the treatment plant effluent.

The mass removal performance of the FCS was below the 75 percent goal in FY10 and FY12, and the combined FCS and NPS was below the goal in FY12. An operational change made in FY12 improved the FCS performance, and it met the mass removal goal in FY13 and FY14. The contaminant concentrations in the downgradient performance wells were decreasing or stable during the FYR period. Therefore, the OGITS functioned as intended in the Decision Documents during most of the FYR period.

In the NPS, the concentrations of contaminants for most of the CSRG analytes have decreased to below the CSRGs/PQLs in the upgradient wells. The 2010 LTMP mass removal criteria were based on the total mass flux, and did not distinguish between the mass removal performance for contaminants above and below CSRGs. When the concentrations are below the CSRGs/PQLs, using the total mass flux in the calculations can cause the performance to be underestimated and not accurately reflect the system's effectiveness. Consequently, revising the LTMP methodology to include only contaminants with concentrations above CSRGs/PQLs in the upgradient wells is proposed.

The 2010 LTMP stated that the 75 percent mass removal goal would be reviewed for potential adjustment after five years of data collection. Based on the performance during this FYR period, increasing the performance goal to greater than 75 percent was considered. However, as contaminant concentrations decline in the future, the contaminant concentrations in the upgradient wells may approach the CRSGs/PQLs. Meeting the 75 percent mass removal goal could then become more difficult, and may also be unnecessary to meet ROD compliance requirements. Consequently, as concentrations decline in the future, lowering the mass removal goal may be appropriate to be consistent with ROD compliance. Additionally, as contaminant concentrations decline, the treatment efficiencies may also decline, which may make attainment of 75 percent mass removal more difficult. Army and Shell will continue to optimize the system operation for mass removal, and proposes to retain the 75 percent mass removal goal.

The **CSRG exceedance monitoring** is conducted to assess contaminant concentration reduction and remedy performance and to support the institutional control component of the off-post remedy. The exceedance monitoring results for this FYR period show contaminant reductions and shrinking plumes in the Off-Post OU for most of the contaminants. The number of contaminants present at concentrations above the CSRGs/PQLs decreased from 15 in FY12 to 10 in FY14. For clarity, in FY14, one contaminant was added and six were deleted compared to FY12. The total exceedance area for DIMP decreased by 54 percent over the FYR period, particularly downgradient of the FCS and upgradient of the NPS. The lower PQL for dieldrin, effective in 2012, causes the exceedance areas to be larger than during the previous FYR period, but the concentrations are similar or lower in the plume areas. Due to the larger extent of the dieldrin exceedance areas, adding dieldrin to the analyte list for four wells in the LTMP Exceedance network, and adding three new wells to the Exceedance network downgradient of the NWBCS is proposed.

The **Off-Post Private Well monitoring** conducted by Tri-County Health Department for the U.S. Army continued during this FYR period. Off-post private wells are sampled to provide data to assess contaminant concentration reduction and remedy performance, to determine the water quality of new off-post wells as required by the Off-Post ROD, and to respond to citizen requests. The Army may also use these data to assist in refining the CSRG exceedance map, and to determine whether CFS wells are acting as conduits for contaminant transport from the UFS to the CFS. Approximately 30 wells are sampled for DIMP each year. The monitoring results for UFS private wells during the FYR period showed that DIMP concentrations have decreased steadily, and only one well contained DIMP concentrations above the CSRG in 2010. All of the UFS private wells sampled in FY11 through FY14 were below the CSRG. The results were below the CSRG for DIMP in the private CFS wells, except for one questionable result in 2011, based on historical data that was not confirmed when it was re-sampled.

Surface water quality monitoring was conducted in accordance with the Off-Post ROD to evaluate the effect of groundwater treatment on surface water quality. Surface water leaving RMA met applicable water quality standards for the target constituents, except arsenic. The arsenic concentrations were intermittently above the CSRG, however, the concentrations are within the concentration range of upstream surface water sites that are considered background concentrations. Attenuation of inorganic contaminants and treatment of organic groundwater contaminants at the NBCS and the OGITS appear to be having a positive effect on First Creek water quality.

Groundwater and Surface Water Events

The 2010 LTMP consultation trigger event approach was used as a guide to identify events that would prompt Regulatory Agency notification and consequently were labeled as events for this FYR period. Over the review period, noteworthy events related to the groundwater and surface water remedy included:

- An RI/FS for the Lime Basins DNAPL was conducted and the Lime Basins DNAPL remedy was chosen and implemented. The effect of the DNAPL on continued system operation was evaluated during this FYR period, and no impacts on system effectiveness or integrity of the Lime Basin slurry wall were apparent.
- At the OGITS First Creek System, the mass removal goal was not achieved in FY12. An operational change made in late FY12 improved the mass removal to exceed the goal in the subsequent years.
- After the dieldrin PQL was lowered in 2012, the NWBCS effluent concentration was above the PQL during one quarter of FY12. Changes in the treatment operation successfully lowered the effluent concentrations to be equal to or below the PQL. Additional treatment changes may be needed to lower the effluent concentrations further. Evaluation of the validity of the dieldrin analytical data and the new PQL should also be considered. The dieldrin recoveries vary greatly and do not meet the desired rates. This calls the data validity into question. More data are needed to statistically evaluate the validity of the data, however.
- After the dieldrin PQL was lowered in 2012, dieldrin was detected above the PQL in some of the NWBCS downgradient performance wells in 2012 through 2014 and in one OGITS downgradient performance well in 2014.
- At the BANS, historically high water levels after the 2013/2014 storms caused the reverse hydraulic gradient to be reduced during part of 2014, and the concentrations of a few analytes increased to above CSRGs/PQLs in two of the four downgradient performance wells in 2014.
- The Shell Disposal Trenches did not meet the water-level goal in one of six compliance borehole locations by the 2012 date established in the 2010 LTMP. Water levels continued to fall inside the slurry wall and the goal was met in 2013, but the water levels rose after the 2013/2014 storms, and the goal was not maintained at the single borehole location during part of FY14. Water levels are expected to resume falling inside the

slurry wall and the water-level goal will be re-attained. There is no adverse impact on the protectiveness of the remedy because the groundwater contamination is contained by the slurry wall.

- The CADT did not meet the dewatering goal in one of two compliance wells by the 2014 date established in the 2010 LTMP. Progress toward meeting the goals is being made and the protectiveness of the remedy is not adversely affected. The slurry wall provides containment and the dewatering and treatment systems provide significant contaminant mass removal.
- The Lime Basins Slurry Wall Dewatering Project did not meet the dewatering goals by the 2014 date established in the 2010 LTMP. Significant progress is being made toward meeting the dewatering goals, and the protectiveness of the remedy is not adversely affected. The slurry wall provides containment and the dewatering and treatment systems provide significant contaminant mass removal.
- The Colorado aquatic life standards for copper, manganese, nickel, and zinc in surface water were exceeded in one of two samples collected at former Basin E Pond. The chronic aquatic life standard for copper was exceeded at the North Plants site. Additional monitoring will be conducted to further assess these sites.

The exceedance of the effluent standard at the NWBCS treatment system was a one-time event that was addressed through operational measures. Additional treatment changes may be needed to lower the NWBCS effluent concentrations further, and may help lower the concentrations in the downgradient performance wells. Attainment or re-attainment of the dewatering goals at Shell Disposal Trenches, CADT, and Lime Basins are longer-term events that were affected by the higher groundwater levels after the 2013/2014 storms. Progress is being made toward meeting the goals at all three sites, and there is no adverse impact to the protectiveness of the remedy. Operational changes at the FCS and BANS resolved the mass removal and reverse gradient events, respectively. Additional surface water sampling will be conducted to further assess the metals detections at the two sites.

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1.0 Introduction

This Five-Year Summary Report (FYSR) for Groundwater and Surface Water was prepared as part of the Rocky Mountain Arsenal (RMA) Five-Year Review (FYR) of remedial actions at RMA. Section 121(c) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986, together with the implementing regulation in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), requires that remedial actions resulting in any hazardous substances, pollutants, or contamination remaining at the site above concentrations that allow for unlimited use and unrestricted exposure be reviewed every five years to ensure protection of human health and the environment. The information compiled in this FYSR will be used to make protectiveness determinations in the RMA 2015 Five-Year Review Report (FYRR).

The objectives of the 2015 FYSR are to assess the following events:

- Environmental monitoring and analytical data results from October 1, 2009, through September 30, 2014, corresponding to the five fiscal years included in the review period.
- Changes in laws, applicable or relevant and appropriate requirements (ARARs), and criteria to be considered (TBC) between April 1, 2010, and March 31, 2015.
- Construction Completion Reports (CCRs) approved by the U.S. Protection Agency (EPA) between April 1, 2010, and March 31, 2015.

Note that previous versions of this report used the terms water year (WY) and fiscal year (FY) interchangeably. This report uses the term fiscal year to be consistent with the monitoring descriptions in the LTMP and Annual Summary Reports (ASRs). This change is administrative only as the water year and fiscal year refer to the same monitoring time period (October 1 through September 30). Data and information relevant to preparation of the FYSR, or necessary for response to Regulatory Agency comments that became available after the deadlines noted above, were evaluated for inclusion. Subsequent data and reports were included whenever the information was important to the assessment.

Multiple regulatory authorities govern the cleanup activities and the long-term operations and maintenance (O&M) of the remedy. Operations and maintenance is required pursuant to CERCLA, as implemented through the NCP (40 Code of Federal Regulations [CFR] §300.435) and the Colorado Hazardous Waste Act (Colorado Revised Statutes 25-15-301 to 316) as implemented through the Colorado Hazardous Waste Regulations (6 Code of Colorado Regulations1007-3).

1.1 Background

The RMA site consists of two operable units (OUs). The On-Post OU consists of a portion of the Rocky Mountain Arsenal National Wildlife Refuge (RMANWR) that occupies approximately 1.7 square miles in southern Adams County, approximately 10 miles northeast of downtown Denver. The Off-Post OU encompasses groundwater Containment System Remediation Goal (CSRG) exceedance areas that underlie rural, agricultural, commercial, residential, and industrial-zoned areas north and northwest of RMA as well as property where the Off-Post Groundwater Intercept and Treatment System (OGITS) is located. The Off-Post and On-Post OUs are depicted on Figure 1.1-1.

The U.S. Army established RMA in 1942 to produce chemical warfare agents and incendiary munitions used in World War II. Following the war and through the early 1980s, the Army continued to use these facilities. Beginning in 1946, some RMA facilities were leased to private companies to manufacture industrial and agricultural chemicals. Shell Oil Company (Shell), the principal lessee, manufactured primarily pesticides at RMA from 1952 to 1982. Common industrial and waste disposal practices during those years resulted in significant concentrations of contamination. The principal contaminants are organochlorine pesticides (OCPs), heavy metals, agent-degradation products and manufacturing by-products, and chlorinated and aromatic solvents.

The Remedial Investigation (RI) and subsequent investigations identified chemicals at more than 180 sites contaminating soil, ditches, stream and lakebed sediments, sewers, groundwater, surface water, biota, and structures. Unexploded ordnance has been identified at several locations on site. Contaminated areas identified in the RI included approximately 3,000 acres of soil, 15 groundwater plumes, and 798 structures. Sites that posed potential immediate risks to human health and the environment were addressed through Interim Response Actions (IRAs), which were followed by the actions required by the On-Post Record of Decision (ROD) (FWENC 1996).

The overall remedy required by the On-Post ROD includes these specific actions:

- Interception and treatment of contaminated groundwater at three existing on-site treatment systems.
- Construction of new Resource Conservation Recovery Act (RCRA) and Toxic Substances Control Act-compliant landfills on post. The on-post facilities include the On-Post Hazardous Waste Landfill (HWL) and a triple-lined landfill, referred to as the Enhanced Hazardous Waste Landfill (ELF).
- Demolition of structures with no designated future use and disposal of the debris in either the new HWL or the Basin A consolidation area, depending upon the degree of contamination.
- The contaminated soil at RMA is addressed primarily through containment in the HWL (or ELF) or under caps/covers, or through treatment depending upon the type and degree of contamination. Areas that have been capped or covered require long-term maintenance and will be retained by the Army. These areas will not become part of the wildlife refuge.
- The Basin A disposal area is used for consolidation of biota risk soil and structural debris from other RMA contamination areas and is covered with a soil cover including a biota barrier.

Other components of the remedy include containment of soil and/or groundwater contamination within slurry walls and/or under caps/covers at the Shell Disposal Trenches, Complex (Army) Disposal Trenches (CADT), Lime Basins, South Plants, and former Basins A and F.

Groundwater contamination migrated off post prior to the implementation of groundwater pump-and-treat systems, resulting in the necessity for the Off-Post OU, which addresses groundwater contamination north and northwest of RMA. The risk assessment performed for the Off-Post OU indicated that only human exposure via contaminated groundwater needed to be addressed. As a result, an Off-Post ROD was prepared and approved on December 19, 1995 (HLA 1995).

The area is ecologically unique and was designated to become the RMANWR in the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 (Public Law 102-402 1992). As components of the remedy are completed, jurisdiction will be administratively transferred to the U.S. Fish and Wildlife Service (USFWS) or other parties purchasing the land, except for the property and facilities continuing to be used for response actions.

The RMANWR was officially established on April 21, 2004. As of March 31, 2015, nearly 93 percent of the surface media at RMA had been deleted from the National Priorities List and more than 15,000 acres transferred to USFWS (Figure 1.1-1). Groundwater has also been deleted in the eastern and southern perimeter areas of the RMA (Figure 1.1-1). However, groundwater underlying the central and northwestern portions of the site has not met remediation goals and remains on the National Priorities List (NPL).

1.2 Report Organization

The general structure of this report was based on current EPA FYR Guidance (EPA 2001). To enable the reader to better understand this report, the following outline is provided:

- **Section 1.0, Introduction**—Provides the background and objectives for the review and description of the groundwater containment, mass removal, and treatment systems, and other remedies as well as a description of the structure of the report.
- **Section 2.0, On-Post Monitoring Programs**—Provides a description of Long-Term Monitoring Plan (LTMP) and operational monitoring for each containment and mass removal system, other remedy-related monitoring, and site-wide LTMP monitoring.
- **Section 3.0, Off-Post Monitoring Programs**—Provides a description of mass removal system monitoring, off-post exceedance monitoring, and surface water monitoring.
- **Section 4.0, Progress Since Last Review**—Lists the status of recommendations and follow-up actions from the 2010 FYRR and whether the follow-up actions achieved the intended purpose.
- **Section 5.0, Five-Year Review Process**—Provides a list of participants in the FYR process as well as the approach taken in performing this review. This section also presents data collected in the groundwater, surface water, biota, and air monitoring programs and summarizes remedy costs.
- **Section 6.0, Events and Follow-Up Actions**—Identifies monitoring and system events that would require Regulatory Agency notification under the 2010 LTMP.

- **Section 7.0, Conclusions**—Provides overall conclusions of the system and monitoring program evaluations.
- **Section 8.0, References—**Lists the references cited in the document.

1.3 Purpose and Objectives

1.3.1 Five-Year Summary Report Purpose

The purpose of the FYSR is to:

- Report and evaluate extraction and treatment system performance and compliance.
- Report and evaluate the monitoring results from all RMA monitoring programs conducted during the FYR period.
- The conclusions reached in the FYSR are further evaluated against the FYR criteria in the FYRR.

1.3.2 Remedial Action Objectives

1.3.2.1 Remedial Action Objectives for Groundwater

The groundwater monitoring data collected under the 2010 LTMP (TtEC and URS 2010) were evaluated to determine the effectiveness of the remedial actions in achieving the ROD Remedial Action Objectives (RAOs). The RAOs for on-post and off-post groundwater are cited below from the respective RODs.

On-Post Groundwater

The following RAOs for on-post groundwater, designed to comply with the On-Post ROD (FWENC 1996) requirement for protection of human health and the environment, provide the objectives for capture and treatment of contaminated groundwater:

- Ensure that the boundary containment and treatment systems protect groundwater quality off post by treating groundwater flowing off RMA to the specific remediation goals identified for each of the boundary systems.
- Develop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems.

Off-Post Groundwater

The following RAOs for off-post groundwater were designed to satisfy the Off-Post ROD (HLA 1995) requirement for protection of human health and the environment and provide the objectives for capture and treatment of contaminated groundwater:

Human Health

- Reduce the Contaminant of Concern (COC) concentrations in groundwater and/or prevent exposure associated with groundwater within the Off-Post OU to meet groundwater remediation goals and to attain the NCP-prescribed cumulative risk range.

- Prevent domestic use of, ingestion of crops irrigated with, and ingestion of livestock watered with groundwater containing COCs at concentration levels in excess of groundwater remediation goals.

Environmental Protection

- Prevent acute or chronic toxicity to biota from groundwater within the Off-Post OU by containing COC concentrations in excess of groundwater remediation goals.

1.3.2.2 Remedial Action Objectives for Surface Water

The On-Post and Off-Post RODs both include surface water monitoring requirements. The On-Post ROD (FWENC 1996) identified the following surface water monitoring requirements:

- The Army will continue to conduct air, groundwater, and surface water monitoring programs at RMA, and will continue to fund USFWS to conduct on-post wildlife monitoring programs. Samples will be collected periodically to assess the effectiveness of the remedy for protection of human health and the environment.
- Surface water will be monitored and managed in a manner consistent with the selected remedy.

The On-Post ROD also identified the following RAOs for ecological and human health protection:

- Ensure that biota are not exposed to biota COCs in surface water at concentrations capable of causing acute or chronic toxicity.
- Ensure that biota are not exposed to COCs that have migrated from soil or sediment to surface water at concentrations capable of causing acute or chronic toxicity via direct exposure or bioaccumulation.
- Prevent migration of COCs from soil or sediment that may result in off-post groundwater, surface water, or windblown particulate contamination in excess of off-post remediation goals.

The Off-Post ROD (HLA 1995) identified the following surface water monitoring requirements:

- Groundwater and surface water monitoring: Samples will be collected periodically from groundwater monitoring wells and surface water locations throughout the Off-Post Study Area and analyzed to assess changes in groundwater and surface water quality during and after remediation.

The Off-Post ROD description of the selected alternative includes further clarification of the purpose and objectives of the off-post surface water monitoring program:

- In addition, the preferred alternative includes long-term monitoring of off-post groundwater and surface water to assess contaminant concentration reduction and remedy performance. Groundwater monitoring will continue utilizing both monitoring wells and private drinking water wells. Selected surface water monitoring locations will be included to evaluate the effect of groundwater treatment on surface water quality. Monitoring will continue after system shut-off to assure continued compliance with containment system remediation goals.

1.4 Remedial Actions

The On-Post ROD specified that the remedy address four essential parts: groundwater, structures, soil, and "other." Specific components of the selected remedy for on-post groundwater are provided below.

The on-post remedial actions for groundwater include operation of containment and mass removal systems as well as dewatering systems in containment areas. The Detailed Analysis of Alternatives component of the RMA On-Post Feasibility Study (FS) (FWENC 1995) identified 15 groundwater contaminant plumes that were consolidated into the following five groups:

- North Boundary Plume Group
- Northwest Boundary Plume Group
- Western Plume Group
- Basin A Plume Group
- South Plants Plume Group

Groundwater contaminant plumes in each of these groups were treated at three boundary containment and treatment systems: the North Boundary Containment System (NBCS), the Northwest Boundary Containment System (NWBCS), and the Irondale Containment System (ICS). The ICS and Motor Pool IRA extraction wells met shut-off criteria and were shut off on October 1, 1997, and April 1, 1998, respectively. Additional extraction and treatment systems were installed as IRAs at the Motor Pool, Rail Classification Yard (Railyard), Basin F, and Basin A Neck areas and off post at the OGITS. The on-post IRA systems were installed to limit the migration of contaminants near source areas to the extent practicable prior to remedy selection. The Railyard Containment System (RYCS), which extracts and treats Railyard contamination previously treated at ICS, has been reduced to two operating extraction wells, based on ROD-specified shut-off criteria, and is approaching system shut-off. A RYCS pre-shut-off monitoring program was successfully completed in 2014, and the shut-off process will proceed during the next five-year review period. The north of Basin F IRA extraction well was shut off in 2000 based on decreased system efficiency and increased maintenance requirements because of reduced influent concentrations and flow.

The Section 36 Bedrock Ridge Extraction System (BRES) was installed in accordance with the On-Post ROD to prevent contaminant migration from the Basin A area toward First Creek. Extracted water is treated at the Basin A Neck System (BANS).

The CADT slurry wall and dewatering system were installed in accordance with the On-Post ROD to lower groundwater levels below the disposal trenches. Extracted water is treated at the BANS.

The STF and Lime Basins groundwater extraction/recharge and monitoring systems of the Groundwater Mass Removal (GWMR) Project were installed and became operational in 2006. These were short-term mass removal projects and groundwater extracted from these respective systems was treated at the CERCLA Wastewater Treatment Facility (CWTF) before it was decommissioned in 2010. The GWMR Project had required treated groundwater regulated under the Underground Injection Control Program to be reinjected under an exemption that allowed recharge of groundwater at concentrations that exceed the Colorado Basic Standards for Groundwater (CBSGs) (Washington Group International 2005a). Because a change was made to the Lime Basins soil remedy in 2005, an encircling slurry wall and dewatering system were installed to contain Lime Basins contamination (TtEC 2005). Extracted water that had been treated at the CWTF was treated at the BANS after the CWTF was decommissioned. The Lime Basins dewatering system is independent of the Lime Basins mass removal system. The GWMR Project was decommissioned in July of 2010.

Remedies for contaminated soil have been implemented to reduce contaminant mobility and thereby enhance the effectiveness of the groundwater containment systems. Several soil containment areas have been constructed for this purpose. These areas, which are shown in Figure 1.4-1, include landfills that have caps with liners and containment areas that have leachate collection systems and covers with percolation monitoring. The On-Post ROD specifies the groundwater monitoring for soil sites where human health exceedances are left in place as follows:

> *Where human health exceedances are left in place at soil sites, groundwater will be monitored, as necessary, to evaluate the effectiveness of the remedy.*

Human health exceedance soils with concentrations above specified criteria for groundwater monitoring are left in place or were disposed of at nine sites as follows:

- South Plants Central Processing Area
- South Plants Balance of Areas, SPSA-2d Ditch
- Shell Disposal Trenches
- Section 36 Lime Basins
- Complex (Army) Disposal Trenches
- Basin A
- Closed Basin F RCRA Interim Status Unit
- HWL
- ELF

The Off-Post ROD was signed by the Army, EPA, and Colorado Department of Public Health and Environment (CDPHE) on December 19, 1995, with concurrence of USFWS and Shell. The Army, serving as the lead agency and Shell are implementing the selected off-post remedy, which includes the following monitoring, analysis, and supply activities:

- Continued operation of the OGITS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet remediation goals for groundwater consistent with the on-post remedial action
- Institutional controls to prevent the use of groundwater in which contaminants exceed remediation goals
- Mapping of contaminants that exceed CSRGs
- Provision of a water supply for well owners with wells within the diisopropylmethyl phosphonate (DIMP) plume footprint

Water quality monitoring, termed exceedance monitoring, is conducted in compliance with the Off-Post ROD to create exceedance area maps for contaminants that exceed CSRGs. The exceedance area maps are provided to the State Engineer's Office (SEO) and to Commerce City, city of Brighton, and Adams County officials for their use in issuing well permits and providing notifications to reduce the potential for exposure to off-post groundwater with contaminant concentrations exceeding CSRGs. The notification and agency review process is described in detail in the 2005 FYRR (Army 2007), which also includes data that show significant reductions in the off-post exceedance area have been achieved since implementation of the ROD.

1.4.1 On-Post Groundwater Extraction, Containment, and Mass Removal Systems

1.4.1.1 Northwest Boundary Containment System

The original NWBCS, located in the southeast quarter of Section 22, was installed to intercept and treat groundwater contaminant plumes migrating from the South Plants and the Basins A, C, and F areas to the RMA boundary.

The NWBCS is a containment system designed to prevent the off-post migration of contaminated groundwater. A summary of the elements in the Off-Post ROD relevant to the FYSR includes the following monitoring, analysis, and supply activities:

- Continued operation of the NWBCS until shut-off criteria are met
- Long-term groundwater monitoring
- Institutional controls to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs
- Provision of a water supply for well owners with wells within the DIMP plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The selected remedy presented in the On-Post ROD for the NWBCS and the other two boundaries is as follows:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems, slurry walls (NBCS and*

NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria are met.

The system performance objective for the NWBCS is defined as follows:

- *Prevent off-post migration of contaminated groundwater through containment and capture of contaminated water migrating toward the northwest boundary.*

The NWBCS is divided into the following three components with different monitoring objectives:

- NWBCS Original System: The Original System, installed in 1984, consists of 15 extraction wells, 21 recharge wells, and a 1,425-foot (ft)-long slurry wall. The slurry wall extends across a portion of the system. The recharge wells are located northwest (downgradient) of the extraction wells and slurry wall. The objective of the combined system is to create a reverse (counter-regional) hydraulic gradient to contain the contaminant plumes. Dieldrin and chloroform are the primary contaminants in the Original System.
- NWBCS Northeast Extension (NEE): The NEE was installed in 1990 and consists of a 660-ft extension of the Original System slurry wall and two extraction wells that were installed to intercept a small northwest-trending alluvial channel. Additional recharge wells were not installed because the groundwater flow turns to the southwest and travels between the Original System recharge wells and slurry wall and is captured at the southwestern end of the slurry wall. Maintaining a reverse hydraulic gradient, therefore, is not required for this portion of the NWBCS. Dieldrin is the primary contaminant at the NEE.
- The NWBCS Southwest Extension: The Southwest Extension was installed in 1991 and consists of four extraction wells and four recharge wells located southwest of, and separate from, the Original System, which were installed to intercept a separate dieldrin plume. No slurry wall is present in this area. The recharge wells were installed in an uncontaminated zone between the Southwest Extension and Original System, cross-gradient of the extraction wells, to prevent the Southwest Extension and Original System plumes from shifting away from their respective extraction systems. Consequently, the Southwest Extension has a hydraulic capture system design. Dieldrin is the only contaminant at the Southwest Extension. Dieldrin concentrations were below the practical quantitation limit (PQL) of 0.05 µg/L in all four extraction wells and the associated upgradient and downgradient monitoring wells between 2004 and 2012, when the PQL was lowered to 0.013 µg/L. The dieldrin concentrations in some of the upgradient wells have been above the new PQL since then.

In fiscal year 2014 (FY14), the NWBCS flow rate averaged 924 gallons per minutes (gpm). The ROD established CSRGs for the NWBCS effluent for eight contaminants potentially present in the groundwater that migrates toward the northwest boundary. These contaminants and their respective CSRGs are listed in Table 1.4.1-1.

Table 1.4.1-1. Northwest Boundary Containment System (NWBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L)	CSRG Source
Volatile Halogenated Organics (VHOs)	Trichloroethylene (TCE)	3		ROD health-based value
	Chloroform	6		ROD CBSG[2]
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organochlorine Pesticides (OCPs)	Dieldrin	0.002	0.05/0.013	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value
Other Organic Compounds	n-Nitrosodimethylamine (NDMA)	0.007	0.033/0.018	EPA Integrated Risk Information System risk-based value
Arsenic	Arsenic	2.35		ROD health-based value

Notes:
[1] Practical Quantitation Limits; ROD PQL/ PQL from 2012 PQL study (effective April 2012)
[2] Colorado Basic Standard for Groundwater

1.4.1.2 North Boundary Containment System

The NBCS is located immediately south of the RMA north boundary in Sections 23 and 24. The system treats water from the North Boundary Plume Group as the plumes approach the north boundary of RMA. The North Boundary Plume Group includes the Basins C and F Plume and the North Plants Plume. The sources of the Basins C and F Plume contamination are the two basins that were used for disposal of a wide range of chemical wastes between the late 1950s and the early 1970s. Extensive source removal was conducted under the Basin F IRA.

The NBCS is a containment system designed to prevent further off-post migration of contaminated groundwater (USACE 1985). A summary of the elements in the Off-Post ROD relevant to the FYSR include the following monitoring, analysis, and supply activities:

- Continued operation of the NBCS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action

- Institutional controls to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs
- Provision of a water supply for well owners with wells within the DIMP plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The selected remedy presented in the On-Post ROD for the NBCS is as follows:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems, slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria are met. Chloride and sulfate are expected to attenuate naturally to CSRGs.*

The performance objective presented in the On-Post ROD for the NBCS is as follows:

- *Prevent off-post migration of contaminated groundwater through containment and capture of contaminated water migrating toward the North Boundary.*

Additionally, chloride and sulfate are expected to attenuate naturally to CSRGs.

The NBCS containment system originally consisted of a barrier wall with extraction wells upgradient and injection wells downgradient of the barrier wall. This system was installed as a pilot project in 1979 and was expanded to its current configuration in 1981. In 1988 and 1990, 15 recharge trenches were installed to maintain a reverse hydraulic gradient across the barrier. The recharge trenches replaced the injection (recharge) wells. The current NBCS consists of (1) a system of extraction wells that remove contaminated groundwater from the unconfined flow system (UFS), (2) a soil/bentonite barrier that impedes migration of contaminated groundwater to the Off-Post OU, (3) a carbon-adsorption treatment system that removes organic contaminants from extracted groundwater, (4) an ultraviolet (UV)-oxidation system for treatment of n-nitrosodimethylamine (NDMA), and (5) a system of recharge trenches that returns treated groundwater to the UFS north of the barrier wall. A reverse hydraulic gradient across the barrier is maintained to prevent contaminated groundwater from moving off post.

In 2003, two groundwater extraction wells were added upgradient of the NBCS to intercept the plumes nearer to the source, provide added operational flexibility, prevent the plumes from shifting toward less contaminated areas, and accelerate groundwater cleanup. The additional groundwater from the wells also helps maintain the reverse hydraulic gradient at the NBCS. In FY14, the NBCS flow rate averaged 216 gpm.

The North of Basin F IRA extraction well was constructed upgradient of the NBCS to reduce the contaminant load on the system and accelerate cleanup of contaminated groundwater associated with Basin F. The water extracted from this well was treated at BANS. The system began operations on October 1, 1990, and was shut off on September 22, 2000. The decision to permanently discontinue operation was based on decreased system efficiency and increased maintenance requirements because of reduced influent concentrations and flow. The CCR for the North of Basin F well was approved by EPA in 2005 (Washington Group International 2005b).

In-situ anaerobic biodegradation treatment of groundwater was initiated in the Basin F Plume in May 2005 for the purpose of reducing contaminant load on the NBCS through implementation of the North Boundary Enhancement (NBE) system. O&M of this Hydrogen Release Compound® (HRC) injection system was discontinued in 2007, because the system was unsuccessful in achieving its contaminant reduction goals (URS Washington Division 2009a). The groundwater monitoring results indicated that the HRC substrate did not have any discernable effect on reducing contaminant concentrations that would reduce contaminant loading at the NBCS or increase the mass removal for the north of Basin F Plume. Based on the analytical results, it was concluded that a third year of groundwater monitoring and the optional two years of additional monitoring would not produce significantly different results. The effect of the HRC substrate in reducing the groundwater contaminant concentrations may have been limited since, based on the limited depth of the injection points, the entire saturated portion of the Denver Formation sandstone did not receive the substrate. The NBCS will continue to capture and treat the groundwater plume targeted by the NBE project.

CSRGs for the NBCS effluent were established for 29 contaminants potentially present in the groundwater migrating toward the north boundary. Of these compounds, which are listed with their respective CSRGs in Table 1.4.1-2, chloride and sulfate concentrations were to be reduced to CSRGs through attenuation over time periods of 30 and 25 years, respectively. The RMA On-Post OU identified attenuation as a remedy for chloride and sulfate at NBCS, and a study of regional concentrations and flow rates upgradient of the NBCS was conducted to evaluate remediation goals as well as remediation timeframes for these compounds (MK Environmental Services and FWENC 1996). Based on this study, the CSRG for chloride was set at the CBSG of 250 milligrams per liter (mg/L), and the timeframe for achieving the CSRG in the NBCS effluent was predicted to be 30 years. For sulfate, the CSRG was set at 540 mg/L based on regionally high concentrations of sulfate in groundwater, and the timeframe for achieving the CSRG was predicted to be 25 years.

Table 1.4.1-2. North Boundary Containment System (NBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[3]
	1,2-Dichloroethylene	70		ROD CBSG
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Methylene chloride	5.0		ROD CBSG
	Tetrachloroethylene (PCE)	5		ROD CBSG/MCL[4]
	Trichloroethylene (TCE)	3		ROD health-based value
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	3		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		ROD CBSG/MCL
Organosulfur Compounds; Mustard Agent Related (OSCMs)	1,4-Oxathiane	160		ROD health-based value
	Dithiane	18		ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
	Malathion	100		ROD health-based value

Table 1.4.1-2. North Boundary Containment System (NBCS) CSRG Analytes (Concluded)

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Organochlorine Pesticides (OCPs)	Aldrin	0.002	0.05/ 0.014	ROD CBSG
	Dieldrin	0.002	0.05/ 0.013	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value
Other Organic Compounds	Dibromochloropropane (DBCP)	0.2		ROD CBSG/MCL
	n-Nitrosodimethylamine (NDMA)	0.007	0.033/ 0.018	ROD- EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		ROD CBSG
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value

Notes: [1] µg/L unless otherwise noted. [2]Practical Quantitation Limits; ROD PQL/PQL from 2012 PQL study (effective April 2012).
[3] Colorado Basic Standard for Groundwater. [4] Maximum Contaminant Level

1.4.1.3 Railyard Containment System

The Western, Motor Pool, and Railyard plumes are collectively defined as the Western Plume Group. The Irondale, Motor Pool, and Railyard systems were identified in the On-Post ROD (FWENC 1996) as integral to controlling the migration of these contaminant plumes.

The selected remedy presented in the On-Post ROD for the ICS is as follows:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems; slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria…are met.*

The ICS, which became operational in 1981, was located at the southern end of the RMA northwest boundary in Sections 33 and 28 and consisted of a hydraulic control system of extraction and recharge wells and a granular activated carbon (GAC) treatment system. The ICS was originally designed to treat the Railyard dibromochloropropane (DBCP) plume. In October 1997, the Irondale extraction system was shut off after having met shut-off criteria, and five years of shut-off monitoring were successfully completed in August 2002 (PMRMA 2005a).

The Motor Pool extraction system, located in Section 4, was shut off in April 1998 and shut-off monitoring was conducted through December 2003 (PMRMA 2005b). During the shut-off monitoring period, trichloroethylene (TCE) concentrations in shut-off monitoring well 04535 were detected above the CSRG for two sampling events in 2002. These elevated detections corresponded to a rise in the water table in the Motor Pool area. For this reason, the shut-down monitoring period for the Motor Pool was extended from April 2003 to December 2003. Well 04535 was sampled annually from 2005 through 2009, with no detections above the CSRG. Well 04535 was included in the water quality tracking network in the 2010 LTMP, pending completion of the Motor Pool CCR for completion of shut-off monitoring, and development of a Motor Pool post-shut-off monitoring plan. The EPA approved the CCR for the Motor Pool shut-down on October 25, 2011.

The RYCS is designed as a capture system. When the Irondale and Motor Pool extraction systems were shut off, treatment of the remaining Railyard Plume was moved from the ICS to the new RYCS in July 2001. Recharge of the treated water was also transferred from the ICS to the Railyard. Two Railyard extraction wells (03306 and 03307) located downgradient of the primary Railyard extraction well field were converted to recharge wells 03401 and 03402. The objective of the original Railyard system, which applies to the current system, was to contain and intercept the plume, as specified in the Decision Document, which states that "(a) groundwater interception/containment strategy fulfills all the assessment criteria for IRAs and has been selected as the preferred strategy for the Rail Classification Yard IRA" (MK Environmental Services 1990). In FY14, the average flow rate for the RYCS was 113 gpm.

The CSRGs established in the On-Post ROD for the ICS for TCE and DBCP apply to RYCS and are listed in Table 1.4.1-3.

Table 1.4.1-3. Railyard Containment System (RYCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	CSRG Source
Volatile Halogenated Organic Compounds (VHOs)	Trichloroethylene (TCE)	5	ROD CBSG[1]/MCL[2]
Other Organic Compounds	Dibromochloropropane (DBCP)	0.2	ROD CBSG/MCL

Notes:
1 Colorado Basic Standard for Groundwater
2 Maximum Contaminant Level

1.4.1.4 Basin A Neck System

The BANS is a mass removal system that treats water migrating through the Basin A area as well as water extracted by the CADT dewatering system, Lime Basins Slurry Wall dewatering system and the BRES. The selected remedy as presented in the On-Post ROD for the BANS is as follows:

> *Operation of existing on-post groundwater IRA systems continues.…The Basin F extraction system continues to extract water that is treated at the Basin A Neck*

system and the Basin A Neck system continues to extract and treat water from Basin A until shut-off criteria are met.

The On-Post ROD established the following RAO as follows:

> *…(d)evelop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems.*

Four objectives for the BANS were identified in the IRA Decision Document (Army 1989) as follows:

- Minimize the spread of contaminated groundwater migrating through the Basin A Neck as soon as practicable
- Improve the efficiency and efficacy of the boundary treatment system
- Collect operational data on the interception, treatment, and recharge of contaminated groundwater from this area that may be useful in the selection and design of a Final Response Action
- Accelerate groundwater remediation within RMA

The mass removal objective of the BANS was clarified in a Memorandum for Record dated September 28, 2004. The purpose of the memorandum was "to re-state and clarify the requirements for the BANS in the Record of Decision for the On-Post Operable Unit" (RVO 2004). The BANS consists of seven alluvial extraction wells, a slurry wall, an air stripper, a GAC adsorption system for treatment, and five gravel-filled recharge trenches. Two of these trenches were installed in 2004. The three original trenches are located across the more permeable, deeper portions of the Basin A Neck area paleochannel downgradient from the extraction wells. A soil/bentonite slurry wall extends across the Basin A Neck area between the extraction wells and the recharge trenches to limit recirculation of water between the two systems and inhibit flow of contaminants not captured by the extraction wells. In FY14, the average total flow rate for the BANS extraction wells was 13 gpm.

Treated water from the CWTF was previously conveyed to the Basin A Neck treatment plant by an underground pipeline, combined with effluent from the plant at a maximum rate of five gpm, and reinjected in the Basin A Neck recharge trenches. Previous to demolition, the CWTF was used for treatment of water extracted under the GWMR Project (STF and Lime Basins mass removal) and the Lime Basins Slurry Wall Dewatering Project, and this water was reinjected in the STF and Lime Basins areas under a reinjection exemption that allows recharge of groundwater at concentrations that exceed the CBSGs (Washington Group International 2005a). Groundwater from the Lime Basins Slurry Wall Dewatering Project was conveyed to and treated at the BANS treatment plant after the CWTF was decommissioned in 2010.

CSRGs for the BANS effluent were established for 25 contaminants potentially present in the groundwater migrating toward the Basin A Neck and these contaminants and their respective CSRGs are listed in Table 1.4.1-4.

Table 1.4.1-4. Basin A Neck System (BANS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L)	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40[2]		ROD CBSG[3]
	1,1,1-Trichloroethane	200		ROD CBSG/MCL[4]
	1,1-Dichloroethylene	7		ROD CBSG/MCL
	1,2-Dichlorobenzene	600[5]		CBSG/MCL
	1,3-Dichlorobenzene	94[5]		CBSG
	1,4-Dichlorobenzene	75[5]		CBSG
	Carbon tetrachloride	0.30[2]		ROD CBSG
	Chlorobenzene	100		ROD CBSG/MCL
	Chloroform	6		ROD CBSG
	Tetrachloroethylene (PCE)	5		ROD CBSG/MCL
	Trichloroethylene (TCE)	5		ROD CBSG/MCL
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		Off-Post ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	5		ROD CBSG/MCL
Organosulfur Compounds; Mustard Agent Related (OSCMs)	1,4-Oxathiane	160		Off-Post ROD health-based value
	Dithiane	18		Off-Post ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
Semivolatile Halogenated Organic Compounds (SHOs)	Hexachlorocyclopentadiene	50		ROD CBSG

Table 1.4.1-4. Basin A Neck System (BANS) CSRG Analytes (Concluded)

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L)	CSRG Source
Organochlorine Pesticides (OCPs)	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	0.1		ROD CBSG
	Dieldrin	0.002	0.05/ 0.013	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
Arsenic	Arsenic	50		ROD CBSG
Mercury	Mercury	2		ROD CBSG/MCL

Notes:
1 Practical Quantitation Limits; ROD PQL/PQL from 2012 PQL study (effective April 2012)
2 CBSG achieved and replaced PQL during 2010 FYR period
3 Colorado Basic Standard for Groundwater
4 Maximum Contaminant Level
5 Adopted based on change to the ROD documented in the Explanation of Significant Differences for Lime Basins Dense Non-Aqueous Phase Liquid Remediation Project (TtEC 2011b).

1.4.1.5 Bedrock Ridge Extraction System

The selected remedy presented in the On-Post ROD for the Section 36 BRES is as follows:

> *A new extraction system will be installed in the Section 36 Bedrock Ridge area. Extracted water will be piped to the Basin A Neck system for treatment (e.g., by air stripping or carbon adsorption).*

The BRES extraction wells were installed in 2000, in accordance with the On-Post ROD (FWENC 1996), to prevent further migration of the Section 36 Bedrock Ridge Plume northeast out of the Basin A area toward the First Creek drainage. The extracted water is treated and recharged to the groundwater at the BANS. Evaluation of the BRES, which originally consisted of three extraction wells, led to a decision to modify the system to improve plume capture. A fourth extraction well, 36306, was installed and became operational in 2005. Water extracted in the Bedrock Ridge area is piped to the BANS for treatment by GAC and air stripping. In FY14, the average flow rate from the BRES was 3.3 gpm. The CCR for this project was finalized in September 2008 (Washington Group International 2008) and the system was accepted as operational and functional by the EPA.

The CSRGs for BANS, which are listed in Table 1.4.1-4, apply to the treated BRES effluent because this water is treated at BANS.

1.4.1.6 Complex (Army) Disposal Trenches

The selected remedy presented in the On-Post ROD for the CADT slurry wall is as follows:

> *Installation of a slurry wall into competent bedrock around the disposal trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be re-evaluated during remedial design.*

The On-Post ROD goals, as presented in Table 9.5-1 of the document, were to:

- *Minimize groundwater flow across the slurry wall with a design goal of 1 x 10^{-7} (centimeters per second) hydraulic conductivity.*
- *Construct slurry wall with sufficient thickness to withstand maximum hydraulic gradient.*
- *Construct slurry wall with materials that are compatible with the surrounding groundwater chemistry.*
- *Minimize migration by keying the slurry wall in an underlying low permeability strata.*
- *Dewater as necessary to ensure containment.*

The dewatering goal was further refined in the Complex Army Trenches and Shell Section 36 Trenches 100 percent design document (RVO 1997), which states:

- The dewatering objective is to lower the water table to below the elevation of the disposal trench bottoms.

Installation of the CADT slurry wall began in 1998 and the project was completed in 2000. Testing of the groundwater extraction trench was completed in February 2000 and operation of the dewatering system began in March 2001.

To meet the ROD-derived requirement of ultimately lowering the water table to below the bottom of the CADT, water is extracted at a flow rate that typically ranges between 1 and 2 gpm and piped to the BANS for treatment. In FY14, the flow rate averaged 1.6 gpm. The CSRGs for BANS, which are listed in Table 1.4.1-4, apply to the treated CADT effluent because this water is treated at BANS.

1.4.1.7 Shell Disposal Trenches

The selected remedy presented in the On-Post ROD for the Shell Disposal Trenches slurry walls is as follows:

> *Expansion of the existing slurry wall around the trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be re-evaluated during remedial design.*

The On-Post ROD also stated the following dewatering goal for the Shell Disposal Trenches in ROD Table 9.5-1:

- *Dewater as necessary to ensure containment.*

The dewatering goal was eliminated in the Complex (Army) Trenches and Shell Section 36 Trenches Groundwater Barrier Project 100 percent design document (RVO 1997), which states:

- *For the Shell Trenches, the groundwater levels are already below the bottoms of the trenches, making dewatering unwarranted.*

The Shell Disposal Trenches slurry wall remedy includes installation of a slurry wall encircling the disposal trenches. The 2-ft-thick slurry wall, installed in 1999, surrounds the 6-inch-thick slurry wall installed in 1991. A RCRA-equivalent cover was included in the Shell Disposal

Trenches remedy design, which was presumed to passively ensure that groundwater levels would remain below the bottom of the trenches. The design document did not revoke the dewatering goal of maintaining water levels below the trenches.

The purpose of groundwater level monitoring, specified in the combined Complex (Army) Trenches and Shell Section 36 Trenches 100 percent design document (RVO 1997), is to measure water level differentials across the barrier wall to obtain information on the direction (i.e., inward or outward) of gradients across the barrier. Monitoring is also conducted to obtain information on the water level differentials that could potentially affect barrier wall stability. The design document stated that dewatering inside the Shell Disposal Trenches slurry wall was not necessary since water levels were already below the bottom of the trenches. Prior to the construction of the Shell Disposal Trenches slurry wall in 1999, 10 existing monitoring wells adjacent to the slurry wall alignment were cut off and capped. Nine of the 10 wells were restored and placed into service after slurry wall/cover construction. Five new wells were installed outside the new slurry wall.

1.4.1.8 Lime Basins Dewatering System

The Lime Basins soil remedy presented in the On-Post ROD was changed in 2005 to include an encircling slurry wall and dewatering well system to lower water levels below the Lime Basins waste and create an inward hydraulic gradient across the slurry wall (TtEC 2005). The groundwater pumped by the Lime Basins dewatering system was treated at the CWTF and reinjected in the Lime Basins recharge trenches until the CWTF was decommissioned in 2010. After the CWTF was decommissioned, the groundwater extracted from the Lime Basins dewatering project has been piped to BANS for treatment and recharge.

For the Lime Basins, the Amendment to the ROD (TtEC 2005) provides standard and monitoring provisions:

- Standard: Dewater as necessary to maintain a positive gradient from the outside to the inside of the barrier wall and maintain groundwater level below the level of the Lime Basins waste for as long as the surrounding local groundwater table is in the alluvium.
- Monitor to ensure that the dewatering standard is met. If the groundwater table drops below the level of the alluvium inside the wall, monitor annually thereafter to check that the groundwater table remains below the alluvium inside the wall.

The performance criteria for the Lime Basins as presented in the Amendment to the ROD are presented below:

- Maintain a positive gradient from the outside to the inside of the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).
- Maintain a groundwater level below the elevation of the Lime Basins waste (5,242 ft) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).

Dewatering of the Lime Basins began in 2009 and groundwater extracted from the Lime Basins Dewatering project was treated at the CWTF until it was decommissioned in 2010, but now the groundwater is piped to the BANS for treatment and recharge.

1.4.1.9 Lime Basins DNAPL Remediation Project

In August 2009, monitoring of the Lime Basins dewatering wells indicated the potential presence of Dense Non-Aqueous Phase Liquid (DNAPL). A Remedial Investigation/ Feasibility Study (RI/FS) was conducted and three suspected DNAPL source zones were identified in the Lime Basins area:

- At the northwest corner of the Lime Basins, near dewatering wells 36315 and 36320;
- at the northeast corner of the Lime Basins, near dewatering well 36319; and
- approximately 300 ft south-southwest of the southwest corner of the Lime Basins, near wells 36001, 36181, and 36182 (wells 36001 and 36182 are closed).

The DNAPL consists of mixtures of the following five compounds: 1,2-dichlorobenzene (12DCLB), 1,3-dichlorobenzene (13DCLB), 1,4-dichlorobenzene (14DCLB), chlorobenzene (CLC6H5), and DCPD. The selected remedy consists of DNAPL source containment, removal of DNAPL to the extent practicable, and DNAPL thickness and groundwater monitoring (Tetra Tech and URS 2012). Operation of the Lime Basins dewatering wells will continue according to the goals and standards for the Lime Basins Dewatering System. The groundwater will be treated at the BANS to meet CSRGs. Eight new monitoring wells (four well pairs adjacent to the slurry wall) were installed in late FY12, and data collection specified in the Design Analysis Report (DAR) (TtEC and URS 2012) began in FY13 and continued in FY14. The Lime Basins DNAPL Remediation Project FY13 Monitoring Results, Conclusions, and Recommendations were presented to the Regulatory Agencies on November 20, 2013 and then formalized in a report in 2015 (Department of the Army 2015). The FY14 results were reported in the FY14 ASR.

1.4.1.10 South Tank Farm and Lime Basins Mass Removal Project

In early 2006 an Explanation of Significant Difference (ESD) was approved to implement short-term groundwater mass removal remedies within the STF Plume and the Lime Basins areas (TtEC 2006b). These remedies entail the extraction of groundwater from the STF Plume and the Lime Basins area with treatment of the extracted groundwater to reduce the contaminant mass within the respective plumes. The STF and Lime Basins groundwater extraction/recharge and monitoring systems of the GWMR Project were installed and became operational in 2006. These are short-term mass removal projects and groundwater extracted from these respective systems is treated at the CWTF. The GWMR Project required the reinjection of treated groundwater that was regulated under the Underground Injection Control Program and was operated under a reinjection exemption that allows recharge of groundwater at concentrations that exceed the CBSGs (Washington Group International 2005a). Operation of the Lime Basins mass removal wells was interrupted during 2008 and 2009 due to cover construction. The GWMR Project was decommissioned in 2010. The EPA approved the CCR on May 16, 2012.

Post-shut-off monitoring for the STF was conducted during this FYR period and is discussed in Section 5.1.5.2. Post-shut-off monitoring for the Lime Basins was not necessary because monitoring for the Lime Basins Slurry Wall Dewatering and DNAPL Remediation Projects is ongoing.

1.4.1.11 North Plants Light Non-Aqueous Phase Liquid (LNAPL)

The Petroleum Release Evaluation Report (TtFW 2004) concluded that light non-aqueous phase liquid (LNAPL) was present in association with groundwater beneath the former North Plants Production Area. In 2001, attempts were made to recover the LNAPL (approximately 18 gallons were recovered) and monitoring was conducted in 2003, 2004, 2005, and 2007. A pilot study on removal of LNAPL was initiated in 2009 (URS Washington Division and TtEC 2009). The wells were installed in February 2009, and monitoring began in March 2009. As of the end of FY14, sufficient LNAPL has not been present in the wells to commence recovery operations. The Colorado Petroleum Storage Tank guidance documents are being used for this project.

In 2009, an LNAPL Removal Pilot Study Action Plan (URS Washington Division and TtEC 2009) was prepared and is currently being used to determine the extent to which removal of LNAPL is practicable using a well recovery skimming system. A total of 22 piezometers and two recovery wells were installed in the North Plants LNAPL Plume. Since the installation of piezometers in 2003, water levels and product levels have been measured to establish LNAPL thickness and extent.

The pilot LNAPL removal system will be operated to the extent necessary to gather data in support of the final action, if any, for the North Plants LNAPL Plume.

Information gathered from pilot system operation will be provided in Water Team meetings between the Remediation Venture Office (RVO) and the Regulatory Agencies or through e-mail transmittals. After one year of operating the pilot system, or until sufficient data are collected to design the final remedial action, the RVO prepared the North Plants Pilot Light Non-Aqueous Phase Liquid Removal Action 2010-2011 Evaluation Report (URS 2012a) that summarized the results, evaluated performance in meeting the pilot study objectives, and made recommendations based on the these results. The RVO proposed to conduct quarterly monitoring of water levels and LNAPL thickness in the existing well network for the remainder of this FYR period to determine if LNAPL accumulated in sufficient thickness for the pilot study to proceed. Criteria for completion of any LNAPL recovery operation will also be developed in the pilot study report. The completion criteria and the potential need for post-shut-off monitoring or periodic operation of the system will also consider the water-level effects on the LNAPL accumulation. Since 2011, the data have been reported in the ASRs.

1.4.2 Off-Post Groundwater Intercept and Treatment System

The OGITS is a mass removal system designed to extract and treat contaminated alluvial groundwater from the First Creek and Northern Pathway paleochannels, downgradient of the NBCS, and return treated water to the alluvial aquifer. The OGITS was installed as an IRA before completion of the Off-Post ROD (HLA 1995). A summary of the elements presented in the Off-Post ROD relevant to the FYSR is as follows:

- Continued operation of the OGITS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action
- Institutional controls to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs
- Provision of a water supply for well owners with wells within the DIMP plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The OGITS was designed as a mass removal system and has operated as such since startup in 1993. The mass removal objectives presented in the IRA Decision Document (HLA 1989) for OGITS are as follows:

- Mitigate migration of contaminants in alluvial groundwater as soon as practicable
- Treat contaminated alluvial groundwater to provide a beneficial impact on groundwater quality

In addition, the RMA Federal Facility Agreement states:

> *The Organizations intend that the Response Actions at the (Rocky Mountain) Arsenal will be sufficient to assure that groundwater and surface water flowing beyond the Arsenal boundaries will be of a quality that is protective of human health and the environment and that Response Actions will be sufficient to prevent the vertical and horizontal migration of on-post contaminated groundwater and surface water so that off-post surface water and groundwater may be used in areas outside of the Arsenal boundaries.*

The major remedy components presented for operation of the OGITS in the Off-Post ROD are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and Northern Pathway paleochannels using groundwater extraction wells
- Treatment of the organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using recharge wells and trenches
- Removal of contaminated groundwater from the alluvial and the weathered upper portion of the Denver Formation (hereafter called the UFS) north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells
- Treatment of the organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using wells and trenches

- Natural attenuation of inorganic chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action

The OGITS includes two extraction and recharge systems consisting of extraction wells, recharge trenches, and recharge wells in the First Creek and Northern Pathway paleochannels. The First Creek System (FCS) consisted originally of five extraction wells and six recharge trenches. Two FCS extraction wells (37803 and 37804) were shut down in 2003. The Northern Pathway System (NPS) has been operating since 1993 and originally consisted of 12 extraction wells and 24 recharge wells. Four NPS extraction wells (37811, 37812, 37813, and 37814) were shut down in 2004. Water is treated by GAC adsorption before reinjection.

An agreement was reached with Amber Homes in 2004 to modify the NPS to accommodate new development (George Chadwick Consulting 2005). New extraction wells and recharge trenches were installed upgradient of the original system. It is expected that the modified system will expedite cleanup of alluvial groundwater between the original and new Northern Pathway extraction wells. The new NPS extraction wells will be operated concurrently with the remaining original NPS extraction wells until the latter meet the ROD-specified shut-off criteria.

The new Northern Pathway extraction system along Highway 2 was designed to meet or exceed the contaminant removal efficiency of the original system. Specific design requirements for the new extraction well system are as follows:

- Achieve similar flow rates in the new extraction wells at Highway 2 as in the original extraction wells within the same plume and flow paths
- Capture the majority of the plume mass for carbon tetrachloride, chloroform, DBCP, DIMP, dieldrin, and tetrachloroethylene (PCE)

The NPS modifications were initiated in 2006 and include the following:

- Abandonment of eight existing recharge wells
- Abandonment of three of the four existing extraction wells that have been turned off; the fourth well will be abandoned at a future date
- Installation of six upgradient extraction wells near Highway 2 in the solvent, dieldrin, and DIMP plumes
- Installation of five recharge trenches near Highway 2 that are in line with and on both sides of each new extraction well in the dieldrin and DIMP plumes

Both the groundwater contaminant concentrations and the areal extent of groundwater contamination have significantly decreased since operation of the NPS began. Four of the original NPS extraction wells were turned off on July 1, 2004 (PMRMA 2005c) and two FCS extraction wells were turned off in September 2003 (PMRMA 2005b).

CSRGs for the OGITS effluent were established for 34 contaminants potentially present in the Off-Post OU and the contaminants and their respective CSRGs are listed in Table 1.4.2-1.

Table 1.4.2-1. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG [1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[3]
	1,3-Dichlorobenzene	6.5		ROD health-based value
	Chlorobenzene	25		ROD CBSG/MCL[4]
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Tetrachloroethylene (PCE)	5		ROD CBSG/MCL
	Trichloroethylene (TCE)	3		ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	3		ROD health-based value
	Ethylbenzene	200		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		ROD CBSG/MCL
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Organosulfur Compounds; Mustard Agent Related (OSCMs)	Dithiane	18		ROD health-based value
	1,4-Oxathiane	160		ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value

Table 1.4.2-1. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes (Concluded)

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
	Malathion	100		ROD health-based value
Semivolatile Halogenated Organic Compounds (SHOs)	Hexachlorocyclopentadiene	0.23		ROD CBSG
	Chlordane	0.03		ROD CBSG
Organochlorine Pesticides (OCPs)	Aldrin	0.002	0.05/ 0.014	ROD CBSG
	Dieldrin	0.002	0.05/ 0.013	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value
	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	0.1		ROD CBSG
	2,2-bis(p-chlorophenyl)-1,1-dichloroethene (DDE)	0.1		ROD CBSG
Other Organic Compounds	Dibromochloropropane (DBCP)	0.2		ROD CBSG/MCL
	n-Nitrosodimethylamine (NDMA)	0.007	0.033/ 0.018	ROD - EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		ROD CBSG;
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value

Notes:
1 µg/L unless otherwise noted
2 Practical Quantitation Limits; ROD PQL/PQL from 2012 PQL study (effective April 2012)
3 Colorado Basic Standard for Groundwater
4 Maximum Contaminant Level

1.4.3 Other Groundwater Remedy Components

Other RMA programs are not considered part of the LTMP because monitoring and reporting is conducted in accordance with RCRA and CERCLA requirements. These monitoring programs include monitoring of the HWL, ELF, Basin F, and Landfill Wastewater Treatment System (LWTS) and are summarized below.

1.4.3.1 Hazardous Waste Landfill/Enhanced Hazardous Waste Landfill

Groundwater beneath the HWL is currently monitored under the requirements of the HWL Post-Closure Groundwater Monitoring Plan (PCGMP) (TtEC 2011c) as modified by approved O&M Change Orders (OCNs). Groundwater beneath the ELF is currently monitored under the requirements of the ELF PCGMP (TtEC 2010a) as modified by approved OCNs.

Monitoring is conducted in upgradient and downgradient wells to detect any migration of landfill contaminants into the groundwater. The monitoring network consists of several two-well clusters that monitor separate sandstone intervals in the weathered Denver Formation.

Post-closure monitoring of the HWL and ELF wells are conducted quarterly, with analytical results presented to the Regulatory Agencies on an annual basis in the Annual Covers Report for RCRA Caps. If a significant increase in analyte concentration is detected in downgradient wells, steps will be taken to determine potential leakage from the landfill, including reviewing data packages, comparing upgradient to downgradient analyte concentrations, comparing downgradient analytes to sump data, and resampling subject monitoring wells.

If groundwater is found to be adversely affected by a leak from the landfills, then a groundwater assessment program will be initiated and developed. Prediction limits are statistical values used to compare the baseline or background concentrations to concentrations in the downgradient wells, and are used to evaluate potential impacts on the groundwater and effectiveness of the remedy. The Regulatory Agencies will be notified of any significant increase in analyte concentrations above prediction limits (TtEC 2010a, 2011c).

1.4.3.2 Basin F

Groundwater beneath Basin F is currently monitored under the requirements of the Basin F PCGMP (TtEC 2011d). This plan is designed for monitoring groundwater quality and flow direction surrounding the former Basin F to evaluate the potential impact of the Basin F remedy on the groundwater quality beneath and migrating from the former Basin F during post-closure activities. Monitoring is conducted in upgradient and downgradient wells for both the Basin F Wastepile and Basin F principal threat areas within Basin F. The monitoring network consists of several wells designed to monitor groundwater flow and water quality within the saturated alluvium and upper Denver Formation and the deeper weathered Denver Formation.

Post-closure monitoring of the Basin F wells is conducted annually. The Army and Shell evaluate chemical contaminants detected in the former Basin F wells using trend analysis, statistical evaluation, and comparison techniques. Trend analyses are conducted to evaluate compounds detected in groundwater samples from selected downgradient monitoring wells, and to track compounds that have not been detected in upgradient groundwater samples, but were detected in downgradient groundwater samples prior to closure of the former Basin F. If detections are above the reporting limit, time verses concentration graphs for selected RMA chemicals of concern are generated.

Water level data collected during each sampling event are used to evaluate the groundwater flow patterns in the area and fluctuations in the water table. Water level data are plotted and contoured after each sampling event and are compared to previous monitoring events to identify any changes in the groundwater flow conditions. Hydrographs are generated for the nine water quality wells because fluctuating water levels may affect the groundwater concentrations due to the presence of residual contamination.

Water quality results are submitted annually to the Regulatory Agencies as part of the Annual Covers Report for Basin F. Water quality and water level monitoring data are also available from the RMA Environmental Database (RMAED).

1.4.3.3 Landfill Wastewater Treatment System

Groundwater beneath the former LWTS was monitored pursuant to Appendix A of the Final Landfill Wastewater Treatment System Closure Plan (URS Washington Division and TtEC 2011). This plan was designed to monitor wells upgradient and downgradient of the LWTS to assess potential releases of hazardous constituents from the LWTS to groundwater. Twelve wells were in the LWTS monitoring network; water level monitoring was conducted quarterly, and water quality monitoring was quarterly for six wells and annually for six wells. Three wells typically were dry, but they were sampled if sufficient water was present. Groundwater monitoring was completed in 2011 and the LWTS was decommissioned. Since the LWTS was decommissioned in 2011, the landfill leachate and wastewater have been treated offsite.

2.0 On-Post Monitoring Programs

The data used to complete this 2015 FYSR were collected under the 2010 LTMP (TtEC and URS 2010), the Sampling and Analysis Plans (SAPs) issued as part of the O&M Plans for the respective extraction and treatment systems, and the SAPs issued as part of the RCRA Post-Closure Plans. The chemical analytes discussed in this report all have analyte-specific method reporting limits (MRLs) established through a laboratory certification process described in the RVO Chemical Quality Assurance Plan (CQAP) (RVO 2009). The discussion of the monitoring results includes terms such as “not detected” or “non-detect,” which means that the analyte in question was not detected at or above its MRL. Similarly “detection” or “detected” refer to analyte concentrations at or above the MRL.

The long-term groundwater monitoring program described in the 2010 LTMP satisfies the requirements of the On-Post and Off-Post RODs (FWENC 1996; HLA 1995). The main objectives, as stated in the RODs, are to evaluate the effectiveness of the remedies, to verify the effectiveness of existing on-post and off-post groundwater treatment systems, to satisfy CERCLA requirements for waste left in place, and to provide data for FYRRs. The main component of the remedy that relates to groundwater is continued operation of the groundwater containment and treatment systems.

2.1 LTMP Monitoring

The 2010 LTMP defined six system-related monitoring categories that were developed to meet the On-Post ROD requirements for long-term groundwater monitoring and to support data evaluation. These categories were applied during this FYR period and are evaluated in this report:

- **Compliance Monitoring**—Monitoring of treatment system effluent water, conducted to confirm that CSRGs are met by on-post and off-post treatment systems (no wells are monitored). Compliance is based on running averages for the last four quarters.
- **Performance Monitoring**—Water level and water quality monitoring performed to measure performance against specific criteria.
- **Pre-Shut-Off Monitoring—**Monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated. A program will be designed for each specific system.
- **Shut-Off Monitoring**—Water quality monitoring at containment systems that have met chemical concentration-based shut-off criteria defined by the RODs. Such monitoring is conducted for specified analytes for a period of five years to ensure that ARARs continue to be met. *This monitoring is to be conducted in accordance with a revised shut-off approach, with sampling frequencies reduced from the current quarterly sampling for 5 years to quarterly for the first and last years and annual in intervening years.*
- **Post-Shut-Off Monitoring**—Monitoring to track groundwater levels, flow directions, and water quality in the area after successful completion of the shut-off monitoring program and termination of system operation.

- **Operational Monitoring**—Monitoring of mass removal system and containment system extraction wells and monitoring wells located near the systems to optimize system performance and ensure that Remedial Action Objectives are met. *Monitoring to evaluate whether individual extraction wells can be shut off or will remain shut-off is conducted under this program instead of the current 5-year shut-off monitoring.*

The site-wide monitoring program categories are as follows:

- **Water Level Tracking**—On-post water level monitoring used to track the effects of the soil remedy to groundwater in the *On-Post Operable Unit*.
- **Water Quality Tracking**—On-post water quality monitoring of indicator analytes is conducted to track contaminant migration in and downgradient of the source areas within the identified plumes.
- **Confined Flow System Monitoring**—Monitoring in response to the On-Post ROD requirement to continue to monitor water quality in the confined aquifer in three areas—Basin A, South Plants, and Basin F.

Monitoring frequencies for the different categories and parameters are listed below:

Monitoring Category	Monitoring Parameter	Monitoring Frequency
Compliance	Water quality[2]	Quarterly[2]
Performance	Water level and water quality	Quarterly and Annual
Pre-Shut-Off	Water quality[1]	Project Specific
Shut-Off	Water quality[1]	Quarterly and Annual
Post-Shut-Off	Water level and water quality	Project Specific
Operational	Water level and water quality	Variable[3]
Water Level Tracking	Water level	Annual
Water Quality Tracking	Water quality	Once or Twice in 5 years
Confined Flow System	Water quality[1]	Twice in 5 years

1 Water level measurements recorded but they were not the primary purpose of monitoring.
2 Quarterly monitoring is reduced to annual monitoring for analytes below CSRGs or PQLs in system influents.
3 Refer to Section 2.2.

Compliance monitoring is conducted quarterly or annually for the respective CSRG analytes identified in the On-Post ROD for each system and the results are reported in the quarterly Effluent Reports as well as in the ASRs.

Performance monitoring is conducted either quarterly or annually for water levels and water quality. Pre-shut-off monitoring is conducted before a system is recommended to be shut-off. Pre-shut-off monitoring was conducted at the Railyard Containment System during this FYR period.

Shut-off monitoring is conducted after a system has been shut off; no shut-off monitoring was performed on post during this FYR period.

Post-shut-off monitoring is conducted after successful completion of the shut-off monitoring program and termination of system operation. Post-shut-off monitoring was performed at the Motor Pool Extraction System, Irondale Containment System (URS 2011) and STF portion of the Groundwater Mass Removal Project during this FYR period.

Water level tracking is conducted annually and the results are presented on water-level maps that are prepared every year. Water quality tracking is conducted on a once or twice in 5 year's frequency in support of the water level tracking to track flow paths and plume migration on post. The results are included in the FYSRs.

Confined flow system (CFS) monitoring is performed on a twice in 5 years frequency for the three areas identified in the On-Post ROD and reported in the FYSRs.

2.2 Operational Monitoring

Operational monitoring is monitoring of system extraction wells, recharge wells, recharge trench piezometers, and/or monitoring wells located near the system. Data are collected from wells upgradient of and at the systems to optimize system performance and ensure that RAOs are met. Most of the wells are used for water level monitoring to ensure proper extraction system operation; selected wells are also used for water quality monitoring of indicator compounds. These monitoring data are used to evaluate and adjust the system to ensure optimal operation for containment, capture, and treatment. Effective system operation depends on water level and water quality data and monitoring frequencies are determined based on operational data needs. Depending on the type of data and operational need, frequencies may be weekly, monthly, quarterly, semiannually, or annually. As operating conditions change, the operational monitoring program may also change. Accordingly, the operational monitoring program is flexible with respect to monitoring locations, frequencies, and chemical analyses. O&M Plans that address operations and monitoring are in place for each system and are updated as necessary. Operational monitoring data will continue to be evaluated and presented in the ASRs. Relevant information from these reports will be included or summarized in FYSRs.

The operational monitoring program for existing containment and treatment systems at RMA is well established. This operational monitoring is conducted to provide the data necessary to ensure optimal performance for the extraction, treatment, and reinjection systems. The operational monitoring program includes water level data collection to determine the hydraulic gradients produced by the extraction system to achieve contaminant plume capture. Water quality data are collected from influents and effluents at various points in the treatment systems to monitor influent contaminant concentrations and treatment system performance. Water quality is also monitored in extraction and monitoring wells associated with the systems to optimize treatment system operation.

The operational monitoring program was expanded during the implementation of the remedy to include monitoring of additional remedy components, such as the former Basin F/Basin F

Wastepile, the HWL, ELF, Bedrock Ridge, Shell Disposal Trenches, CADT, Lime Basins, and North Plants.

2.3 Other Groundwater Monitoring

2.3.1 Post-Closure Monitoring

Post-closure care requirements for the HWL, ELF, and the former Basin F Surface Impoundment and former Basin F Wastepile, collectively referred to herein as Basin F, are detailed in separate post-closure plans (TtEC 2011e, TtEC 2010b, and 2011f, respectively). The post-closure care requirements include groundwater monitoring as described in the respective post-closure groundwater monitoring plans (PCGMPs) (TtEC 2011c, TtEC 2010a, and 2011d, respectively). Basin F, the HWL and ELF, and the Integrated Cover System, comprise the Army Maintained Areas (AMAs) of the RMA and as such will be retained by the Army and not become part of the RMANWR.

2.3.1.1 HWL Post-Closure Groundwater Monitoring

The groundwater monitoring requirements identified in the RCRA Corrective Action Management Unit (CAMU) regulations [6 Code of Colorado Regulations 1007-3 Subpart S, Section 264.552 (e) (5)] establish the requirements for monitoring during the landfill post-closure periods. In addition, the ROD identifies applicable substantive requirements of 40 Code of Federal Regulations 264 (6 Code of Colorado Regulations 1007-3, Part 264) as Applicable or Relevant and Appropriate Requirements including requirements of Subpart F, Groundwater Monitoring.

The regulations specify that groundwater monitoring be sufficient to:

- Continue to detect and characterize the nature, extent, concentration, direction, and movement of existing release of hazardous constituents in groundwater from sources located within the CAMU.
- Detect and subsequently characterize releases of hazardous constituents to groundwater that may occur from areas of the CAMU in which remediation wastes will remain in place after closure of the CAMU.

In conformance with these regulations, the HWL Operational Groundwater Monitoring Plan (OGMP) (FWENC 2003) and HWL Closure/Post-Closure Groundwater Monitoring Plan (TtEC 2007a) for the HWL and LWTS were written and approved to address two separate purposes: 1) to monitor for existing hazardous constituents in groundwater; and 2) to monitor for potential releases of hazardous constituents from the HWL and LWTS.

The HWL PCGMP addresses the specific monitoring for the HWL well network, sampling frequency, and analyte list for the post-closure monitoring period. This groundwater monitoring program was developed based on the information obtained from the pre-operational and operational plans and the closure and post-closure requirements for the HWL. The post-closure groundwater monitoring program is an integral part of the overall landfill performance evaluation. The monitoring program includes four critical components to evaluate the landfill performance as follows:

1. The post-closure groundwater monitoring well system. This system includes the wells used to monitor groundwater upgradient and downgradient of the HWL.
2. Monitoring of the leachate collection system (LCS). The LCS will be monitored regularly for quantity of leachate and to identify compounds that are present in the leachate.
3. Monitoring of the leak detection system (LDS). The LDS will be monitored regularly for quantity of liquid and to identify compounds that are present in the liquid.
4. Supplemental Operational Monitoring (SOM) wells. A series of additional wells were installed just outside the perimeter berm of the HWL to assist with the evaluation of the performance of the LDS and tracking potential contaminants along the western edge of the North Plants/Bedrock Ridge Plume.

The assessment of landfill performance and integrity includes the review of available data concerning these four components to evaluate whether a release from the landfill has occurred. Using this approach, a statistically significant increase (SSI) in a certain compound in the groundwater will not alone constitute a conclusion that the landfill performance and integrity have been compromised, unless similar conclusions can be drawn from data collected in the LCS and LDS. A comparison of data from the downgradient groundwater monitoring well system, LCS, LDS, and SOM wells, if applicable, will be used to assess whether leakage has occurred from the HWL. If a release is suspected, a groundwater quality assessment will be implemented to confirm the postulated release from the HWL and evaluate the nature and extent of the contaminant migration.

The HWL post-closure groundwater monitoring program began in July 2009, after final cap construction was completed and the final inspection was signed by the Program Management Contractor, RVO, and the Regulatory Agencies. Annual post-closure groundwater monitoring reports were provided to the Regulatory Agencies as part of the Annual Covers Reports for Resource Conservation and Recovery Act (RCRCA) Caps beginning in 2009.

2.3.1.2 ELF Post-Closure Groundwater Monitoring

The groundwater monitoring requirements identified in the RCRA CAMU regulations [6 Code of Colorado Regulations 1007-3 Subpart S, Section 264.552 (e) (5)] establish the requirements for monitoring during the landfill post-closure periods.

The regulations specify that groundwater monitoring be sufficient to:

- Continue to detect and characterize the nature, extent, concentration, direction, and movement of existing release of hazardous constituents in groundwater from sources located within the CAMU.
- Detect and subsequently characterize releases of hazardous constituents to groundwater that may occur from areas of the CAMU in which remediation wastes will remain in place after closure of the CAMU.

The ELF started receiving waste on April 3, 2006 and accepted its final waste load on July 17, 2008. Prior to ELF construction, groundwater monitoring was performed as described in the ELF

Pre-operational Groundwater Monitoring Plan (FWENC 2002). During waste placement operations groundwater monitoring continued as described in the ELF Operational Groundwater Monitoring Plan (OGMP) (TtEC 2006a).

The ELF PCGMP was prepared to describe groundwater monitoring requirements for the post-closure period. This plan describes requirements for the collection, laboratory analysis, and evaluation of groundwater data. The ELF PCGMP was designed for two separate purposes: 1) monitor for existing hazardous constituents in groundwater, and 2) monitor for potential releases of hazardous constituents from the ELF.

The ELF PCGMP addresses the specific monitoring for the ELF well network, sampling frequency, and analyte list for the post-closure monitoring period. This groundwater monitoring program was developed based on the information obtained from the preoperational, operational, and closure plans and the post-closure requirements for the ELF. The ELF PCGMP is an integral part of the overall landfill performance evaluation. During the post-closure period, the monitoring program will include three critical components to evaluate the landfill performance as follows:

1. The post-closure groundwater monitoring well system. This system includes the wells used to monitor groundwater upgradient, downgradient, and cross-gradient of the ELF.
2. Monitoring of the leak detection system. The LDS will be monitored regularly for quantity of liquid and to identify compounds that are present in the liquid.
3. Monitoring of the leachate collection system. The LCS will be monitored regularly for quantity of leachate and to identify compounds that are present in the leachate.

The assessment of landfill performance and integrity includes reviewing available data concerning these three components to evaluate whether a release from the landfill has occurred. Using this approach, a SSI in a certain compound in the groundwater will not alone constitute a conclusion that the landfill performance and integrity have been compromised, unless similar conclusions can be drawn from data collected in the LDS and/or LCS. If a comparison of data from the three components suggests that a leak may have occurred, a groundwater quality assessment will be implemented to confirm the postulated release from the landfill and evaluate the nature and extent of the contaminant migration.

The ELF post-closure groundwater monitoring program began in July 2010, after final cap construction was completed and the final inspection was signed by the Program Management Contractor, RVO, and the Regulatory Agencies. Annual post-closure groundwater monitoring reports were provided to the Regulatory Agencies as part of the Annual Covers Reports for RCRCA Caps beginning in 2011.

2.3.1.3 Basin F Post-Closure Groundwater Monitoring

The groundwater monitoring requirements for post-closure care for RCRA Interim Status Units, such as Basin F, are found in 6 CCR 1007-3 Subpart F, Section 265.90-265.94. In conformance with these regulations, the Basin F groundwater monitoring program described in the Basin F

PCGMP (TtEC 2011d) is designed to monitor general trends and provide information on water quality to assess the effectiveness of the Basin F remedy. On July 22, 1987, Basin F was listed on the NPL as part of the RMA site (52 FR 27620 and 52 FR 27643) and is also subject to CERCLA O&M requirements defined in the RCRA-Equivalent, 2-, and 3-Foot Covers Long Term Care Plan (LTCP) (TtEC 2011g) and Basin F Post-Closure Plan (TtEC 2011f). This includes the post-construction process and "Operational and Functional" determination described in items 1 and 2 of Section 1.0 of the LTCP. However, during the post-closure period, compliance with other CERCLA O&M requirements is achieved through implementation of the O&M activities identified in the post-closure plan. Basin F entered the post-closure period on March 2, 2010 following the physical completion of the Basin F RCRA-Equivalent Cover.

The post-closure groundwater monitoring program includes annual sampling as follows:

- Water quality monitoring in three upgradient wells
- Water quality monitoring in six downgradient wells
- Water level tracking in 27 monitoring wells/piezometers

The Army and Shell evaluate chemical contaminants detected in the former Basin F wells using trend analysis, statistical evaluation, and comparison techniques. Trend analyses are conducted annually to evaluate compounds detected in groundwater samples from selected downgradient monitoring wells, and to track compounds that have not been detected in upgradient groundwater samples, but were detected in downgradient groundwater samples prior to closure of the former Basin F. If detections are above the reporting limit, time verses concentration graphs for selected RMA chemicals of concern are generated.

Groundwater quality downgradient of the former Basin F is evaluated by comparing indicator compound concentrations in samples collected from upgradient Wastepile (WP) and Principle Threat (PT) monitoring wells with concentrations in samples collected from downgradient WP and PT monitoring wells. The statistical comparison and trend analyses results provide quantitative evidence regarding the potential impact of the former Basin F on groundwater. Comparisons with historical data may be used to qualitatively evaluate potential short-term increases in concentrations caused by mobilization of contaminants during intrusive activities associated with remedy implementation and pre-existing residual contamination that may be mobilized by fluctuating water levels.

Water level data collected during each sampling event are used to evaluate the groundwater flow patterns in the area and fluctuations in the water table. Water level data are plotted and contoured after each sampling event and compared to previous monitoring events to identify any changes in the groundwater flow conditions. Hydrographs are generated for the nine water quality wells because fluctuating water levels may affect the groundwater concentrations due to the presence of residual contamination.

2.3.2 Landfill Wastewater Treatment System Closure

Operation and monitoring of the LWTS was performed under RCRA. The LWTS was designed and constructed to process wastewater associated with the operation of the HWL (RVO 2006a). Since commencement of operations in 1999, the LWTS treated wastewater that consisted of HWL leachate, HWL decontamination wastewater, and HWL potentially contaminated storm water, which is storm water runoff from waste and covered areas inside the HWL waste containment cell, access ramp, and decontamination pad.

The LWTS discharged to First Creek. First Creek is a tributary to the Upper South Platte River Segment 16c. As a tributary, the use classifications for First Creek are Aquatic Life Warm 2, Recreation 2, and Agriculture. The LWTS effluent discharge limits were based on the Colorado Basic Standards and Methodologies for Surface Water (CBSMSW) for organics, surface water quality standards and criteria for aquatic life and human health, effluent limitations, and groundwater standards stated in the On-Post ROD.

In 2010, the LWTS Closure Project was performed in accordance with the Landfill Wastewater Treatment System Closure Plan (URS 2010) and documented in the LWTS CCR (TtEC 2011h). Groundwater monitoring wells in this area will be retained and monitored as necessary to fulfill the requirements of the 2010 LTMP (TtEC and URS 2010).

2.3.3 2014 On-Post Plume Mapping

The On-Post ROD states, "Where human health exceedance soils are left in place at soil sites, groundwater will be monitored, as necessary, to evaluate the effectiveness of the remedy." In order to periodically evaluate the status of the on-post groundwater contamination, the 2010 LTMP (TtEC and URS 2010) stated that on-post plume-extent mapping will be used to evaluate the long-term progress of the remedy. Beginning in 2014, on-post plume-extent mapping for selected indicator analytes will be conducted on a 20-year frequency. Any impact on non-indicator analytes can only be inferred, but not substantiated with this program.

The last comprehensive RMA on-post plume mapping was conducted in 1994, and was considered to be pre-ROD baseline monitoring. Since the On-Post ROD was issued in 1996, the groundwater monitoring data collected under the LTMP are evaluated to determine the effectiveness of the remedial actions in achieving the ROD RAOs. The RAOs for on-post groundwater are described below.

The following RAOs for on-post groundwater, designed to satisfy the On-Post ROD (FWENC 1996) requirement for protection of human health and the environment, provide the objectives for capture and treatment of contaminated groundwater:

- Ensure that the boundary containment and treatment systems protect groundwater quality off post by treating groundwater flowing off RMA to the specific remediation goals identified for each of the boundary systems.

- Develop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems.

The 2010 LTMP did not include details for the plume mapping task, therefore, the Army, Shell, and the Regulatory Agencies entered into consultation in 2013 to develop the scope and objectives for this monitoring effort, which are captured in the 2014 On-Post Plume Mapping SAP (Navarro 2014b).

The 2010 LTMP included monitoring of groundwater water levels and water quality in on-post wells to track contaminant migration in and downgradient of source areas, and to demonstrate that the RAOs in the On-Post ROD (FWENC 1996) are met. Since most groundwater plumes emanate from sources where human health exceedance soils were left in place, the groundwater monitoring in the LTMP addresses the above ROD monitoring requirement. The RAOs in the On-Post ROD require meeting groundwater remediation goals at the RMA boundaries, but do not include criteria for aquifer restoration on post (i.e., lowering concentrations below remediation goals). Consequently, site-wide groundwater contaminant plume mapping on post does not have a ROD requirement, and has not been conducted since 1994. In order to periodically evaluate the status of the on-post groundwater contamination, the 2010 LTMP states that on-post plume-extent mapping will be used to evaluate the long-term progress of the remedy. The plume-extent mapping project will provide additional data in and downgradient of sources where human health exceedance soils were left in place, and thus, further support the evaluation of the effectiveness of the remedy in these areas.

Eight indicator analytes were selected in the 2010 LTMP and included DIMP, dieldrin, chloroform, benzene, NDMA, carbon tetrachloride, dithiane, and arsenic. DBCP subsequently was added to the indicator analyte list in the SAP. The analytes mapped in 1994 included chloride, fluoride, arsenic, DIMP, dieldrin, endrin, benzothiazole, summed chlorophenylmethyl sulfur compounds (CPMS, CPMSO, and CPMSO2), summed dithiane and oxathiane, parathion, 1,1-dichloroethyene, benzene, chlorobenzene, chloroform, DBCP, DCPD, tetrachloroethylene, toluene, trichloroethylene, and cyanazine (USGS 1997). NDMA was also mapped using 1993, 1994, and 1995 data (HLA 1996). Carbon tetrachloride is the only indicator analyte that was not mapped for 1994; however, a map of the 1994 data has been prepared for comparison to the 2014 data.

The Water Quality Tracking well network, which consists of 59 wells, is the site-wide well network that is used to monitor water quality in and downgradient of groundwater source areas to track concentration trends in the contaminant migration pathways, and to provide data to demonstrate that the RAOs are met. The Water Quality Tracking network is the primary network for the plume-extent mapping network. Most of the wells in the Water Quality Tracking network are sampled twice in five years, including in 2014. Sixteen wells in this network are sampled once in five years (last sampled in FY12), however, they were included in the 2014 plume mapping network. The plume-extent mapping network was expanded from the Water Quality Tracking network to include selected groundwater system performance and operational wells, and project-specific wells. These various groups of wells are monitored under existing monitoring programs. The wells most useful for plume-extent mapping in the existing monitoring programs were identified and included in the SAP (Navarro 2014b). In addition, 55 wells that are not sampled under existing programs were added to the plume-extent mapping network to better define plume edges, and includes wells within the interior and exterior of the historical plumes. Thus, a total of 180 wells are included in the SAP for water quality monitoring. It should be noted that all groundwater quality data for the indicator analytes collected under the existing monitoring programs in 2014 were used in mapping the plumes. Other relevant water quality data collected during 2014, such as treatment plant effluent data, was considered during evaluation and interpretation of the well data. After the 2014 water quality data were collected and evaluated, a second phase consisting of sampling 14 wells was conducted in 2015 to provide additional data in selected areas. The 2015 data were incorporated into the maps. A Data Summary Report (DSR) for the 2014 plume mapping task, including the 2015 data, was finalized in September of 2015.

Groundwater contaminant plumes have only been found to exist in the UFS, which is comprised of the alluvium and weathered, unconfined portion of the Denver Formation bedrock. Thus, monitoring of CFS wells in the confined Denver Formation is not within the scope of this task.

All sampling was conducted in accordance with the 2014 On-Post Plume Mapping Sampling and Analysis Plan (Navarro 2014b).

2.3.4 On-Post 1,4-Dioxane Characterization

1,4-dioxane has been classified as an emerging contaminant by the EPA. An emerging contaminant is defined as a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environment or a lack of published health standards. As historical 1,4-dioxane data are non-existent on the RMA, an investigation was necessary to assess the potential for 1,4-dioxane groundwater contamination at the RMA.

A new 1,4-dioxane standard was promulgated by the State of Colorado in 2005. The 2005 standard established a limit of 6.1 µg/L for 1,4-dioxane for groundwater. The groundwater standard was revised to 3.2 µg/L in March 2012 and 0.35 µg/L in January 2013. As 1,4-dioxane was not an identified COC at RMA, no historical data existed prior to 2011 to determine the presence of 1,4-dioxane in the RMA groundwater.

In general industry, 1,4-dioxane is used as a stabilizer for chlorinated solvents such as 1,1,1-trichloroethane, commonly known as TCA. Historical data for TCA in RMA groundwater is available and results exceeding the MRL have been reported. Note that TCA is listed as 111TCE in the RMAED. Given the industrial use of 1,4-dioxane as a stabilizer for TCA, the monitoring program was designed to sample selected wells with recent and historical TCA detections exceeding the MRL for TCA, including wells in and downgradient of TCA source areas. Wells located farther downgradient of TCA source areas, where TCA has not been detected historically, were also sampled.

In order to determine if 1,4-dioxane was present in RMA groundwater at concentrations exceeding the MRL, 18 wells were sampled in 2011. Sampling was conducted in accordance with the 1,4-Dioxane Investigation Sampling and Analysis Plan (URS 2012b). The well network included on-post wells where TCA had been detected during the recent period from 2009 through 2011 and wells located in and downgradient of potential TCA source areas. The selected wells are located in both the On-Post and Off-Post OUs. TCA detections in wells associated with non-RMA sources located south and west of RMA were outside the scope of this program.

The results of the 2011 investigation indicated that 1,4-dioxane contamination is present above the MRL both on-post and off-post of the RMA. In 2012, additional monitoring was conducted to characterize the horizontal and vertical extent of 1,4-dioxane in groundwater at the RMA and assess the concentrations in the treatment plant influent and effluent. Selected surface water sampling locations were also included to assess potential 1,4-dioxane contamination where surface water/groundwater interaction potentially occurs. In 2015, sampling of 12 additional wells was conducted to provide additional data in selected areas. The 2015 data were incorporated into the 1,4-dioxane plume map. Refer to Section 5.1.5.3 for discussion of the combined on-post 2012 and 2015 characterization results and plume map.

The well network included on-post and off-post water quality wells from existing well networks that were scheduled to be sampled in FY2012. 1,4-Dioxane was added to the analyte lists for FY2012 at the following locations:

- The influent and effluent at BANS, NBCS, NWBCS, OGITS, and RYCS for the FY2012 third quarter sample event
- Performance water quality wells (annual event) at BANS, NWBCS, NBCS, OGITS, and RYCS for FY2012
- LTMP water quality tracking wells (once in 5 years and twice in 5 years events)
- Off-post CSRG exceedance wells (twice in 5 years event)
- Confined Flow System wells (twice in 5 years event)
- Motor Pool/Irondale System and Groundwater Mass Removal post-shutoff wells (annual and twice in 5 years events)
- Selected wells downgradient of the NBCS and NWBCS (single event for 1,4-dioxane only)
- Selected on-post and off post surface water locations where surface water/groundwater interaction potentially occurs (single event for 1,4-dioxane only)

2.4 Surface Water Monitoring

During the multi-year period that contaminated soil areas have been excavated, surface water quality has been monitored as it enters and leaves the RMA site boundary as well as in the off-post area. During 2009, when contaminated soil was being excavated, no target analytes were detected in samples from the on-post First Creek surface water sampling sites near the north boundary. Further, all contaminated soil with concentrations above site-specific action criteria has either been removed and disposed in landfills or has been covered, thereby eliminating the potential for movement of contaminated soil to surface water. The soil remedy was completed by mid-2010.

An On-Post Short-Term Surface Water Sampling program was implemented in FY12 and continued in FY13 to confirm that surface water quality is not adversely impacted by cover soils during the establishment of cover vegetation and that groundwater plumes are not migrating into the lakes. Future surface water monitoring related to volume and flow (quantity) will be managed by USFWS beginning in FY11.

Surface water quality has been monitored by collecting and analyzing data from streams, ditches, lakes, and ponds at RMA since the late 1980s. The 2013 Surface Water Quality Monitoring Report (URS 2013) summarizes the surface water data collected since the On-Post ROD and Off-Post ROD were signed (FWENC 1996, HLA 1995).

Surface water monitoring programs were conducted at RMA to meet the ROD requirements for surface water monitoring. Long-term on-post monitoring was conducted through 2009. Off-post surface water monitoring, not including storm event monitoring, will continue to be conducted in accordance with the RAOs for surface water presented in the Off-Post ROD.

3.0 Off-Post Monitoring Programs

3.1 LTMP Monitoring

The 2010 LTMP (TtEC and URS 2010) identified the following eight monitoring categories that meet the monitoring requirements identified in the Off-Post ROD:

- **Compliance Monitoring**—Monitoring of treatment system effluent water, conducted to confirm that CSRGs are met by on-post and off-post treatment systems (no wells are monitored). Compliance is based on running averages for the last four quarters.
- **Pre-Shut-Off Monitoring**—Monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated. A program will be designed for each specific system.
- **Shut-Off Monitoring**—Water quality monitoring at containment systems that have met chemical concentration-based shut-off criteria defined by the RODs. Such monitoring is conducted for specified analytes for a period of five years to ensure that ARARs continue to be met. *This monitoring is to be conducted in accordance with a revised shut-off approach, with sampling frequencies reduced from the current quarterly sampling for 5 years to quarterly for the first and last years and annual in intervening years.*
- **Post-Shut-Off Monitoring**—Monitoring to track groundwater levels, flow directions, and water quality in the area after successful completion of the shut-off monitoring program and termination of system operation.
- **Off-Post Water Level Monitoring**—Water level monitoring off post conducted in support of the exceedance monitoring to assess flow paths and contaminant migration in the exceedance areas. *(Separated from "Water Level Tracking" because it serves a different purpose.)*
- **Operational Monitoring**—Monitoring of containment system extraction wells, recharge wells, recharge trench piezometers, and monitoring wells located near the systems to optimize system performance and ensure that Remedial Action Objectives are met. *Monitoring to evaluate whether individual extraction wells can be shut off or will remain shut-off is conducted under this program instead of the current 5-year shut-off monitoring.*
- **Exceedance Monitoring**—Long-term water quality monitoring of off-post groundwater, conducted in compliance with the Off-Post ROD, to assess contaminant concentration reduction and remedy performance and to create groundwater CSRG exceedance area maps to support well permit institutional controls The exceedance area maps are provided to the SEO and to Commerce City, city of Brighton, and Adams County officials for their use in issuing notifications to well permit applicants and for controlling inappropriate use of off-post water with contaminant concentrations exceeding CSRGs.
- **Surface Water Monitoring**—Off-post surface water monitoring to assess changes in surface water quality related to the RMA remedy.

Monitoring frequencies for the different categories and parameters are listed below:

Monitoring Category	Monitoring Parameter	Monitoring Frequency
Compliance	Water quality	Quarterly[2]
Pre-Shut-Off	Water quality[1]	Project Specific
Shut-off	Water quality[1]	Quarterly/Annual
Post-Shut-Off	Water level and water quality	Project Specific
Operational	Water level and water quality	Variable[3]
Off-Post Water Level Monitoring	Water level	Annual
Exceedance	Water quality[1]	Twice in 5 years
Surface Water	Water quality	Annual

[1] Water level measurements recorded but they were not the primary purpose of monitoring.
[2] Quarterly monitoring is reduced to semiannual or annual monitoring for analytes below CSRGs or PQLs in system influents.
[3] Refer to Section 3.2.

3.2 Operational Monitoring

As for the on-post systems, operational monitoring conducted for OGITS consists of monitoring system extraction wells, recharge wells, recharge trench piezometers, and monitoring wells located near the system. Data are collected from wells upgradient of and at the systems to optimize system performance and ensure that RAOs are met. Most of the wells are used for water level monitoring to ensure proper extraction system operation; selected wells are also used for water quality monitoring of indicator compounds. These monitoring data are used to evaluate and adjust the system to ensure optimal operation for containment, capture, and treatment. Effective system operation depends on water level and water quality data and monitoring frequencies are determined based on operational data needs. Depending on the type of data and operational need, frequencies may be weekly, monthly, quarterly, semiannually, or annually. As operating conditions change, the operational monitoring program may also change. The operational monitoring program, therefore, is flexible with respect to monitoring locations, frequencies, and chemical analyses. O&M Plans that address operation and monitoring are in place for each system and are updated as necessary. Operational monitoring data will continue to be evaluated and presented in the ASRs. Relevant information from these reports will be included or summarized in FYSRs.

3.3 Private Well Monitoring

In accordance with the 1997 Memorandum of Agreement (MOA) between Tri-County Health Department (TCHD) and the Army (PMRMA 1997), TCHD conducts sampling of private wells in the Off-Post OU. Private well sampling is conducted to meet the following objectives:

- Provide data to assess contaminant concentration reduction and remedy performance
- Sample new wells installed in the off-post area as required by the Off-Post ROD (HLA 1995)

- Sample existing wells in response to citizen requests
- Sample a selected group of Arapahoe Formation CFS wells to assess well integrity and potential cross contamination from the overlying unconfined aquifer

The private well monitoring program is modified as new wells are installed and citizen requests are received. According to the Off-Post ROD, owners of domestic wells with DIMP concentrations at or above the CBSG of 8 micrograms per liter (µg/L) will be provided with an alternate water supply. In addition, wells that create a pathway for vertical migration of contaminants from the UFS to the CFS will be closed if contaminant concentrations in these wells exceed remediation goals (provided the contaminants originated at RMA). To verify the suitability of their water supplies for use, owners of wells within the DIMP plume footprint as defined in the On-Post ROD (FWENC 1996) can request that their wells be included in the private well monitoring program that is conducted by TCHD with oversight from the Army. In addition, new wells installed in this area may be sampled to determine their water quality. When requests for sampling are received, TCHD recommends and the Army approves the private wells to be included in this program.

As of September 2014, there were 580 off-post private wells in use or used seasonally for irrigation, drinking water supplies, and other domestic purposes. An off-post private well may be selected for sampling based on its use, location, construction characteristics, and historical sampling information, as well as public concern with regard to RMA-related contaminants.

3.4 Other Groundwater Monitoring

3.4.1 Off-Post 1,4-Dioxane Characterization

Refer to Section 2.3.4 for discussion of the FY11 and FY12 off-post 1,4-dioxane investigations.

3.5 Surface Water Monitoring

According to the RMAED, DIMP is the only RMA organic groundwater contaminant detected off post at concentrations above both the CBSMSW and CSRG at station SW37001 (First Creek at Hwy. 2 north of RMA) since 1991. At First Creek station SW24004, located at the north boundary of RMA, there is little groundwater/surface water interaction and DIMP has never been detected. At SW37001, DIMP is detected at elevated concentrations during low-flow conditions (i.e., approximately 0.5 cubic ft per second [cfs] or less), which is when groundwater is discharging into the creek bed. In accordance with the Off-Post ROD, off-post surface water monitoring is conducted to evaluate the effect of groundwater treatment on surface water quality. This is best evaluated under low-flow conditions and so sampling during these conditions will be emphasized in the future. Conducting storm event monitoring at SW37001 also was specified in the Off-Post Remediation Scope and Schedule (RS/S) (HLA 1996). However, the purpose of monitoring storm events is to evaluate the effects of runoff and higher flows in First Creek. Since the on-post soil remedy is complete and all soil contamination has been placed in landfills or is under soil covers, surface water contamination from runoff is not likely. Therefore, sampling of First Creek will occur during low-flow conditions, and monitoring of storm events at SW24004 and SW37001 will be discontinued. Surface water monitoring of storm events on-post is continuing under the On-Post Short-Term Surface Water Monitoring Program.

As specified in the 2010 LTMP (TtEC and URS 2010), in order to continue to evaluate the effect of groundwater treatment on surface water quality in the Off-post OU, which is not monitored during storm events, surface water quality monitoring will continue at SW24004 (First Creek at the north fence line) and off-post site SW37001 (First Creek at Highway 2). An upstream sampling location (SW08003), where First Creek flows onto RMA, was added in FY13 to provide data to compare to the two downstream sites (see Figure 5.1.3.3-1 for the LTMP surface water locations). Annual surface water quality samples will be collected at these sites when there is low flow in First Creek. Typically, this occurs during the spring or summer. The target analyte list was expanded from arsenic and DIMP in FY13 to include aldrin, arsenic, chloride, dieldrin, DIMP, NDMA, and sulfate. The requirements for sampling can be found in the 2010 LTMP, Section 6.3. However, in FY13 several changes were implemented, including the addition of the upstream monitoring location, field parameters for sample collection, and the sample analyte list (OCN-LTMP-2014-001). Sampling in FY14 was conducted in accordance with the Long-Term Monitoring Plan for Groundwater and Surface Water Sampling and Analysis Plan (Navarro 2014c).

4.0 Progress Since Last Review

The 2010 FYRR (TtEC 2011a) identified four water-related issues with corresponding recommendations for follow-up actions to be addressed during the 2010–2015 FYR period. Table 4.0-1 provides a status of the follow-up actions taken for these issues and Sections 4.1 through 4.3 provide additional detail on each of them. The issues are further assessed against the 2010 FYRR recommendations in the 2015 FYRR.

Table 4.0-1. Status of Follow-Up Actions to Address 2010 FYR Issues

2010 FYRR Issue	Description of Issue	Recommendation	Follow-Up Action
DNAPL discovery in Lime Basins	Presence of DNAPL in Lime Basins	Perform RI/FS to recommend remedy; prepare CECRLA Decision Document for remedy selection.	Completed RI/FS and Remedial Design. Remedy selection was documented in an ESD, which was approved Jan. 6, 2012. EPA accepted the Lime Basins DNAPL Remediation Project CCR on Sept. 5, 2014.
OGITS Gamma Chlordane MRL above CSRG	The gamma chlordane MRL was above the CSRG of 0.03 µg/L during part of the previous FYR period.	Change the MRL during the next laboratory re-certification.	The gamma chlordane MRL was lowered to 0.0185 µg/L in 2011.
Establishing Site-Specific PQLs	The existing process for determining PQLs/MRLs was identified as an issue for the compounds for which the PQLs remain above the CSRGs in part because Army has used an MRL-based approach, which differs from industry practice. Establishing site-specific PQLs remained a continuing issue for the FYR period as the PQL Study Report was not finalized and new PQL values were not established at the end of the 2005–2010 FYR period.	Complete PQL Study Report and establish new PQL values for NDMA, aldrin, and dieldrin based on regulatory approval.	A PQL Work Plan and a PQL study were completed. PQL studies were conducted in accordance with 40 CFR 136 Appendix B Colorado State PQL Guidance. The revised determination process was documented in an ESD, which was approved in Sept. 2012. The new PQLs are documented in the Decision Document issued in 2011 and the Study Report issued in Feb. 2012. CDPHE approved the PQL Study Report and adoption of the PQLs on April 12, 2012.

Table 4.0-1. Status of Follow-Up Actions to Address 2010 FYR Issues (Concluded)

2010 FYRR Issue	Description of Issue	Recommendation	Follow-Up Action
Potential inclusion of 1,4-dioxane in RMA ARARs	1,4-Dioxane is a constituent of TCA, which is an RMA contaminant. Recent improvements to analytical methods have allowed 1,4-dioxane detection in the parts per billion range beginning in 1997. Analysis of 1,4-dioxane often must be specifically requested. The common practice of analyzing by a limited list of available methods for regulatory compliance has precluded detection of 1,4-dioxane. Although TCA has been detected occasionally in RMA groundwater, the detections have been very limited in extent and very low in concentration.	Evaluate existing and historical information, as well as additional groundwater samples to determine whether 1,4-dioxane should be added to the RMA ARAR list. Prepare a technical memorandum to document evaluation and decision.	1,4-Dioxane characterization was conducted during the FYR period to determine the horizontal and vertical extent in groundwater, both on-post and off-post. Data evaluation and remedy decision still need to be completed.

4.1 DNAPL Discovery in Lime Basins

As discussed in the 2010 FYRR, DNAPL consisting of 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, chlorobenzene, and DCPD was discovered in Lime Basins dewatering wells in August 2009. This finding constituted new principal threat contamination that required further investigation according to CERCLA.

An RI/FS was conducted to determine whether there were any impacts on the Lime Basins remedy and whether any follow-up actions were needed.

The remedy for Lime Basins DNAPL consists of:

- Operation of dewatering wells in accordance with the goals and standards specified in the ROD Amendment (TtEC 2005). Treatment of groundwater at BANS to meet CSRGs.
- Monthly DNAPL measurement and removal of recoverable quantities of DNAPL from the sumps of six dewatering wells. DNAPL monitoring and recovery frequency may be modified based on changes in the rate of DNAPL accumulation, following consultation with and approval from the Regulatory Agencies.
- Installation of four monitoring-well pairs along the east and west segments of the slurry wall to facilitate water level measurement, DNAPL detection, and analyses of the five DNAPL-related compounds (1,2-dichlorobenzene, 1,3-dichlorobenzene,

1,4-dichlorobenzene, chlorobenzene, and dicyclopentadiene) that will allow for the evaluation of slurry wall performance and further refinement of the delineation of DNAPL source zones at these locations.

- Following the installation of the four new monitoring-well pairs and the resumption of pumping of the dewatering wells, quarterly water level measurements, DNAPL measurement (and removal, where appropriate), and volatile organic compound (VOC) analyses (including the five DNAPL-related compounds) will be performed at the following monitoring and dewatering wells:

  - Monitoring Wells-36231, 36232, 36233, 36234, 36235, and 36236
  - Dewatering Wells-36315, 36316, 36317, 36318, 36319, and 36320

- Semi-annual water level measurements, DNAPL measurement (and removal, where appropriate), and VOC analyses (including the five DNAPL-related compounds) will be performed at the following monitoring wells:

  - 36054, 36212, 36237, 36238, 36239, 36240, 36241, and the eight new wells

Following completion of the FS, an ESD was prepared to document the selected remedy (TtEC 2011a). The ESD documents and provides the rationale for the selected remedy described above as a change to the ROD. The eight new monitoring wells were installed in September 2012. After the first year of monitoring, data were collected in FY13 and evaluated; the monitoring program was modified for FY14 and subsequent years according to OCN-LTMP-2014-001.

4.2 OGITS Gamma Chlordane MRL above CSRG

The gamma-chlordane MRL was above the CSRG of 0.03 µg/L during a portion of the previous FYR period. The chlordane method was recertified in 2011, and the gamma chlordane MRL was lowered to 0.0185 µg/L.

4.3 Establishing Site-Specific Practical Quantitation Limits

The On-Post ROD identifies the site-specific PQLs as "(c)urrent certified reporting limit or practical quantitation limit readily available from a commercial laboratory." This process for determining PQLs/MRLs was identified as an issue for the compounds for which the PQLs remain above the CSRGs in part because Army has used an MRL-based approach that differs from industry practice. The ongoing changes to the RMA analytical programs and advancements in analytical technology suggested that it would be beneficial to follow a standardized procedure to re-evaluate the PQLs. Therefore, the Army recommended that the approach for establishing site-specific PQLs be revised and that a procedure for site-specific PQLs be developed. Agreement was reached with the Regulatory Agencies that PQL studies would be conducted in accordance with 40 CFR 136 Appendix B and CDPHE PQL guidance for compounds for which MRLs exceed CSRGs.

The PQL study was completed in 2010 for three compounds for which the existing MRLs exceeded the CSRGs; aldrin, dieldrin, and NDMA. New PQLs were calculated in accordance with the PQL Work Plan and CDPHE Guidance and were established as follows:

- Aldrin 0.014 µg/L
- Dieldrin 0.013 µg/L
- NDMA 0.009 µg/L

Agreement was reached for the PQL values for aldrin and dieldrin; however, there were concerns regarding NDMA based on the limited data used to develop the new PQL. Therefore, agreement was reached to use an interim PQL for NDMA set at twice the calculated PQL value. This interim treatment value of 0.018 µg/L was adopted as the PQL for NDMA with a requirement to evaluate the NDMA data in the 2015 FYR to determine whether the data support removal of the interim PQL. The determination of removal of the interim PQL will be made in the 2015 FYRR. The revised PQLs were adopted with approval from CDPHE on April 12, 2012. The revised PQL determination process was documented in an ESD (TtEC 2012a).

4.4 Potential Inclusion of 1,4-Dioxane in RMA ARARs

The need to determine whether the 1,4-dioxane CBSG should be included in the RMA ARARs has been identified as a FYR issue. In recent years, regulators have become aware that 1,4-dioxane is likely to be present at sites where 1,1,1-trichloroethane (1,1,1-TCA, methyl chloroform) is a contaminant. Although 1,4-dioxane has been a constituent of TCA wastes for decades, recent improvements to analytical methods have allowed its detection in the parts per billion range beginning in 1997. Analysis of 1,4-dioxane must be specifically requested. The common practice of analyzing by a limited list of available methods for regulatory compliance has precluded detection of 1,4-dioxane. Although 1,1,1-TCA has been detected occasionally in RMA groundwater, the detections have been very limited in extent and very low in concentration, as is the case at the present time. Moreover, because there is no complete pathway for exposure to RMA groundwater contamination, there is no expected impact on remedy protectiveness even if 1,4-dioxane is present.

To confirm that 1,4-dioxane does not pose an unacceptable human health risk in RMA groundwater, existing and historical information, as well as potential additional groundwater samples, will be evaluated by the RVO and Regulatory Agencies to determine whether the 1,4-dioxane CBSG should be added to the RMA list of ARARs. Evaluation of the 1,4-dioxane standard, effect on remedy protectiveness, and recommendation on whether to adopt the standard is ongoing and is included as an issue in the FYRR.

5.0 Five-Year Review Process

This section presents data collected in the on-post and off-post groundwater and surface water monitoring programs.

5.1 On-Post Data Review, Evaluation, and Assessment

The on-post data review includes evaluations of the following:

- Groundwater monitoring results and operational data for groundwater containment and mass removal systems
- Groundwater monitoring results for project-specific groundwater monitoring programs associated with the soil remedy
- Groundwater monitoring results for site-wide monitoring programs conducted according to the LTMP
- Surface water monitoring results

All chemical data included in this assessment have been determined to meet the quality requirements for usability. The chemical data were validated in accordance with the processes outlined in the RVO CQAPs or the Rocky Mountain Arsenal Sampling Quality Assurance Project Plan (SQAPP) that were in effect at the time of sampling (RVO 2009, Navarro 2014a) as well as the related applicable procedures.

The data validation results for data collected during the FYR period is presented in the Annual Summary Reports (ASRs).

5.1.1 On-Post Containment and Mass Removal System Evaluation

The ASRs are referenced for information regarding the effectiveness of the groundwater extraction and treatment systems (RVO 2011, 2012, Army and Shell 2013, Navarro 2015a and 2015b). The information in the ASRs is summarized for each system in the following sections addressing treatment system effluent compliance monitoring, hydraulic gradients and water level monitoring results, and downgradient performance or operational well water quality monitoring results.

The Off-Post OU RS/S (HLA 1996) established evaluation criteria for the boundary and off-post groundwater systems. These systems are performing effectively if the following conditions are met:

- Concentrations in the treatment plant effluent are below the respective CSRGs
- Acceptable hydraulic gradients are maintained
- Contaminant concentrations in downgradient monitoring wells generally decrease over time

Conformance wells selected in the Off-Post RS/S (HLA 1996) were included in the 1999 LTMP (FWENC 1999). The conformance well category in the 1999 LTMP was replaced by the performance well category in the 2010 LTMP. The 2010 LTMP (TtEC and URS 2010) established performance criteria for all the groundwater systems based on upgradient, downgradient, and cross-gradient performance well networks for monitoring water levels and water quality for each system.

Tables are provided for each system that summarize treatment system information and downgradient well water quality data. The treatment system summaries include flow rates, volumes of water treated, contaminant removal, carbon usage, and annual costs. The treatment plant influent concentration data indicate the general trends in plume concentrations upgradient of the system. Selected CSRG analytes, representing the more widespread contaminants and/or those comprising the majority of the contaminant mass upgradient of the systems, are discussed for each system. The 2010 LTMP includes performance monitoring of water quality in upgradient monitoring wells instead of the extraction wells to obtain data more representative of the plume concentrations upgradient of each system. Beginning in FY10, monitoring of upgradient performance wells was conducted, instead of extraction well monitoring. The upgradient performance well data are provided in Appendix A.

5.1.1.1 Northwest Boundary Containment System

The primary performance requirement for the original NWBCS is to maintain a reverse hydraulic gradient across the system and to ensure plume-edge capture. The secondary performance requirement is that downgradient performance wells are at or below the CSRGs/PQLs, or show decreasing concentration trends. For the Original System, the concentration trend is determined over the previous period of at least five years.

Figure 5.1.1.1-1 is the well location map for the NWBCS. As documented in the ASRs for the FYR period, except for dieldrin, no CSRG or PQL exceedances in the NWBCS treatment plant effluent were detected. Dieldrin concentrations were above the new PQL during the third quarter of FY12. Treatment plant operations were changed and the dieldrin concentrations were at or below the PQL during the remainder of FY12, FY13, and FY14.

Reverse hydraulic gradients and plume capture were maintained. Except for dieldrin, no concentrations above CSRGs/PQLs were detected in the downgradient performance wells during the review period. Dieldrin concentrations were above the PQL in one or more downgradient performance wells in FY12, FY13, and FY14. Table 5.1.1.1-1 shows that the annual contaminant removal ranged from 3.1 to 5.3 pounds (lbs). The NWBCS mass removal is most affected by chloroform concentrations in the NWBCS influent, which have varied year-to-year, but been relatively stable overall.

Table 5.1.1.1-1. NWBCS Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2010	822	432,488,791	3.8	Chloroform 2.8 Dieldrin 0.9 Endrin 0.1	55,400	$619,769
2011	776	405,993,440	4.1	Chloroform 3.0 Dieldrin 0.9 Endrin 0.1	32,100	$637,960
2012	858	454,185,398	5.3	Chloroform 3.7 Dieldrin 1.1 Endrin 0.2	35,700	$814,583
2013	896	464,836,884	3.1	Chloroform 1.6 Dieldrin 1.2 Endrin 0.02	41,700	$565,012
2014	924	485,650,266	3.5	Chloroform 2.4 Dieldrin 0.9 Endrin ketone 0.1	54,300	$563,189
Total	855 (avg.)	2.24 billion	19.8		219,200	$3,200,513

Table 5.1.1.1-2 summarizes the downgradient performance well data for all the CSRG analytes. Except for dieldrin, concentrations were below CSRGs/PQLs for all eight performance wells throughout the FYR period. Beginning in FY12, after the PQL change became effective in April 2012, the dieldrin concentrations were above the PQL in one or more of the Original System and NEE downgradient performance wells. The NEE downgradient performance wells show decreasing trends for dieldrin, which meets the secondary performance goal.

Based on a November 15, 2014 evaluation provided to the Regulatory Agencies, the dieldrin concentrations were above the PQL in the NWBCS downgradient performance wells during the FYR period because of a variety of factors: 1) mobilization of residual dieldrin in the aquifer sediments downgradient of the slurry wall, which was caused by rising regional water levels; 2) dieldrin concentrations have been slightly above, at, or near the PQL in the NWBCS effluent during the FYR period; and 3) a small amount of contaminated flow from the NEE area may be migrating toward one of the downgradient performance wells.

The downgradient performance wells for the Original System are sampled annually and have only been sampled three times with the new MRL. Prior to FY12, the dieldrin results were less than the MRL of 0.03 µg/L and less than the previous PQL of 0.05 µg/L. If the censored data for FY10 and FY11 are used in the trend evaluation, the results would be biased. Hence, Army and Shell prefer not to use the censored data for determining the trend. Thus, additional dieldrin data are needed for evaluating the secondary performance criterion. Furthermore, additional operational changes in treatment may be necessary to lower the treatment plant effluent concentrations, which should help lower the downgradient well concentrations of dieldrin.

Potential treatment changes include pulsing more carbon, using virgin carbon instead of regenerated carbon, evaluating the effects of desorption of dieldrin from carbon fines during sample extraction and analysis, and defining of the treatment system.

Table 5.1.1.1-2. Overview of CSRG Analyte Sampling from NWBCS Downgradient Performance Wells

CSRG Analyte[1] (The concentration in parentheses is the CSRG/PQL for the respective analyte)		Concentrations at or above the CSRG or PQL/Number of Samples Collected							
		Section 27/SWE	Off Post (Original System)					Section 22/NEE	
		27522	37330	37331	37332	37333	37600	22015	22512
Arsenic	(2.35 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Chloroform	(6 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Diisopropylmethyl phosphonate (DIMP)	(8 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dieldrin[a]	(0.002/0.013 µg/L)	0/5	2/5	3/6	4/6	2/5	3/5	3/5	8/21
Endrin	(2 µg/L)	0/5	0/5	0/6	0/6	0/5	0/5	0/5	0/21
Isodrin	(0.06 µg/L)	0/5	0/5	0/6	0/6	0/5	0/5	0/5	0/21
n-Nitrosodimethylamine (NDMA)[b]	(0.007/0.018 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Trichloroethylene (TCE)	(3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5

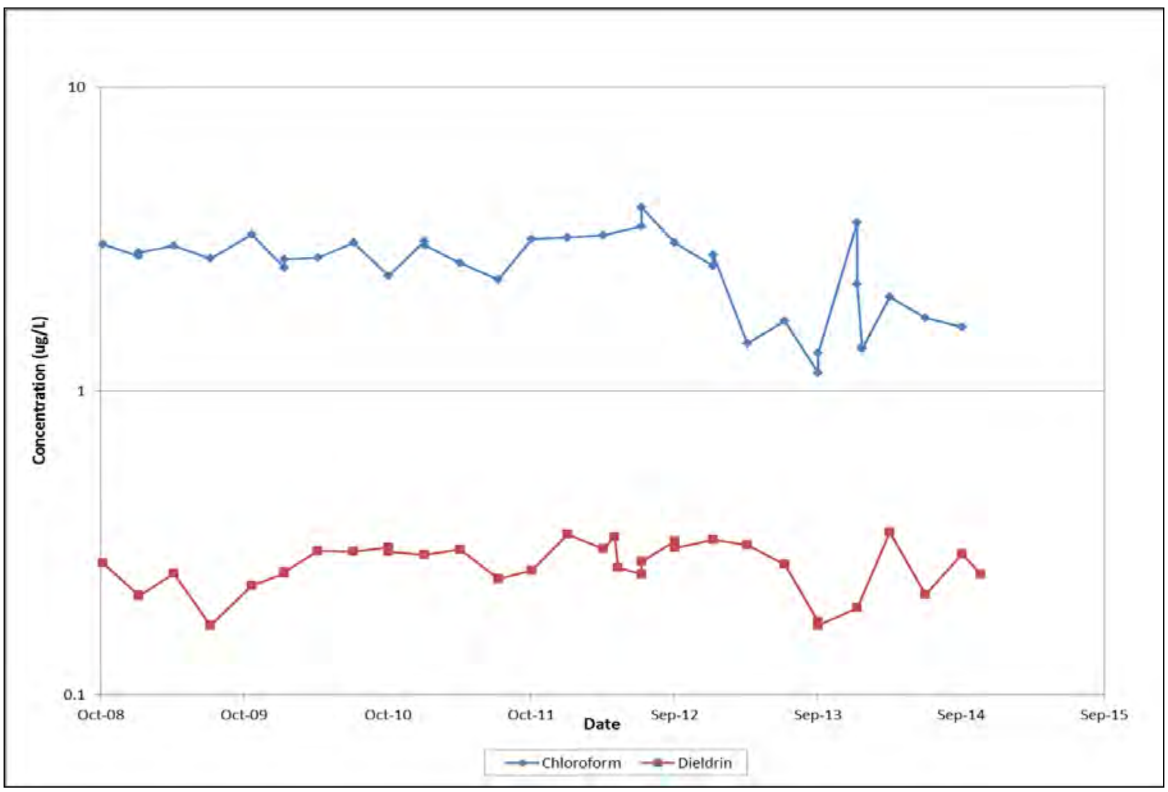
Notes: SWE = southwest extension NEE = northeast extension

[1] The ROD lists the following certified reporting limits or PQLs as readily available: [a] PQLs = 0.05, 0.013 µg/L(eff. 4/2012) [b] PQLs =0.033, 0.018 µg/L (eff. 4/2012)

The treatment plant influent concentration data indicate the general trends in plume concentrations upgradient of the system. Influent concentration graphs for selected analytes from FY09 (previous FYR period) through FY14 are provided for each system. Chloroform and dieldrin are the CSRG analytes of greatest extent upgradient of the NWBCS. Chloroform concentrations in the NWBCS influent were stable overall from FY10 to FY12, and then showed a decreasing trend. During the FYR period, the chloroform concentrations ranged from 1.15 to 4.01 µg/L, averaging 2.54 µg/L (Figure 5.1.1.1-2). These influent concentrations are below the CSRG of 6 µg/L, but chloroform concentrations were still above the CSRG in two of the upgradient performance wells (22008 and 22043) in FY14. Sampling of the NWBCS extraction wells was discontinued in FY10 and upgradient performance wells were sampled instead. Well concentration plots for indicator analytes for the upgradient performance wells for each system are provided in Appendix A. The plots show the distribution of concentrations of selected CSRG analytes in a transect upgradient of the extraction (dewatering) wells. Single-year performance well plots are included in the annual ASRs, but the plots in Appendix A show FY10 (top graph) and FY14 (bottom graph) for each analyte for comparison during the FYR period. Figure A-1 in Appendix A shows that the chloroform concentrations in the upgradient performance wells decreased between FY10 and FY14, similar to the influent trend. The highest concentrations of chloroform occur in wells 22043, 22008, 22053, and 22081. The migration pathways to the Southwest Extension (well 27517 and 27516) and NEE (well 22505) do not contain chloroform concentrations above the CSRG.

Dieldrin concentrations in the NWBCS influent were stable during the FYR period, ranging from 0.169 to 0.342 µg/L, averaging 0.275 µg/L (Figure 5.1.1.1-2). These influent concentrations are above the ROD PQL of 0.05 µg/L and revised PQL of 0.013 µg/L (effective April 2012), and dieldrin concentrations were above the new PQL in all of the upgradient performance wells in FY14. Figure A-2 shows the upgradient performance wells in FY10 and FY14. Wells 27010 and 27516 are cross-gradient wells. The dieldrin concentrations in the upgradient wells were relatively stable. These stable trends in the performance well concentrations are consistent with the stable trend in the influent. The highest concentrations of dieldrin occur in wells 22043, 22008, 22053, and 22081, which are located upgradient of the Original System extraction wells. Upgradient well 27500 is located near the edge of the Original System capture zone and had a decreasing dieldrin trend during the FYR period, and has decreased overall since 1998. This decreasing trend in well 27500 is consistent with a long-term trend in upgradient monitoring wells that indicates the dieldrin plume has been shifting eastward, likely because of source depletion and remedy activities. The eastward shift of the western edge of the plume makes the NWBCS more robust, and reduces the potential for migration of dieldrin around the end of the system. The dieldrin concentrations in the Southwest Extension upgradient performance well (27517) have been below the former PQL of 0.05 µg/L since 2004 and have been slightly above the new PQL of 0.013 µg/L since FY12.

Figure 5.1.1.1-2. NWBCS Influent Concentrations for Chloroform and Dieldrin



NWBCS Evaluation Conclusions

Based on criteria in the On-Post and Off-Post RODs, Off-Post RS/S, and 2010 LTMP, the NWBCS appears to be functioning as intended in the Decision Documents. Concentrations were below CSRGs/PQLs in the treatment plant effluent, except for dieldrin in the third quarter of FY12. The reverse hydraulic gradient and plume capture were maintained. Except for dieldrin, the contaminant concentrations were below CSRGs/PQLs in the downgradient performance wells.

Dieldrin was detected above the PQL at various times in the five Original System downgradient performance wells that are located off-post, but the long-term trend cannot be determined due to the changes in the MRL and PQL. Operational changes were implemented during FY12 and FY13 that improved the NWBCS performance for meeting the new dieldrin PQL, but additional treatment changes may be needed. The potential treatment changes include more frequent pulsing of carbon, using virgin carbon instead of regenerated carbon, evaluation of desorption of dieldrin from carbon fines during sample extraction and analysis, and removing carbon fines (defining) throughout the system. The NWBCS had no CSRG/PQL analyte exceedances of the four-quarter moving averages in the treatment system effluent after FY12. The NWBCS appears to be functioning as intended, but additional monitoring data are needed to confirm that all the performance criteria are being met.

5.1.1.2 North Boundary Containment System

The primary performance requirement for the NBCS is to maintain a reverse hydraulic gradient across the system in the alluvium and to ensure plume-edge capture. Plume-edge capture at the NBCS can be verified by inspection of the water-table map. Water-table contours indicate that groundwater flow is being captured at the edges of the system. The secondary performance requirement is that downgradient performance wells are at or below the CSRGs/PQLs, or show decreasing trends.

Figure 5.1.1.2-1 is the well location map for the NBCS. As documented in the ASRs for the FYR period, there were no CSRG/PQL exceedances of the four-quarter moving averages in the treatment plant effluent during the review period, including chloride and sulfate. Aldrin and dieldrin exceeded the new PQLs once during the third quarter of FY12. Chloride concentrations in the NBCS effluent averaged 192,000 µg/L, and sulfate averaged 467,500 µg/L, during the review period. Fluoride concentrations in the NBCS effluent averaged 1.78 mg/l during the FYR period, and were at the CSRG of 2 mg/L four times (April 5, 2010, January 6, 2011; July 12, 2012, and January 6, 2014). The reverse hydraulic gradient and plume capture were maintained during the FYR period.

Table 5.1.1.2-1 shows that the annual contaminant removal decreased from 8.6 to 7.0 lbs. This decreasing trend was caused by decreases in upgradient concentrations that were reflected in the plant influent and upgradient performance wells.

Table 5.1.1.2-1. NBCS Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2010	199	104,560,923	8.6	DIMP 4.4 DCPD 0.9 Chloroform 1.1 Carbon tetrachloride 1.0 Dieldrin 0.35 PCE 0.04	60,000	$721,422
2011	231	121,414,432	9.7	DIMP 5.4 DCPD 0.8 Chloroform 1.3 Carbon tetrachloride 1.0 Dieldrin 0.2 PCE 0.5	60,000	$843,470
2012	237	125,635,032	11.9	DIMP 5.7 DCPD 0.9 Chloroform 1.4 Carbon tetrachloride 0.9 CPMSO2 1.2 Dieldrin 0.3 PCE 0.6	60,000	$1,081,413
2013	233	121,949,160	6.8	DIMP 3.4 DCPD 0.6 Chloroform 0.5 Carbon tetrachloride 0.5 Dieldrin 0.3 TCE 0.1 PCE 0.7 Endrin 0.01	40,000	$754,221
2014	216	114,570,012	7.0	DIMP 2.6 CPMSO 1.4 DCPD 0.5 Chloroform 0.6 Carbon tetrachloride 0.3 PCE 0.5 Dieldrin 0.3 TCE 0.1 Endrin 0.2	40,000	$479,448
Total	223 (avg.)	588.1 million	44		260,000	$3,879,974

Table 5.1.1.2-2 summarizes the downgradient performance well data for all the CSRG analytes. Concentrations of several analytes were above CSRGs/PQLs in the downgradient performance wells during the FYR period, including chloride, dieldrin, DIMP, fluoride, and sulfate.

Table 5.1.1.2-2. Overview of CSRG Analyte Sampling from NBCS Downgradient Performance Wells

CSRG Analyte[1] (The concentration in parentheses is the CSRG/PQL for the respective analyte)		**Concentrations above the CSRG or PQL/Number of Samples Collected**										
		Section 23				**Section 24**						**Off Post**
		23405	**23434**	**23436**	**23438**	**24004**	**24006**	**24415**	**24418**	**24421**	**24424**	**37362**
1,2-Dichloroethane	(0.40 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
1,2-Dichloroethylene	(70 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
1,4-Oxathiane	(160 µg/L)	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A	N/A
Aldrin[a]	(0.002/0.014 µg/L)	0/5	0/5	0/5	0/5	0/5	1/5	0/5	0/5	0/5	0/5	0/5
Arsenic	(2.35 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Atrazine	(3 µg/L)	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	(3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Carbon tetrachloride	(0.3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Chloride	(250 mg/L)	0/5	4/4	3/4	0/4	0/5	0/5	0/5	1/5	0/5	3/5	0/5
Chloroform	(6 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Dibromochloropropane (DBCP)	(0.2 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Dicyclopentadiene (DCPD)	(46 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Dieldrin[b]	(0.002/0.013 µg/L)	4/5	2/5	0/5	0/5	5/5	4/5	5/5	5/5	2/5	3/5	1/5
Diisopropylmethyl phosphonate (DIMP)	(8 µg/L)	4/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Dithiane	(18 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Endrin	(2 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Fluoride	(2 mg/L)	0/5	5/5	3/5	2/5	0/5	2/5	1/5	3/5	1/5	3/5	4/5
Isodrin	(0.06 µg/L)	0/5	0/5	0/5	0/5	0/5	1/5	0/5	0/5	0/5	0/5	0/5
Malathion	(100 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	(5.0 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
n-Nitrosodimethylamine[c]	(0.007/0.018 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Chlorophenylmethyl sulfide	(30 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chlorophenylmethyl sulfone	(36 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chlorophenylmethyl sulfoxide	(36 µg/L)	0/1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfate	(540 mg/L)	0/5	5/5	4/5	0/5	0/5	0/5	0/5	1/5	0/5	2/5	0/5

Table 5.1.1.2-2. Overview of CSRG Analyte Sampling from NBCS Downgradient Performance Wells (Concluded)

CSRG Analyte[1] (The concentration in parentheses is the CSRG or PQL for the respective analyte)		**Concentrations above the CSRG or PQL/Number of Samples Collected**										
		Section 23				**Section 24**						**Off Post**
		23405	**23434**	**23436**	**23438**	**24004**	**24006**	**24415**	**24418**	**24421**	**24424**	**37362**
Tetrachloroethylene (PCE)	(5 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Toluene	(1,000 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Trichloroethylene (TCE)	(3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Xylenes	(1,000 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5

Notes:
[1] The ROD lists the following certified reporting limits or PQLs as readily available:
[a] PQLs = 0.05, 0.014 µg/L [b] PQLs = 0.05, 0.013 µg/L [c] PQLs = 0.033, 0.018 µg/L (lower PQLs effective April 2012)

As noted in the 2005 and 2010 FYRRs, these downgradient detections in the former conformance wells and performance wells are not representative of system effectiveness, but indicate that residual contamination was present and migrated to these areas before the NBCS was installed in 1981 and/or before the reverse hydraulic gradient was established across the entire length of the slurry wall in 1992. Additionally, some of the detections occur where the groundwater flows through finer-grained aquifer sediments where the groundwater moves much more slowly than in other areas. The concentration trends in the downgradient performance wells observed during this FYR period are decreasing or stable, and are consistent with the evaluation in the 2005 and 2010 FYRRs. Some of the performance wells have only been sampled three times and the trend in these wells cannot be determined. No other explanations for the downgradient detections in the performance wells (e.g., underflow or bypass) are feasible. The following discussion summarizes the evidence supporting the conclusions in the 2005 and 2010 FYRRs regarding the downgradient detections in the performance wells. These conclusions were re-evaluated based on additional data collected since the 2005 and 2010 FYRRs and are still valid.

The NBCS was completed in 1981, but a reverse hydraulic gradient was not established along the entire length of the slurry wall until 1992. Underflow likely occurred in portions of the system until 1992, which may have increased contaminant concentrations in the unconfined Denver Formation in the western part of the NBCS where older remnant contamination has been identified. For example, DIMP concentrations in unconfined Denver well pair 23540/23541 have been significantly higher than the contemporaneous concentrations in upgradient extraction wells. These wells are located at the bend in the slurry wall. DIMP concentrations similar to the highest concentrations in wells 23540 (2,700 µg/L in 2000) and 23541 (1,700 µg/L in 2002) occurred in upgradient alluvial wells in 1977 and 1979, which indicates this contamination has been stagnant in wells 23540/23541 for over 30 years. In the 2005 FYRR, an analysis using historical chloride concentration trends indicated that the chloride present in downgradient former conformance well 37339 between 1985 and 2005 migrated past the future location of the NBCS slurry wall between 1968 and 1973, about 10 years before the NBCS was installed. Since chloride is a conservative contaminant, these timeframes represent approximate groundwater travel times of between 17 and 32 years from the NBCS (well 23001) to well 37339. Using an average travel time of 25 years, the contaminated groundwater that was downgradient of the NBCS when it was completed in 1981 would not reach well 37339 until 2006. The effects of establishing the reverse gradient in 1992 would not affect well 37339 until about 2017. Thus, based on these estimates, concentrations of chloride, DIMP, fluoride, and sulfate above the CSRGs in former conformance well 37339 and the downgradient performance wells during this FYR period (Table 5.1.1.2-2) appear to represent contamination that predated installation of the NBCS. The DIMP concentrations in well 37339 decreased to below the CSRG on a consistent basis beginning in 2004, which strongly agrees with these estimates. This is additional evidence that contaminant concentrations in former conformance well 37339 and in the downgradient performance wells are not representative of current system performance.

In many cases, the contaminant concentrations were high in the groundwater that migrated off post before the NBCS was installed. The maximum concentrations at or downgradient of the north boundary for selected analytes (chloride [3,400,000 μg/L]; DIMP [11,900 μg/L]; dieldrin [6.76 μg/L]; fluoride [10,000 μg/L]; and sulfate [3,100,000 μg/L]) may have been higher before monitoring began. These high concentrations likely caused substantial residual contamination to be retained in the aquifer sediments that may act as continuing sources of groundwater contamination that impact the downgradient former conformance and performance wells.

The NBCS effluent concentrations have been consistently below the CSRGs for the affected analytes, so inadequate treatment is not a possibility. Although the alluvium and unconfined Denver Formation are combined in the UFS, they are discussed separately because they have different hydraulic and chemical properties that are relevant to this discussion. With very few exceptions, a reverse hydraulic gradient has consistently been maintained in the alluvium for the entire length of the NBCS since 1992, so bypass of contaminants in the alluvium is not a likely scenario. Many more contaminants are present at concentrations above CSRGs upgradient than are detected downgradient. If bypass were occurring, these other contaminants likely would also be detected downgradient, but they are not detected.

Underflow of contaminants in the underlying Denver Formation bedrock is not likely because flat to reverse hydraulic gradients are present in the contaminated unconfined Denver well pairs in the western part of the system. The unconfined Denver well pairs were installed in the western part of the system because shallow to subcropping Denver sandstones are present beneath the slurry wall in that portion, and the slurry wall was not keyed as deeply in the bedrock as in the eastern portion. There was, therefore, greater concern for evaluating potential underflow in the western portion. The Denver well pairs were installed at or near the mid-points between recharge trenches because this is the worst-case location for monitoring the reverse hydraulic gradient. By inference, if a reverse gradient exists in the unconfined Denver bedrock in the western portion of the system, a reverse gradient would likely also exist in the eastern portion. Additionally, the analytes detected in upgradient unconfined Denver wells are not consistent with the analytes detected downgradient, so underflow is not likely.

Underflow of contaminants also is not likely because an upward hydraulic gradient from the unconfined Denver Formation to the alluvium exists on the extraction side of the slurry wall in most of the alluvial/unconfined Denver well pairs in the western part of the system. This upward gradient is induced by pumping of the alluvial extraction wells. Alluvial/Denver monitoring-well pairs, with adjacent alluvial and unconfined Denver wells on both sides of the slurry wall are present in the western part of the system. Again by inference, if pumping of the alluvial extraction wells creates an upward gradient from the unconfined Denver to the alluvium exists in the western portion of the system, pumping of the alluvial extraction wells would also create an upward gradient in the eastern portion.

Underflow of contaminants in the CFS of the Denver Formation, which underlies the Denver UFS, is not likely because the CFS wells at the NBCS are uncontaminated.

The concentrations are above CSRGs only for certain analytes and only in certain areas. The alluvial aquifer is not homogeneous downgradient of the NBCS slurry wall and ranges from sand to silt to clay. In places, the alluvium is unsaturated and the groundwater migrates through bedrock claystones, siltstones, and thin, discontinuous sandstones. The organic carbon content of the alluvial aquifer and bedrock sediments also is not homogeneous, and varies by three orders of magnitude. The organic carbon content of the aquifer sediments affects adsorption/desorption rates of organic contaminants. The organic carbon content of the alluvium in downgradient former conformance well 37338 is known to be high, and likely is causing or contributing to the persistent detections of dieldrin in this well and in downgradient performance wells.

Seasonal variation in groundwater levels near First Creek of more than 5 ft probably is mobilizing residual dieldrin from higher portions of the alluvium downgradient of the NBCS slurry wall. The water table was higher when contaminants were migrating off post before the NBCS was installed. Flow in First Creek recharges the groundwater and affects the groundwater levels. Since 2000, the groundwater elevations in wells at the NBCS near First Creek have risen about 10 ft, likely because of increased flows in First Creek that are caused by development and increased runoff south (upstream) of RMA. This trend in water levels correlates with an increasing trend in dieldrin concentrations in well 37338.

The concentrations of a few analytes above CSRGs/PQLs in some of the downgradient wells are caused by a combination of desorption of dieldrin downgradient of the NBCS slurry wall in areas of higher organic carbon content in the aquifer sediments; very slow migration of DIMP, chloride, fluoride, and sulfate in finer-grained sediments (silts, clays, and claystones) in the alluvium and Denver Formation bedrock in the western part of the system; and natural occurrence of sulfate in the Denver Formation. Gypsum crystals ($CaSO_4$) frequently are observed in Denver well borelogs. This groundwater contamination was already present downgradient of the system when it was installed and it is taking longer to flush out than for other contaminants and longer than in other areas where the aquifer is more permeable and where the organic carbon content is lower.

To monitor wells that potentially are more representative of system performance, the downgradient performance well network was revised in the 2010 LTMP. The concentration trends in the revised well network and the representativeness of the selected wells were evaluated during the current FYR period. Prior to FY13, the NBCS downgradient former conformance wells were also sampled for comparison to the current downgradient performance wells. The water quality data in the downgradient performance wells were similar to data from the former conformance wells, and the performance wells were retained. With agreement from the Regulatory Agencies, sampling of the former conformance wells was discontinued in FY13 according to OCN-LTMP-2013-001.

Although the concentrations are above CSRGs/PQLs in some of the downgradient performance wells, several wells display decreasing concentration trends. Figures 5.1.1.2-2 and 5.1.1.2-3 show concentration trends for selected wells and analytes. The wells in Figure 5.1.1.2-2 are UFS Denver Formation wells where the elevated DIMP concentrations are older remnant contamination that is migrating in finer-grained sediments. The wells either show decreasing trends overall or they are below the CSRG, which indicates that the operation of the NBCS is reducing contamination, albeit more slowly than in the overlying alluvium. Figure 5.1.1.2-3 shows dieldrin concentrations in the downgradient performance wells where dieldrin is typically detected. The dieldrin concentrations either are decreasing overall or stable in these wells.

Figure 5.1.1.2-2. Time Concentration Plot for Wells 23194, 23195, 23235, 23540, 23541, 23542, 23543, and 24191

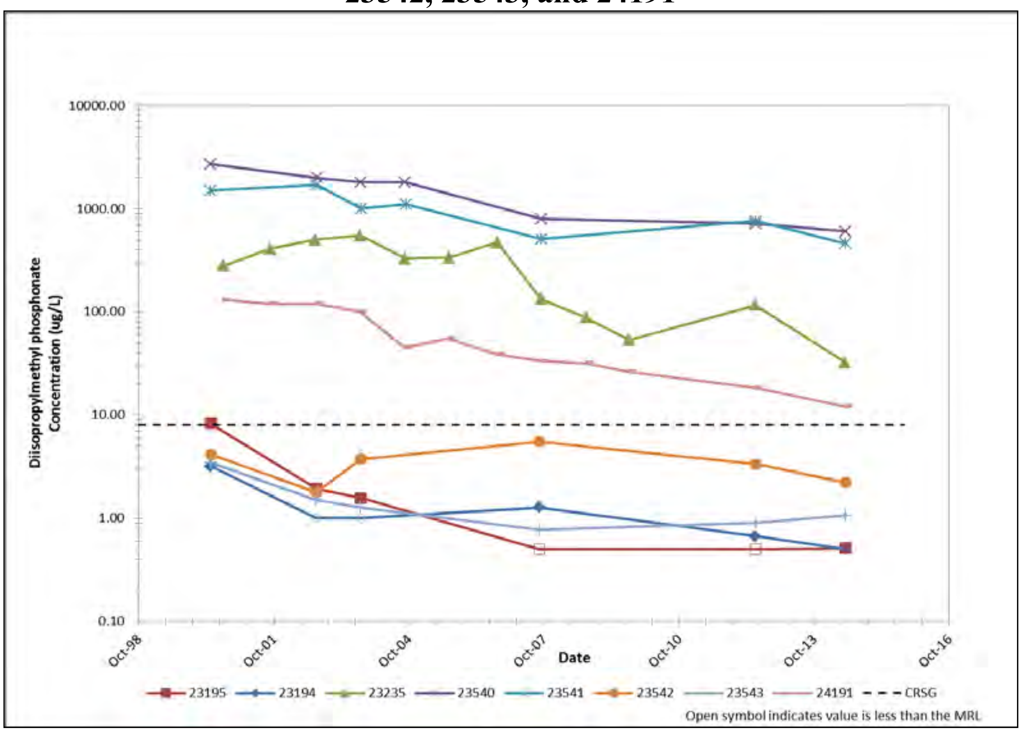
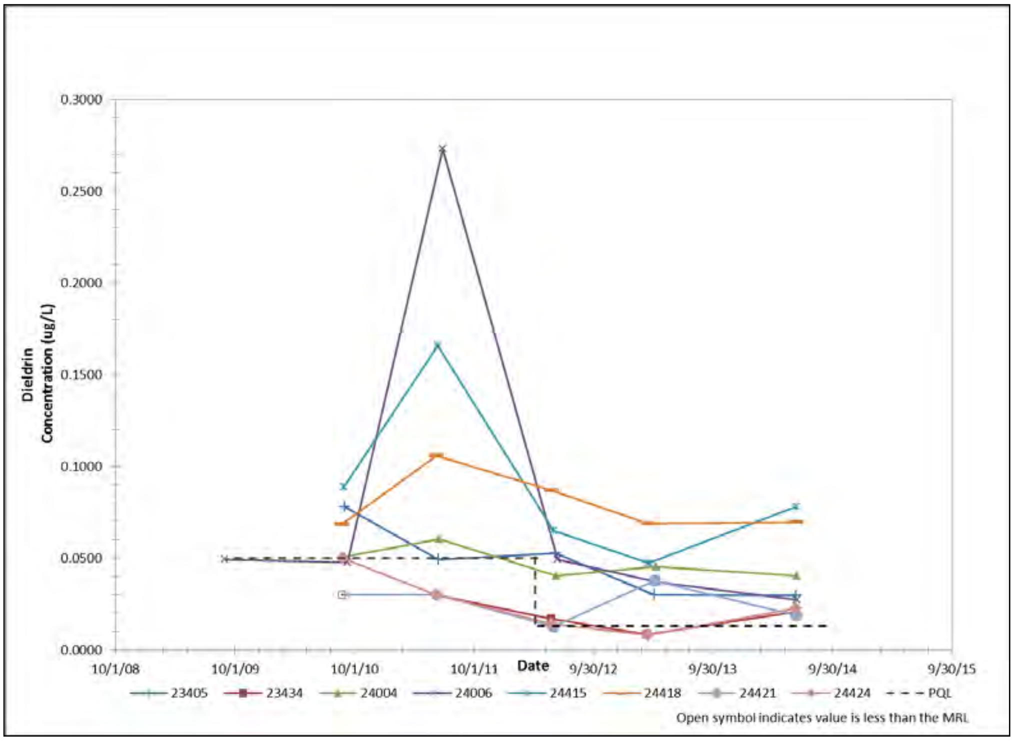


Figure 5.1.1.2-3. Time Concentration Plot for Wells 23405, 23434, 24004, 24006, 24415, 24418, 24421, and 24424



At the Regulatory Agencies' request, the hydrogeology in the area north of the NBCS slurry wall, where the former conformance wells and current downgradient performance wells are located, was evaluated to compare the two groups of wells and better understand the associated water quality data. This evaluation is in Appendix B and the conclusions and recommendation are provided below.

1. Similar mechanisms causing concentrations of a few CSRG analytes to be above the CSRGs/PQLs appear to apply both to the former conformance wells and the current downgradient performance wells. These mechanisms appear unrelated to system effectiveness.

2. Some of the downgradient performance wells are former recharge wells. The NBCS recharge wells were installed in uniform spacing parallel to the slurry wall and distance from the slurry wall to create a reverse hydraulic gradient along the length of the slurry wall. The variation in the lithology along the recharge well alignment indicates that the design of the recharge well array was independent of the hydrogeology. The corresponding conformance and performance wells generally were completed in similar lithologic units. Sometimes the former conformance well is in a more permeable unit and sometimes the current performance well/former recharge well is in a more permeable unit. Therefore, the assumption that the recharge wells were installed in more permeable areas is incorrect.

3. The assumption that flushing of the contaminants occurred in the vicinity of the former recharge wells that now are performance wells also appears incorrect. While the more mobile contaminants such as DIMP may have been effectively flushed from the aquifer sediments, the flushing of the more sorptive compound dieldrin appears incomplete. The data suggest that flushing of one of the former recharge wells (23438) may have been greater than the corresponding conformance well (23198), but the flushing of the other former recharge wells is not indicated.

4. As stipulated in the 2010 LTMP, when the primary performance criteria are met, the NBCS is functioning as intended. The mechanisms causing the downgradient concentrations of a few analytes to be above the CSRGs/PQLs appear to be unrelated to system performance. Therefore, when the primary criteria are met, the NBCS is functioning as intended, and the downgradient performance well water quality data should be reported, but not considered in the NBCS performance evaluations. Army and Shell recommend that the LTMP be revised accordingly.

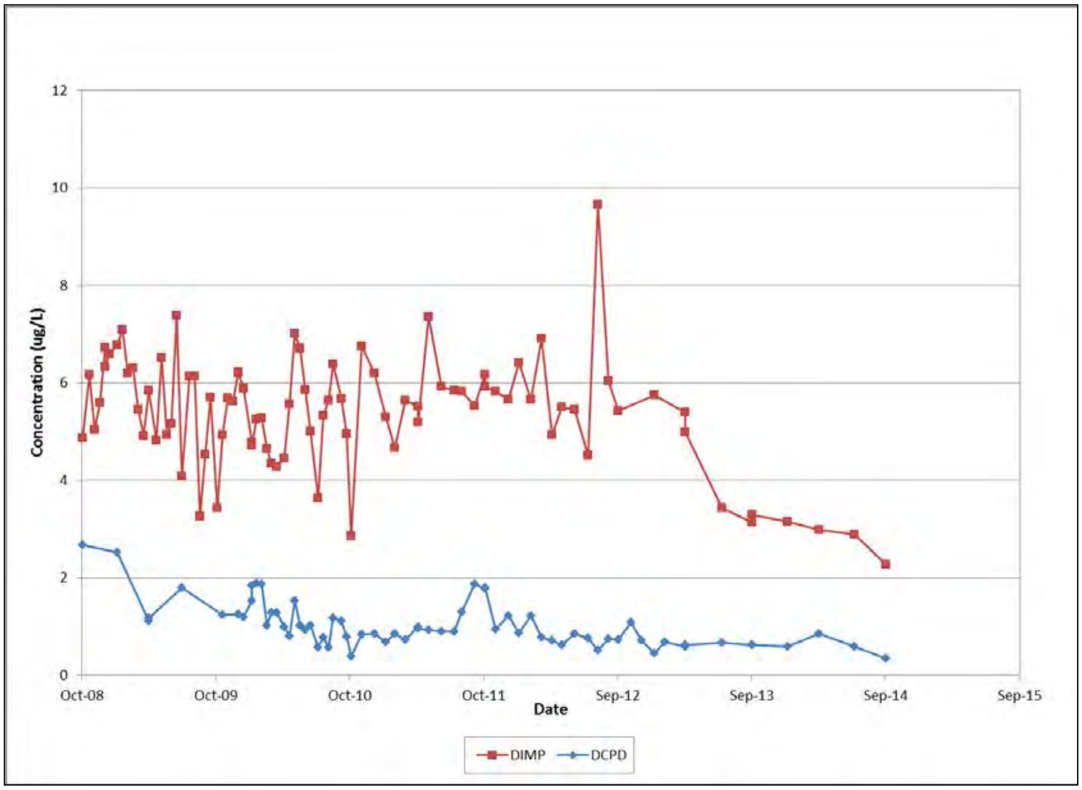
5. Changes to the downgradient performance well network are recommended based on the evaluation in Appendix B. The proposed revisions to the downgradient performance well network and rationale are as follows:

   a. Replace well 23405 with 23253; stagnant zone near well 23405, no borelog for well 23405.
   b. Replace well 24006 with 24412; lower fines content and more permeable aquifer at 24412.
   c. Replace well 24418 with 24163; lower fines content and more permeable aquifer at 24163.
   d. Replace well 24421 with 24164; lower fines content and more permeable aquifer at 24164.
   e. Replace well 37362 with 24429; lower fines content and more permeable aquifer at 24429.

The treatment plant influent concentration data indicate the general trends in plume concentrations upgradient of the system. DIMP, dieldrin, and dicyclopentadiene (DCPD) are the organic CSRG analytes of greatest extent upgradient of the NBCS. As stated in the On-Post ROD, the concentrations of chloride and sulfate, which are inorganic compounds not treated by the NBCS, will meet CSRGs in the NBCS effluent by attenuation, and also are discussed below. Most of the CSRG analytes showed decreasing concentration trends during the FYR period.

DIMP concentrations in the NBCS influent decreased steadily during the FYR period, averaging 5.3 μg/L in FY10 and 3.1 μg/L in FY14 (Figure 5.1.1.2-4). Except for one sample, the influent concentrations for the FYR period were below the CSRG of 8 μg/L. The influent graphs include FY09 data from the previous FYR period. In FY14, the DIMP concentrations were above the CSRG in 2 of the 11 upgradient NBCS performance wells. Figure A-3 shows the upgradient performance well concentrations for DIMP in FY10 and FY14. The performance wells are oriented from west (left) to east (right). The DIMP FY14 concentrations decreased significantly in all wells containing detectable DIMP in FY10, consistent with the decreasing influent trend. The highest concentrations occur in the western part of the system, where the saturated alluvium is only a few feet thick and the wells pump at low flow rates. The thickness of the saturated alluvium increases to the east of well 23160 and the extraction wells pump at higher flow rates. The DIMP concentrations are below the CSRG on the eastern side of the system. Pumping of wells in this area is needed to provide sufficient water for maintaining the reverse hydraulic gradient for the whole system. The majority of the DIMP plume migrates to the NBCS from the former Basins C and F area; a minor component migrates from North Plants.

Figure 5.1.1.2-4. NBCS Influent Concentrations for DIMP and DCPD



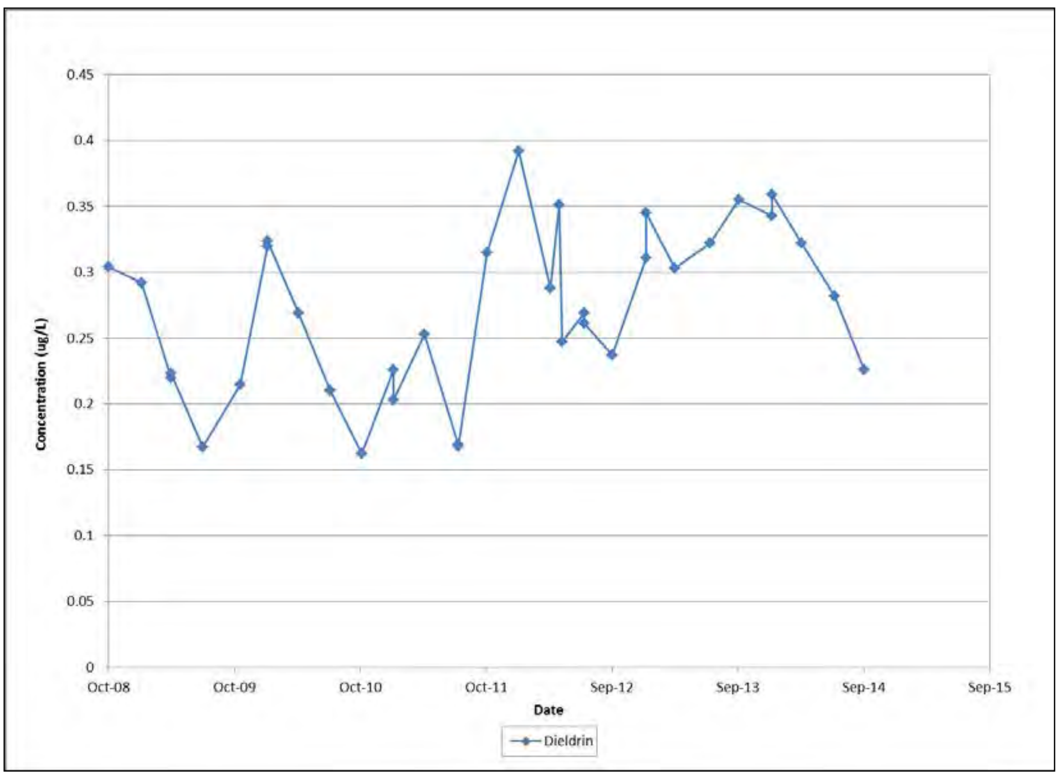
DCPD concentrations in the NBCS influent decreased overall during the FYR period, ranging from about 1 µg/L in FY10 to 0.66 µg/L in FY14, averaging 0.87 µg/L (Figure 5.1.1.2-4), which is well below the CSRG of 46 µg/L. In FY10 and FY14, the DCPD concentrations were below the CSRG in all NBCS upgradient performance wells. Figure A-4 shows that the DCPD concentrations in two of the three upgradient performance wells with detections were lower in FY14 than in FY10, consistent with the influent trend. The highest DCPD concentrations occur in the western part of the system, but they are below the CSRG. The DCPD plume migrates to the NBCS from former Basin F.

Dieldrin concentrations in the NBCS influent increased overall during the FYR period, ranging from 0.25 µg/L in FY10 to 0.0.33 µg/L in FY14, averaging 0.279 µg/L (Figure 5.1.1.2-5). These influent concentrations are above the PQLs of 0.05 and 0.013µg/L, and dieldrin concentrations were above the PQL in nine of the 11 NBCS upgradient performance wells in FY14. Figure A-5 shows that the dieldrin concentrations in most wells were higher in FY14, consistent with the increasing trend in the influent concentrations.

The long-term trend in dieldrin concentrations in the NBCS influent is downward, but the short-term trend during the FYR period was slightly upward. Between 2009 and 2014, the groundwater elevations upgradient of the NBCS were two to four feet higher (Figure 5.1.3-7), which may explain the increase in dieldrin concentrations in the influent due to mobilization of additional dieldrin from the previously unsaturated aquifer sediments. Overall, the dieldrin concentrations in the NBCS plant influent have been relatively stable, consistent with the less soluble and less mobile nature of dieldrin compared to the more mobile contaminants that have shown decreases in concentrations in the influent.

As with DIMP, the highest dieldrin concentrations occur in the western part of the system, and the concentrations are below the PQL on the eastern side. The dieldrin plume migrates to the NBCS from the former Basins C and F area.

Figure 5.1.1.2-5. NBCS Influent Concentrations for Dieldrin



Other contaminants present upgradient of the NBCS include chloroform, carbon tetrachloride, NDMA, chloride, and sulfate. Chloroform concentrations in the NBCS influent decreased overall during the FYR period, ranging from 1.35 µg/L in FY10 to 0.68 µg/L in FY14, averaging 1.15 µg/L, which is below the CSRG of 6 µg/L. Chloroform concentrations were above the CSRG in only 1 of the 11 upgradient performance wells in FY10 and no wells in FY14). The chloroform plume migrates to the NBCS from former Basin F and the North Plants area.

Carbon tetrachloride concentrations in the NBCS influent decreased from 1.29 µg/L in FY10 to 0.44 µg/L in FY14 during the FYR period, averaging 0.87 µg/L. In FY14, the carbon tetrachloride concentrations in 3 of the 11 upgradient performance wells were above the CSRG. Figure A-6 shows that carbon tetrachloride concentrations in two of the three wells above the CSRG were lower in FY14 Figure A-6 shows that the carbon tetrachloride plume has two components; one is present at well 24201 and the second is present at wells 24185 and 24117. Carbon tetrachloride migrates to the NBCS from the North Plants area and eastern RMA.

The NDMA concentrations in the NBCS influent were relatively stable from FY10 to FY14, averaging 0.015 µg/L, which is below the former PQL of 0.033 µg/L and current PQL of 0.018 µg/L. In FY14, the NDMA concentrations in two of the 11 upgradient performance wells were above the PQL. Figure A-7 shows that the performance well concentrations were similar or lower in FY14, consistent with the stable trend in the influent. The highest NDMA concentrations occur in the western part of the system, and the plume migrates to the NBCS from former Basin F.

The chloride concentrations in the NBCS influent were relatively stable during the FYR period, and averaged 186,500 µg/L, which is below the CSRG of 250,000 µg/L. In FY14, the chloride concentrations exceeded the CSRG in four of the 11 upgradient performance wells. Figure A-8 shows that the chloride concentrations were higher in two performance wells and stable in the other nine wells, consistent with the stable trend in the influent. The highest chloride concentrations occur in the western part of the system, and the plume migrates to the NBCS from the former Basins C and F area.

Sulfate concentrations in the NBCS influent were about the same at the beginning and end of the review period, averaging 467,500 µg/L, which is below the CSRG of 540,000 µg/L. In FY14, the sulfate concentrations exceeded the CSRG in six of the 11 upgradient performance wells. Figure A-9 shows that the sulfate concentrations in the performance wells were similar in FY10 and FY14. The highest sulfate concentrations occur in the western part of the system, and the plume migrates to the NBCS from the former Basins C and F area.

NBCS Denver Formation Well Evaluation

Evaluation of the NBCS includes additional elements, such as lateral and vertical hydraulic gradients in 14 Denver Formation UFS wells (seven well pairs), water quality monitoring in three Denver UFS well pairs, and water quality monitoring in two other Denver UFS wells and three CFS wells. The 2010 LTMP changed the Denver UFS well-pair sampling program based on the status of the reverse gradients in the well pairs. Four of the well pairs typically have reverse hydraulic gradients and sampling was discontinued, provided the reverse gradients are maintained. Water quality monitoring in the other three Denver UFS well pairs was retained because they have flat to forward gradients. Water levels in the Denver Formation UFS wells are measured quarterly. The three Denver Formation UFS well pairs and the three CFS wells were sampled in 2012 and 2014. Denver UFS wells 23235 and 24191 are located farther downgradient from the NBCS slurry wall and were sampled in 2012 and 2014.

The lateral and vertical hydraulic gradients in the unconfined Denver Formation wells were similar to those noted in the previous FYR, with reverse gradients in most unconfined Denver Formation well pairs, and flat to small forward or small reverse gradients in three well pairs (23194/23195, 23540/23541, and 23542/23543). An upward hydraulic gradient from the unconfined Denver Formation to the alluvium indicates that there is hydraulic containment with depth. An upward hydraulic gradient exists in most well pairs on the extraction-well side of the slurry wall.

An upward gradient is present intermittently in the well pair at the bend in the slurry wall (23533/23541). Flat, small downward, and small upward gradients were present during portions of each fiscal year during the FYR period (Figure 5.1.1.2-6). The average vertical gradient was upward with a head differential of 0.09 ft, although the recent gradients have been downward more frequently. No changes occurred during the FYR period that would affect the NBCS effectiveness, however.

Figure 5.1.1.2-6. NBCS Vertical Gradient Head Differential between Wells 23541 (Denver) and 23533 (Alluvial)

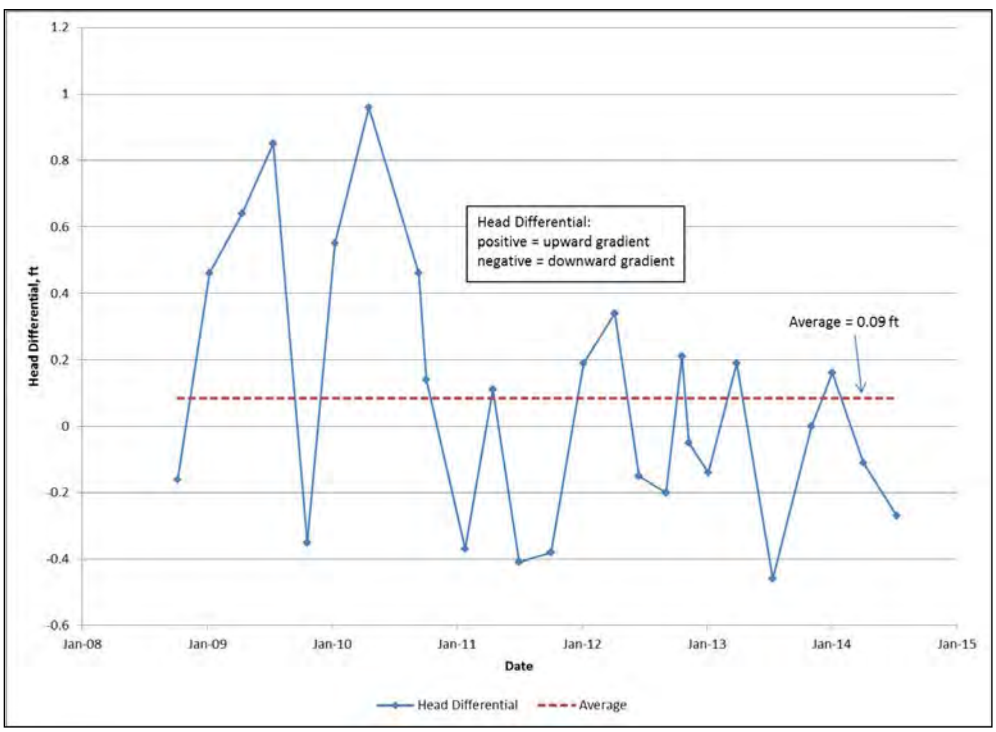


Table 5.1.1.2-3 summarizes the water quality data collected for the Denver Formation UFS and CFS wells where the concentrations were near or above CSRGS/PQLs. The wells are listed in order from west to east along the slurry wall and the position relative to the slurry wall is indicated (N = north/downgradient, S = south/upgradient). The typical hydraulic gradient for the Denver Formation UFS well pairs is indicated for the south-side well. Concentration data from the previous FYR period (collected in 2007 or 2009) are shown for comparison with the current period.

Wells 23536, 23537, 23538, 23539, 23138, 23126, 23242, and 23243 were not sampled during this FYR period per the changes in the LTMP. The reverse gradients were maintained in these well pairs.

In the Denver Formation UFS well pairs that were sampled during this FYR period, the concentrations for most of the analytes decreased; the majority of the detections above CSRGs were for chloride and sulfate. Concentrations of aldrin and DIMP decreased in wells 23540 and 23541. Carbon tetrachloride was detected intermittently in wells 23194 and 23195. Only a few increases in concentrations occurred during the FYR period: sulfate increased slightly in well 23543, and dieldrin increased in wells 23540 and 23541. Historically, aldrin has been detected intermittently in well 23540, and detected less frequently in other wells in this area.

Table 5.1.1.2-3. Summary of Concentrations above CSRGs/PQLs in Unconfined and Confined Denver Formation Wells

Well	Hydraulic Gradient	Analyte	Concentration (µg/L)		
Denver UFS Wells			**2009**	**2012**	**2014**
23536 (N)		Sulfate	1,910,000	—	—
23537 (S)	Reverse	Chloride	247,000	—	—
		Sulfate	2,060,000	—	—
23538 (N)		Sulfate	1,240,000	—	—
23539 (S)	Reverse	Sulfate	1,330,000	—	—
23138 (N)		Chloride	243,000	—	—
23126 (S)	Reverse	Chloride	348,000	—	—
		Sulfate	695,000	—	—

Table 5.1.1.2-3. Summary of Concentrations above CSRGs in Unconfined and Confined Denver Formation Wells (Continued)

Well	Hydraulic Gradient	Analyte	Concentration (µg/L)		
Denver UFS Wells			2009	2012	2014
23540 (N)		Aldrin	0.143	0.135	0.0314
		Chloride	531,000	518,000	530,000
		DIMP	796	711	601
		Dieldrin	LT 0.0356	0.105	0.0416
23541 (S)	Flat/forward	Aldrin	0.0843	0.113	LT 0.0029
		Chloride	529,000	559,000	502,000
		DIMP	509	760	460
		Dieldrin	LT 0.0356	0.0741	0.0413
23194 (N)		Carbon tetrachloride	0.405	LT 0.2	LT 0.263
		Chloride	423,000	226,000	243,000
		Sulfate	1,320,000	800,000	1,040,000
23195 (S)	Flat/reverse	Carbon tetrachloride	LT 0.2	0.354	LT 0.263
		Chloride	385,000	420,000	395,000
		Sulfate	1,070,000	1,090,000	1,060,000
23542 (N)		Sulfate	1,040,000	903,000	928,000
23543 (S)	Forward	Chloride	313,000	305,000	295,000
		Sulfate	1,080,000	1,050,000	1,110,000
23242 (N)		1,2-dichloroethane	1.73	—	—
		Chloride	383,000	—	—
		DIMP	327	—	—
		Dieldrin	0.141	—	—
		NDMA	0.0145	—	—
		Sulfate	658,000	—	—
		PCE	4.25	—	—
23243 (S)	Reverse	1,2-dichloroethane	9.05	—	—
		Chloride	330,000	—	—
		DIMP	550	—	—
		Dieldrin	0.278	—	—
		NDMA	0.0425	—	—
		Sulfate	590,000	—	—
		PCE	12.1	—	—

Table 5.1.1.2-3. Summary of Concentrations above CSRGs in Unconfined and Confined Denver Formation Wells (Concluded)

Well	Hydraulic Gradient	Analyte	Concentration (µg/L)		
Denver UFS Wells		**Analyte**	**2009**	**2012**	**2014**
23235	Not applicable (NA)	1,2-dichloroethane	1.14	0.667	0.404
		Chloride	563,000	537,000	1,240,000
		DIMP	53.7	116	32.4
		Sulfate	590,000	575,000	1,160,000
24191	NA	DIMP	26.3	18.3	12.1
Denver CFS Wells		**Analyte**	**2009**	**2012**	**2014**
23161	NA	Sulfate	1,210,000	1,040,000	1,050,000
23200	NA	NDMA	0.0137	0.0102	LT 0.00116
24171	NA	None	—	—	—

For the Denver UFS wells farther north of the slurry wall (wells 23235 and 24191), 1,2-dichloroethane concentrations decreased to the CSRG in well 23235, and DIMP decreased in both wells. Chloride and sulfate had anomalously high concentrations in well 23235 in 2014.

For the CFS wells, sulfate, which is naturally occurring in the Denver Formation, decreased in well 23161. NDMA concentrations were below the 2012 PQL of 0.018 µg/L and decreased to below the MRL of 0.00116 µg/L in well 23200. This decreasing trend for NDMA in well 23200 is consistent with the 2005 FYRR, which concluded that contamination may have been introduced when the well was installed and has since been attenuating. In well 24171, there were no detections of organic contaminants and the inorganic compounds were well below CSRGs.

NBCS Evaluation Conclusions

Based on criteria in the On-Post and Off-Post RODs, Off-Post RS/S, 1999 LTMP, and 2010 LTMP, the NBCS is functioning as intended in the Decision Documents. The four-quarter moving averages were below the CSRGs/PQLs in the treatment plant effluent. The reverse gradient and plume capture were maintained. The contaminant concentrations are decreasing or are below CSRGs/PQLs in the downgradient performance wells that are representative of system performance. Residual contamination in downgradient wells is still above CSRGs/PQL in a few wells, but this contamination is not representative of current system effectiveness. The concentrations are also decreasing in most of these wells. The downgradient performance wells selected in the 2010 LTMP were found to be comparable to the former conformance wells. With Regulatory Agency approval, sampling of the former conformance wells was discontinued in FY13. Replacing five of the downgradient performance wells in the performance well network with other wells that may be more suitable is proposed.

5.1.1.3 Railyard Containment System

Figure 5.1.1.3-1 is the well location map for the RYCS. As documented in the ASRs, there were no CSRG exceedances in the RYCS treatment plant effluent, plume capture was maintained, and there were no concentrations above the CSRG in the downgradient wells monitored during the FYR period. Table 5.1.1.3-1 shows that the annual contaminant removal ranged from 0.001 to 0.008 lb. DBCP is the only contaminant in the Railyard Plume.

Table 5.1.1.3-1. RYCS Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2010	119	62,435,744	0.005	DBCP 0.005	2,200	$120,000
2011	117	61,304,540	0.008	DBCP 0.008	2,200	$173,230
2012	116	60,831,612	0.005	DBCP 0.005	0	$148,682
2013	115	60,920,614	0.001	DBCP 0.001	0	$137,982
2014	114	59,786,431	0.007	DBCP 0.007	2,200	$105,962
Total	116 (avg.)	305.3 million	0.026	DBCP 0.026	6,600	$685,856

The RYCS performance water quality well network in the 2010 LTMP includes upgradient, cross-gradient, and downgradient wells. Table 5.1.1.3-2 summarizes the water quality data for downgradient and cross-gradient performance wells. Wells 03001, 03527, 03529, and 03530 are located downgradient of the extraction wells, and wells 03507, 03508, 03509, and 04506 are downgradient of the recharge wells. No DBCP concentrations were above the CSRG in these wells.

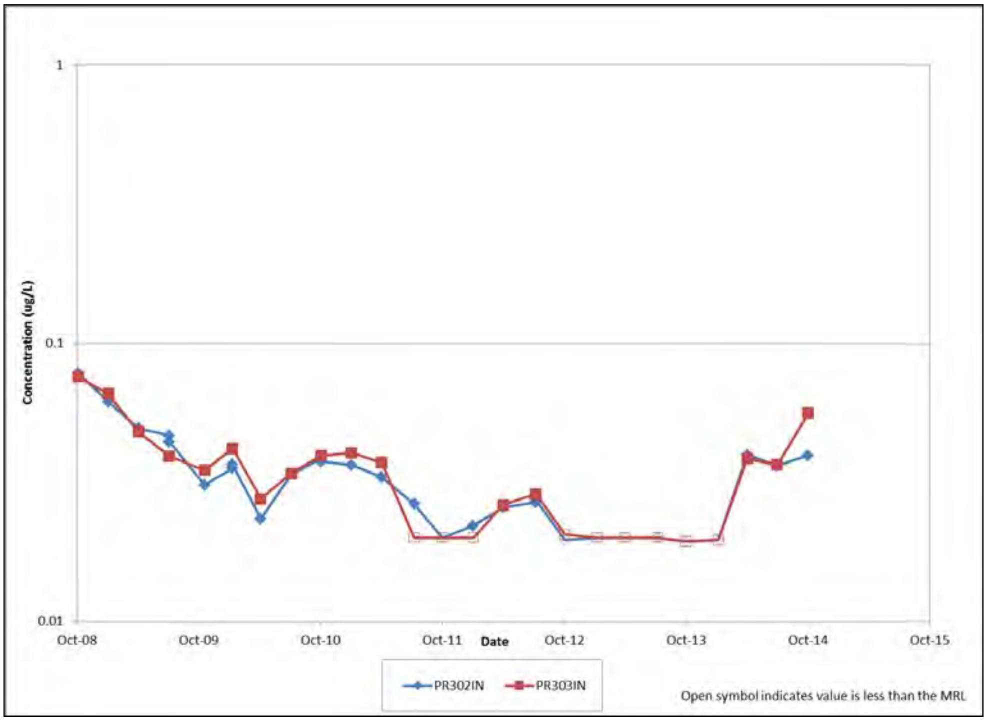
Table 5.1.1.3-2. Overview of CSRG Analyte Sampling from RYCS Downgradient and Cross-Gradient Performance Wells

CSRG Analyte (The concentration in parentheses is the CSRG for the respective analyte)	Concentrations above the CSRG/Number of Samples Collected							
	Section 3							Section 4
	03001*	03507	03508	03509	03527*	03529	03530	04506
Dibromochloropropane (DBCP) (0.2 µg/L)	0/4	0/4	0/5	0/4	0/4	0/5	0/5	0/4

Notes: *Cross-gradient

No common influent sump is present in the RYCS treatment plant. Consequently, the inlets to the two carbon adsorbers are sampled to provide influent concentration data. The data for the two absorber inlets are shown in Figure 5.1.1.3-2. The DBCP concentrations were below the CSRG in both adsorber inlets. The DBCP concentrations in the upgradient and downgradient performance wells (Figure A-10) were below the CSRG of 0.2 µg/L during the FYR period. The highest concentration of 0.132 µg/L occurred in August 2014 in upgradient well 03503.

Figure 5.1.1.3-2. RYCS Influent Concentrations for DBCP



A RYCS pre-shut-off monitoring program was successfully completed during FY14 (Navarro 2015c). In addition to analyzing for the CSRG analytes DBCP and TCE, an expanded analyte list was monitored to confirm that no other contaminants were present above CBSGs. A total of seven wells (five extraction wells and two monitoring wells) were sampled in a transect perpendicular to the historical DBCP plume extent during a temporary shutdown of the RYCS extraction wells to obtain more representative samples from the extraction wells. Historically high groundwater elevations have been present in the Railyard wells after the 500- to 1000-year storm event in September 2013. The DBCP concentrations in some of the wells increased slightly after the storm, possibly due to mobilization of residual DBCP, but remained below the CSRG. The next step in the LTMP shut-off process will be preparation of a shut-off monitoring SAP for Regulatory Agency approval, a draft of which was issued in November 2015.

RYCS Evaluation Conclusions

Based on criteria in the Railyard IRA Decision Document (MK Environmental Services 1990), On-Post ROD, 1999 LTMP, and 2010 LTMP, the RYCS is functioning as intended in the Decision Documents. Concentrations were below CSRGs in the treatment plant effluent, plume capture was maintained, and the contaminant concentrations were below the CSRG in the downgradient and cross-gradient performance wells. The shut-off process was initiated during the current FYR period and will continue during the next period.

5.1.1.4 Basin A Neck System

Figure 5.1.1.4-1 is the well location map for the BANS. The BANS treats groundwater from the dewatering systems at BANS, BRES, CADT, and Lime Basins. As documented in the ASRs, there were no CSRG exceedances in the BANS treatment plant effluent.

Table 5.1.1.4-1 shows that the annual contaminant removal is variable, but increased from 97 lbs in FY10 to 242.7 lbs in FY14. With more consistent operation of the Lime Basins dewatering wells during and after FY12, the contaminant removal increased significantly. The majority of the TCE and other volatile organic compounds (VOCs) are extracted by the CADT, Lime Basins, and Bedrock Ridge extraction systems. DIMP is not a CSRG analyte for BANS, but is shown in Table 5.1.1.4-1 because it represents a large portion of the contaminant removal.

Table 5.1.1.4-1. BANS Treatment Summary (Including Extraction at BANS, CADT, BRES, and LB)

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2010 Does not include LB	20	10,497,923	97	DIMP 26.8 TCE 34.7 Dithiane 10.1 Chlorophenylmethyl sulfone 6.0 1,1,2,2-Tetrachloroethane 3.0 1,4-Oxathiane 1.0	18,600 (liquid) 4,500 (vapor)	$1,752,904
2011	16	8,317,169	52.5	DIMP 16.1 TCE 15.5 Dithiane 6.9 Chlorophenylmethyl sulfone 3.9 1,1,2,2-Tetrachloroethane 1.6 1,4-Oxathiane 0.8	11,100	$2,112,080

Table 5.1.1.4-1. BANS Treatment Summary (Including Extraction at BANS, CADT, BRES and LB) (Concluded)

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2012	20	10,453,161	141.7	DIMP 22.0 TCE 18.5 Dithiane 7.7 Chlorophenylmethyl sulfone 4.4 1,1,2,2-Tetrachloroethane 1.9 Chloroform 57.7 ACET 9.1 CH2CL2 3.8 PCE 3.6 12DCLB 1.8 CLC6H5 2.0 14DCLB 1.9	12,200	$2,318,646
2013	18	9,558,389	316.2	DIMP 39.4 TCE 65.4 Dithiane 6.2 Chlorophenylmethyl sulfone 2.7 1,1,2,2-Tetrachloroethane 6.5 Chloroform 139.8 CH2CL2 11.6 PCE 10.6 CLC6H5 8.6 12DCLB 6.2 14DCLB 6.1 12DCLP 2.5 12DCE 3.3 C6H6 1.6	12,700	$791,833
2014`	`17	9,099,741	242.7	DIMP 31.6 TCE 44.0 Dithiane 6.2 Chlorophenylmethyl sulfone 4.8 1,1,2,2-Tetrachloroethane 3.7 Chloroform 124.6 PCE 10.4 ACET 4.9 12DCE 2.4 CH2CL2 2.3 12DCLP 1.8 CLC6H5 1.0 CPMSO 0.9	11,100	$584,620
Total	18 (avg.)	47.9 million	850.1		65,700 (liquid) 4,500 (vapor)	$7,560,083

Performance criteria for BANS as required by the 2010 LTMP are to demonstrate effective mass removal for each CSRG analyte and demonstrate that concentrations in downgradient performance wells are below CSRGs/PQLs or are stable or decreasing. There are no LTMP performance requirements for the BANS reverse hydraulic gradient. A reverse gradient is maintained in the central portion of the system where the recharge trenches are present. Typically, there is a forward gradient at the ends of the slurry wall. In FY14, historically high groundwater levels occurred at BANS after the combined effects of the unprecedented September 2013 precipitation/flood event and May 2014 rainstorms, and caused the BANS reverse hydraulic gradient to decrease to a smaller portion of the system than in previous years. The reduced extent of the reverse gradient is the expected cause of the increase in contaminant concentrations in some of the downgradient performance wells.

Prior to FY10, there were no quantitative mass removal criteria for evaluating the performance of the BANS. Beginning in FY10, 75 percent mass removal was set as the goal in the 2010 LTMP (TtEC and URS 2010), pending further evaluation after collecting additional data for five years. As opposed to treatment system compliance with CSRGs, the mass removal criterion refers to removing at least 75 percent of the contaminant plume mass migrating toward the system during a specified time period (mass flux).

The BANS mass removal is calculated two ways; using the BANS dewatering well water quality data and the water quality data from the BANS-specific influent (PADW1-7). Thus, there are two estimates of the mass removal each year. Table 5.1.1.4-2 shows the mass flux, mass removed and mass removal percentage each year. The BANS exceeded the 75 percent mass removal goal every year, averaging 87.8 to 90.6 percent of the mass flux.

Table 5.1.1.4-2 BANS Mass Flux, Mass Removed, and Mass Removal Percentage

Fiscal Year	Mass Flux, lbs/year	Mass Removed, lbs/year	Mass Removal, percent
2010	20.5	19.2-19.7	94-96
2011	15.1-16.7	13.7-15.4	91-92
2012	24.7-22.6	21.5-19.4	87-86
2013	14-20.6	11.4-18.5	81-90
2014	15.7-17.4	13.6-15.3	87-88
Average	18-19.4	15.9-17.7	87.8-90.6

During the FYR period, the downgradient performance wells were sampled annually, and well 26006 is a water quality tracking well located farther downgradient that was sampled for indicator analytes in 2009, 2012, and 2014. Additional analytes were monitored in well 26006 in 2014 because it was included in the 2014 plume mapping network. Since well 26006 is a water quality tracking well, it is also discussed in Section 5.1.3.1 and Figure 5.1.3-8 shows its location. Concentrations were below the CSRGs for most analytes as demonstrated in Table 5.1.1.4-3.

Table 5.1.1.4-3. Overview of CSRG Analyte Sampling from BANS Performance/Water Quality Tracking Wells

CSRG Analyte[1] (The concentration in parentheses is the CSRG/ PQL for the respective analyte)		**Concentrations above the CSRG or PQL/Number of Samples Collected**				
		Performance				**Water Quality Tracking**
		26501	**26505**	**35505**	**35525**	**26006**
1,1,1-Trichloroethane	(200 µg/L)	0/5	0/5	0/5	0/5	0/1
1,1-Dichloroethylene	(7 µg/L)	0/5	0/5	0/5	0/5	0/1
1,2-Dichloroethane	(0.40 µg/L)	0/5	2/5	0/5	0/5	0/1
1,4-Oxathiane	(160 µg/L)	0/5	0/5	0/5	0/5	0/2
Arsenic	(50 µg/L)	0/5	0/5	0/5	0/5	0/2
Atrazine	(3 µg/L)	0/5	0/5	0/5	0/5	No data
Benzene	(5 µg/L)	0/5	0/5	0/5	0/5	0/1
Carbon tetrachloride	(0.30 µg/L)	0/5	0/5	0/5	0/5	0/1
Chlorobenzene	(100 µg/L)	0/5	0/5	0/5	0/5	0/1
Chloroform	(6 µg/L)	0/5	0/5	0/5	0/5	0/1
Chlorophenylmethyl sulfide	(30 µg/L)	0/5	0/5	0/5	0/5	0/2
Chlorophenylmethyl sulfoxide	(36 µg/L)	0/5	0/5	0/5	0/5	0/2
Chlorophenylmethyl sulfone	(36 µg/L)	0/5	1/5	0/5	2/5	0/2
2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	(0.1 µg/L)	0/5	0/5	4/5	4/5	2/2
Dicyclopentadiene (DCPD)	(46 µg/L)	0/5	0/5	0/5	0/5	0/1
Dieldrin[a]	(0.002/0.013 µg/L)	1/5	3/5	5/5	5/5	2/2
Dithiane	(18 µg/L)	0/5	1/5	0/5	0/5	0/2
Endrin	(2 µg/L)	0/5	0/5	0/5	0/5	0/2
Hexachlorocyclopentadiene	(50 µg/L)	0/5	0/5	0/5	0/5	0/2
Mercury	(2 µg/L)	0/5	0/5	0/5	0/5	No data
Tetrachloroethylene (PCE)	(5 µg/L)	0/5	0/5	0/5	0/5	0/1
Trichloroethylene (TCE)	(5 µg/L)	0/5	0/5	0/5	0/5	0/1

Notes:
[1] The ROD lists the following certified reporting limits or PQLs as readily available:
[a] PQLs: ROD PQL = 0.05 µg/L,PQL from 2012 PQL study = 0.013 µg/L (effective April 2012)

Only dieldrin and 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT) were detected consistently above the CSRG/PQL in wells 35505, 35525 (Figure 5.1.1.4-2 and Figure 5.1.1.4-3) and 26006 (Figure 5.1.1.4-4). These compounds are less mobile and are subject to sorption/desorption, providing a secondary source in the aquifer sediments, and would be expected to clean up more slowly than the other analytes. Concentrations of dieldrin and DDT in the downgradient wells were relatively stable or decreasing overall during the FYR period. The DDT concentrations decreased to below the CSRG in all four downgradient performance wells in FY14.

Concentrations of 12DCLE, CPMSO2, dieldrin, and dithiane increased to above the CSRG/PQL in well 26505 in FY14, likely due to the decreased extent of the reverse gradient. Additionally, water levels are at historic highs at BANS, and some of the increase in concentrations in the downgradient wells may have come from mobilization of contamination from the aquifer sediments downgradient of the slurry wall that previously had been above the water table. The performance requirement does not apply to DIMP, but DIMP concentrations in well 35525 are above the CBSG of 8 µg/L. The DIMP concentrations in well 35525 have decreased steadily from 200 µg/L in FY10 to 12.5 µg/L in FY13, but increased to 19.6 µg/L in FY14. DIMP was below the CBSG in the other three wells during the FYR period. The CPMSO2 and dieldrin concentrations in well 35525 increased in FY14. Although short-term concentration increases occurred for several analytes in FY14, the long-term trends are not increasing according to Mann-Kendall statistical tests.

The BANS dewatering well flow rates were increased in FY15, and the reverse gradient was restored to its historical extent. The Regulatory Agencies were informed about the reduced reverse gradient and concentration increases that occurred in FY14 after the annual BANS evaluation was conducted.

Figure 5.1.1.4-2. Time Concentration Plot (Dieldrin) for Downgradient Performance Wells 26501, 26505, 35505, and 35525

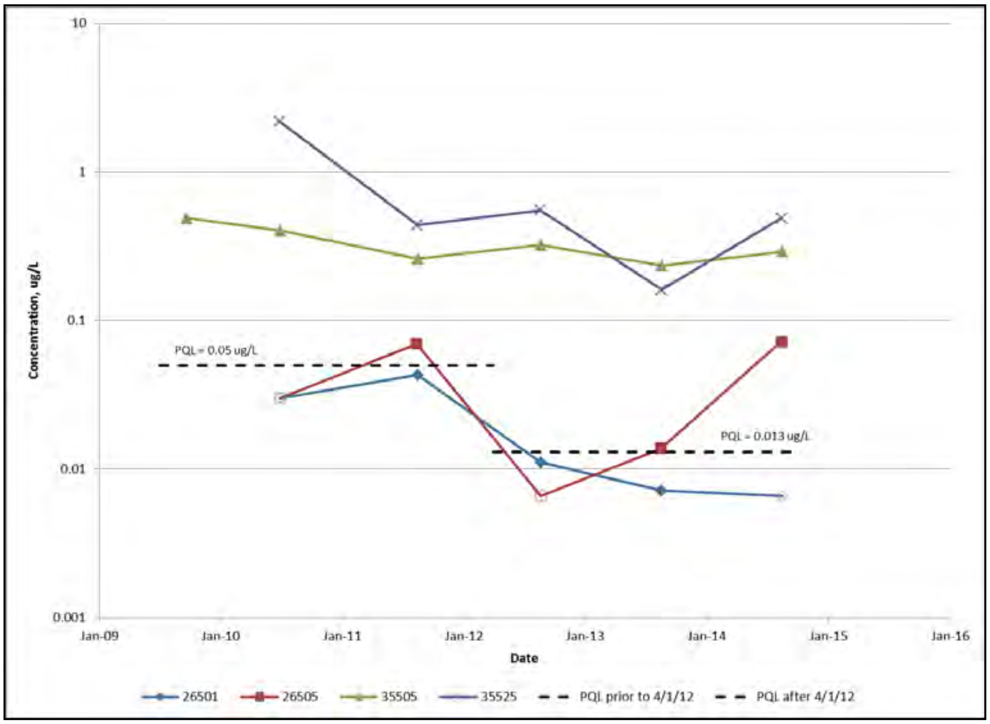


Figure 5.1.1.4-3. Time Concentration Plot (DDT) for Downgradient Performance Wells 26501, 26505, 35505, and 35525

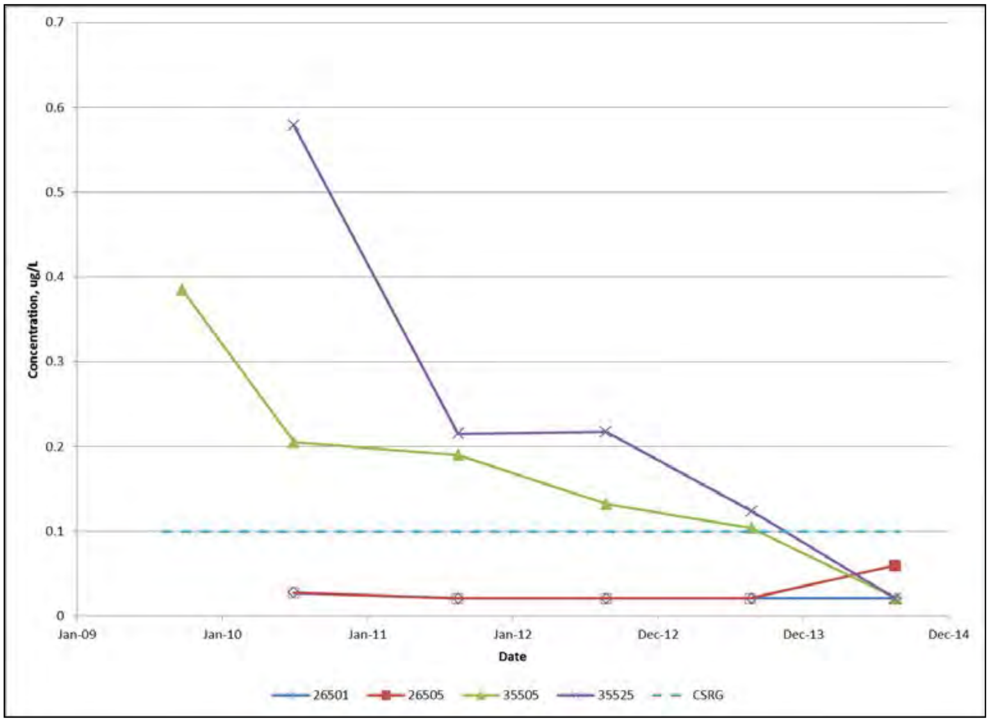
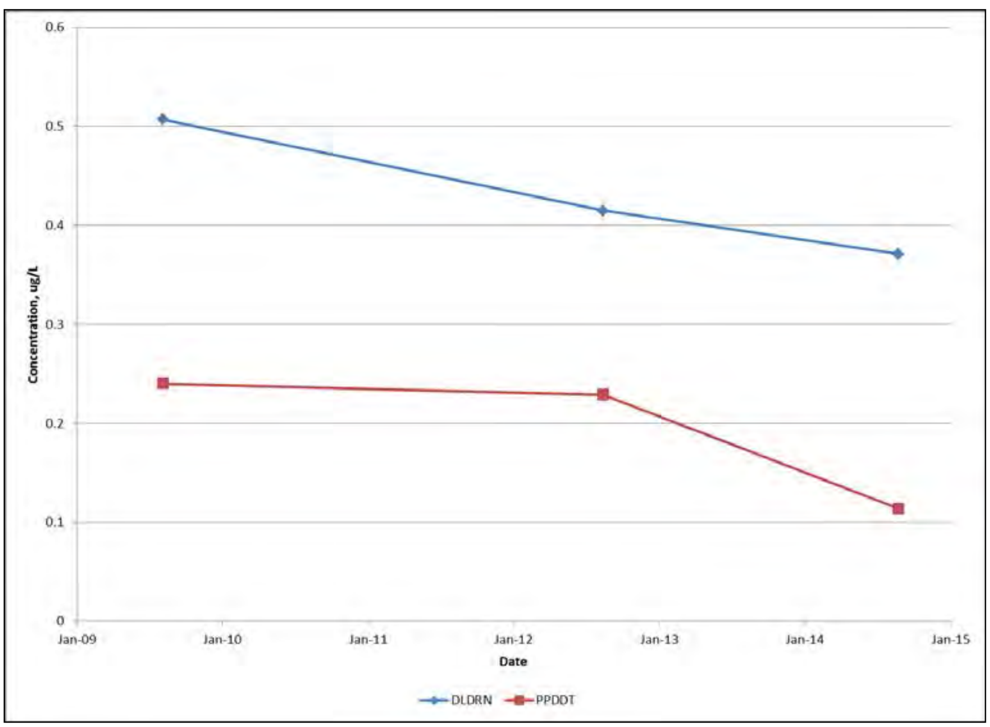
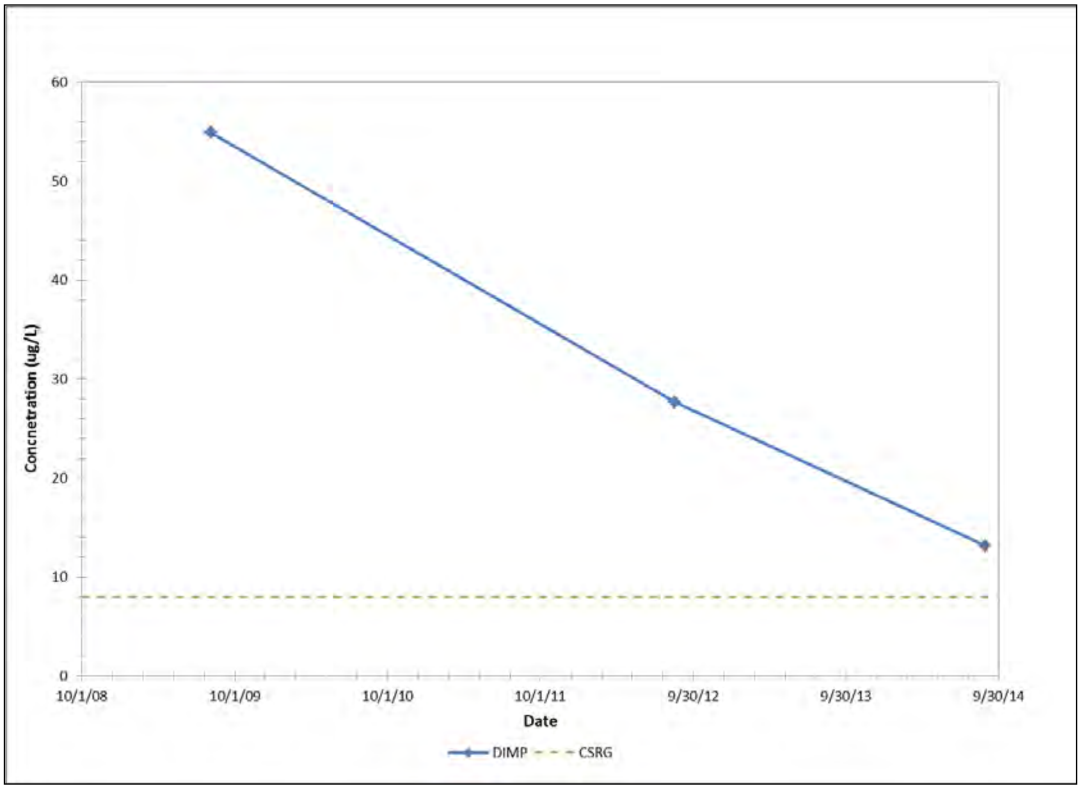


Figure 5.1.1.4-4. Time Concentration Plot (DLDRN and DDT) for Downgradient Water Quality Tracking Well 26006



Although DIMP is not a BANS CSRG analyte, it represents a significant portion of the contaminant mass and is monitored in downgradient well 26006. Figure 5.1.1.4-5 shows the DIMP concentration trend in well 26006 where the concentrations have decreased by 76 percent between 2009 and 2014.

Figure 5.1.1.4-5. Time Concentration Plot (DIMP) for Well 26006

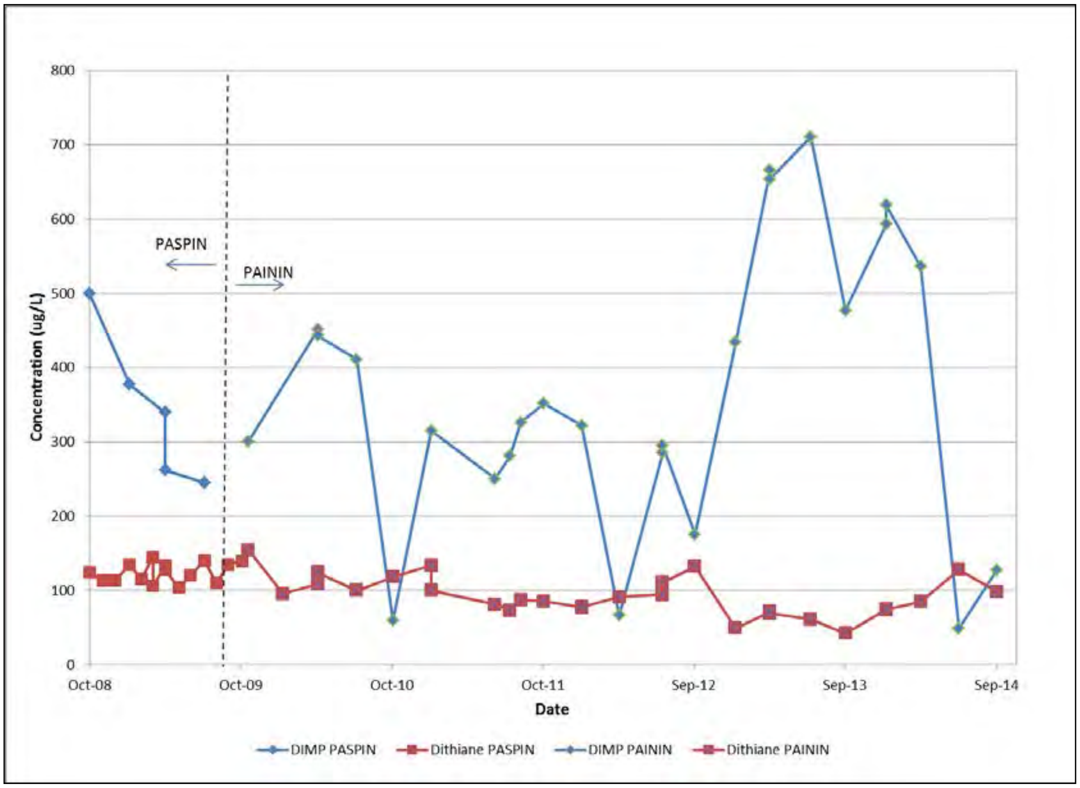


Since the BANS influent receives flow from four different extraction/dewatering systems, the influent concentrations are variable according to variability in the flow rates at the various systems. DIMP concentrations in the BANS influent (Figure 5.1.1.4-6) ranged from 48.7 to 711 µg/L, averaging 356 µg/L. For comparison, the average DIMP concentration for the previous FYR period was higher (455 µg/L). Figure A-11 shows lower DIMP concentrations in FY14 in two of the four upgradient performance wells.

Dithiane concentrations in the BANS influent also were variable during the FYR period (Figure 5.1.1.4-6), ranging from 41.9 µg/L to 154 µg/L, averaging 93 µg/L, which is lower than the average of 142 µg/L in the previous FYR period. The CSRG for dithiane is 18 µg/L. The BANS influent site IDs on Figure 5.1.1.4-6 are PASPIN and PAININ and were changed in FY10. Figure A-12 shows that the dithiane concentration in upgradient performance well 35516 decreased to below the CSRG in FY14, and only one of the four upgradient wells was above the CSRG.

Although dieldrin represents a very small component of the contaminant mass at BANS, the influent and upgradient performance well concentrations are important because dieldrin is one of the compounds detected above the PQL in downgradient wells. The dieldrin concentrations in the BANS influent displayed short-term variations, averaging 0.382 µg/L, which is lower than the average of 0.437 µg/L in the previous FYR period. The dieldrin concentrations in all four upgradient performance wells were above the PQLs in FY09 and FY14 (Figure A-13), and are significantly higher than in the downgradient performance wells.

Figure 5.1.1.4-6. BANS Influent Concentrations for DIMP and Dithiane



BANS Evaluation Conclusions

Based on criteria in the BANS IRA Decision Document (Army 1989), On-Post ROD, 1999 LTMP, and 2010 LTMP, the BANS is functioning as intended in the Decision Documents. Concentrations were below CSRGs/PQLs in the BANS treatment plant effluent, the hydraulic gradients were acceptable, except for a portion of FY14, and the contaminant concentrations of most analytes are decreasing or below CSRGs in the downgradient wells.

The BANS mass removal improves the long-term performance of the boundary systems, consistent with the ROD Remedial Action Objective. The BANS-specific contaminant mass removal for the FYR period was an average of 89 percent of the mass flux approaching the system. The BANS-specific contaminant removal for the FYR period was 84 pounds and the total contaminant removal for the groundwater treated at BANS was 850 pounds. BANS eliminates the majority of the groundwater contaminant mass flux migrating from former Basin A and the Bedrock Ridge area toward the NWBCS and NBCS, respectively. While not all of the groundwater contamination removed by BANS treatment would migrate to the boundary systems if the BANS were not in place, the mass removal at BANS reduces the contaminant mass flux at the boundary systems, thereby reducing treatment requirements, and potentially making plume capture at the boundary systems more robust.

In FY14, the extent of the reverse hydraulic gradient was reduced due to the combined effects of a historic flood event in September 2013 and May 2014 rainstorms. Concentrations of several analytes increased in the downgradient wells in FY14, but the overall trends are not increasing based on statistical tests. The reverse gradient has since been restored to the historical extent. The concentrations of two less mobile compounds, dieldrin and DDT, have been above the CSRGs/PQLs in the downgradient performance wells. The DDT concentrations decreased to below the CSRG in FY14. The dieldrin concentrations are relatively stable or are decreasing in the downgradient wells.

The BANS met the mass removal performance goal of 75 percent throughout the FYR period, including in FY14 when the reverse gradient was reduced. The 2010 LTMP stated that the 75 percent goal would be re-evaluated after five years of data collection. Based on the performance during this FYR period, increasing the goal to greater than 75 percent was considered. However, as contaminant concentrations decline in the future, the concentrations in the upgradient wells may approach the CRSGs/PQLs. Meeting the 75 percent mass removal goal could then become more difficult because of limitations in the calculations when the dewatering well and influent concentrations approach the CSRGs/PQLs, and may also be unnecessary to meet ROD compliance requirements. For example, hypothetically assuming that the extraction flow rate equals the contaminated flow rate, the treatment plant influent/effluent concentration differential would equal the mass removal percentage. If the upgradient wells/influent concentration is only slightly above the CSRG (e.g., chloroform at 6.5 µg/L), only an 8 percent reduction would be required to meet the CSRG of 6 µg/L. Seventy-five percent mass removal would reduce the effluent concentration to 1.6 µg/L, which is well below the ROD treatment requirement. Consequently, as concentrations decline in the future, lowering the mass removal goal may be appropriate to be consistent with ROD compliance. Additionally, as contaminant concentrations decline, the treatment efficiencies may also decline, which may make attainment of 75 percent mass removal more difficult. Army and Shell will continue to optimize the system operation for mass removal, and proposes to retain the 75 percent mass removal goal.

A revision to the 2010 LTMP is being considered for 2017. Since the reduced extent of the reverse gradient in 2014 likely caused an increase in some of the downgradient well concentrations, adding reverse gradient performance criteria for BANS will be considered in the LTMP revision. Additionally, the 75 percent mass removal goal and associated methodology will be re-evaluated during the revision process. Until then, both the goal and methodology will be retained. The mass removal will continue to be calculated by both methods (dewatering wells and BANS-specific influent).

5.1.1.5 Bedrock Ridge Extraction System

Figure 5.1.1.5-1 is the well location map for the BRES. The groundwater extracted by BRES is treated at the BANS treatment plant and contains DIMP, chloroform, carbon tetrachloride, and PCE.

The 2010 LTMP performance criteria for the BRES are to demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells, and show downgradient performance wells are at or below the CSRGs/PQLs, or show decreasing trends. Wells 36565, 36567, 36575, and 36578 were designated as upgradient performance wells, and wells 36555, 36566, 36571, and 36572 were selected as downgradient performance wells. Due to limited downgradient well data and low permeability of the Denver Formation sandstones, it was uncertain whether the downgradient water quality data would be representative of system effectiveness. Consequently, five years of data were to be collected in the downgradient performance wells before drawing conclusions about the system performance and determining whether the LTMP criteria should apply.

BRES water level performance well 36576 could not be found during Bedrock Ridge quarterly water level measurements from October 2009 to January 2011 (RVO 2012). The well was probably destroyed by soil removal activities. The well was removed from the network in February 2011. Well 36576 was not replaced because it was never used to draw water-table maps and water level performance wells 36574 and 36575 are located nearby.

The water level data indicate that plume capture was maintained during the FYR period.

The downgradient performance wells and water quality tracking well 25502 provide information regarding the concentration trends downgradient of the BRES. Figure 5.1.3-8 shows the location of well 25502. The performance wells were sampled annually and well 25502 was sampled in FY12 and FY14, and the results are presented in Table 5.1.1.5-1. The concentrations in downgradient performance wells 36555, 36571, and 36572 were below the CSRGs/PQLs, except for one chloroform sample in well 36572 in FY13. This chloroform concentration in well 36572 was just above the CSRG and decreased to below the CSRG in FY14.

Concentrations in downgradient performance well 36566 were above the CSRGs for carbon tetrachloride, chloroform, and tetrachloroethylene. Table 5.1.1.5-1 indicates that the concentrations of 1,2-dichloroethane and trichloroethylene were also above the CSRGs in one of five samples in well 36566. Over the five-year period, concentrations in well 36566 show decreasing trends for carbon tetrachloride, DIMP, and chloroform and increasing trends for 12DCLE, tetrachloroethylene and trichloroethylene. All of these analytes are present upgradient of the system at much higher concentrations than in well 36566. Additionally, these six analytes are present with similar distributions upgradient of the system. If bypass of the system were occurring and causing some of the downgradient concentrations to increase, it seems that all six analytes would show similar concentration trends in well 36566, but they do not.

Plume capture is indicated by the quarterly BRES water-table maps. Well 36566 is located downgradient of extraction well 36302 where the hydraulic gradient is very flat. It is plausible that the contamination in well 36566 is residual and not migrating significantly within this zone. Five years of data have now been collected, but this time frame may be too short for evaluating well 36566. Thus, it may be premature to conclude whether the contamination is present because of slow migration or because of bypass of the system. The flow rates for the extraction wells have been relatively consistent and the water-table contours have shown similar configurations during the five-year period, which precludes a decrease in pumping rates as a possible explanation for the increasing concentrations for some of the analytes in the downgradient well. The concentrations of 1,2-dichloroethane, tetrachloroethylene, and trichloroethylene show steadily decreasing trends in downgradient water quality tracking well 25502, which support that the BRES plumes are captured, but is not conclusive evidence.

At the Regulatory Agencies' request, additional evaluation of the BRES is provided in Appendix C. The conclusions and recommendations are provided below.

Based on the available data, it is premature to conclude that the BRES is not functioning as intended because of the increasing concentrations of three analytes in one of the four downgradient performance wells. The majority of the water level and water quality data indicate that the BRES is intercepting the plumes and effectively reducing the downgradient concentrations. Due to the low hydraulic gradient at downgradient performance well 36566, it is not possible to determine whether the three analytes are present above the CSRGs due to bypass of the system or represent contamination that was present downgradient of the extraction wells when the system commenced operation, and is slower to clean up than the other analytes.

Currently, the downgradient performance wells are sampled annually. Collecting additional water quality data may help resolve the performance question. Increased sampling frequency is listed as an option in LTMP Table 4.7-1 when the downgradient concentrations are increasing. Therefore, Army and Shell propose sampling wells 36569 and 36566 quarterly for one year to assess the contaminant concentration trends. Well 36569 is not currently in the downgradient performance well network, but is included to provide additional data in the area immediately downgradient of extraction well 36302 and upgradient of well 36566. Additionally, extraction well 36302 will be sampled semiannually to provide comparison data for evaluating the concentration trends in the downgradient wells. If this proposal is acceptable to the Regulatory Agencies, an OCN will be issued to temporarily amend the LTMP. The one-year sampling period will commence after the OCN is approved.

The supplemental data will be evaluated in conjunction with the quarterly water level and annual water quality data collected according to the BRES monitoring schedule during the one-year period. A draft interpretation report will be issued within 90 days of the last quarter's water quality data being finalized. The report will evaluate system performance and determine whether the one-year supplemental monitoring period is sufficient or should be extended for one or both wells. The report will also determine whether additional follow-up actions should be considered. The analytical data review/QA and a summary of the results will be provided in the corresponding Annual Summary Report.

Table 5.1.1.5-1. Overview of BANS CSRG Analyte Sampling from BRES Downgradient Performance and Water Quality Tracking Wells

BANS CSRG Analyte[1] (The concentration in parentheses is the BANS CSRG or PQL for the respective analyte)		Concentrations above the BANS CSRG or PQL/Number of Samples Collected				
		Performance				Water Quality Tracking
		36555	36566	36571	36572	25502
1,1,1-Trichloroethane	(200 µg/L)	0/5	0/5	0/5	0/5	0/2
1,1-Dichloroethylene	(7 µg/L)	0/5	0/5	0/5	0/5	0/2
1,2-Dichloroethane	(0.40 µg/L)	0/5	1/5	0/5	0/5	0/2
1,4-Oxathiane	(160 µg/L)	0/5	0/5	0/5	0/5	0/1
Benzene	(5 µg/L)	0/5	0/5	0/5	0/5	0/2
Carbon tetrachloride	(0.30 µg/L)	0/5	3/5	0/5	0/5	0/2
Chlorobenzene	(100 µg/L)	0/5	0/5	0/5	0/5	0/2
Chloroform	(6 µg/L)	0/5	5/5	0/5	1/5	0/2
Chlorophenylmethyl sulfide	(30 µg/L)	0/5	0/5	0/5	0/5	0/1
Chlorophenylmethyl sulfone	(36 µg/L)	0/5	0/5	0/5	0/5	0/1
Chlorophenylmethyl sulfoxide	(36 µg/L)	0/5	0/5	0/5	0/5	0/1
2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	(0.1 µg/L)	0/5	0/5	0/5	0/5	0/1
Dicyclopentadiene (DCPD)	(46 µg/L)	0/5	0/5	0/5	0/5	0/2
Dieldrin[a]	(0.002/0.013 µg/L)	0/5	0/5	0/5	0/5	0/1
Diisopropylmethyl phosphonate (DIMP)[2]	(8 µg/L)	0/5	4/5	0/5	0/5	0/2
Dithiane	(18 µg/L)	0/5	0/5	0/5	0/5	0/1
Endrin	(2 µg/L)	0/5	0/5	0/5	0/5	0/1
Hexachlorocyclopentadiene	(50 µg/L)	0/5	0/5	0/5	0/5	0/1
Tetrachloroethylene (PCE)	(5 µg/L)	0/5	5/5	0/5	0/5	2/2
Trichloroethylene (TCE)	(5 µg/L)	0/5	1/5	0/5	0/5	0/2

Notes:

[1] The ROD lists the following certified reporting limits or PQLs as readily available:

[a] PQL = 0.05 and 0.013 µg/L (the lower PQL became effective in April 2012)

[2] DIMP is listed as it was included in the Bedrock Ridge Design Document (Morrison Knudsen Corporation 1999) interception criteria (Table 2.2-1), but it is not a CSRG analyte at BANS.

No BRES influent data are available because the combined BRES extraction well flow is not monitored for water quality before it enters the BANS influent sump, which receives flow from the BANS, BRES, Lime Basins, and CADT extraction wells. Typically, the contaminant concentrations decrease in the extraction wells from west to east, with the highest concentrations occurring in extraction well 36302, and the concentrations in well 36304 below CSRGs. In FY10, sampling of the dewatering wells was discontinued and sampling of the upgradient performance wells commenced.

Figures A-14 through A-17 show the upgradient performance well concentrations in FY10 and FY14 for DIMP, carbon tetrachloride, chloroform, and PCE, respectively. In Figure A-14, the concentrations of DIMP were above the CBSG in wells 36567 and 36578, but lower in both wells in FY14. In Figure A-15, the concentrations of CCL4 were above the CSRG in well 36567, but lower in FY14. In Figure A-16, the concentrations of chloroform were above the CSRG in wells 36567 and 36578, and higher in well 36567, but lower in well 36578 in FY14. In Figure A-17, the concentrations of PCE were above the CSRG in well 36567 in FY10, but above the CSRG in 36567, 36578, and 36575 in FY14. The PCE concentration in well 36567 was lower in FY14, but wells 36578 and 36575 show increasing PCE trends. Both wells are within the BRES capture zone, and plume capture is indicated by the water-table contours.

BRES Evaluation Conclusions

Based on criteria in the Off-Post RS/S BRES Design Document, On-Post ROD, 1999 LTMP, and 2010 LTMP, the BRES appears to be functioning as intended in the Decision Documents. Concentrations were below CSRGs/PQLs in the BANS treatment plant effluent, plume capture was demonstrated by the water level data, and the contaminant concentrations are below CSRGs/PQLs or decreasing in most of the downgradient wells, as summarized below.

Contaminant concentrations in three of the four downgradient performance wells were below the CSRGs/PQLs. The concentrations in one well (36566) were above the CSRGs for 1,2-dichloroethane, chloroform, tetrachloroethylene, and trichloroethylene at the end of the FYR period in FY14. Over the five-year period from FY10 through FY14, chloroform shows a decreasing trend in well 36566, and the other three analytes have increasing trends.

A total of eight analytes are present above CBSGs or CSRGs/PQLs upgradient of the system. Four of these analytes have shown decreasing trends in well 36566 and four have shown increasing trends. Well 36566 is located in a zone with a very flat hydraulic gradient downgradient of the extraction system. The increasing concentration trends of the three analytes above CSRGs in FY14 in well 36566 may be caused by slow migration within this zone. Decreasing concentration trends for these analytes in downgradient water quality tracking well 25502, which is located farther downgradient, supports plume capture, but is not conclusive evidence. Army and Shell believe the BRES is functioning as intended, but additional data collected in the future will help clarify the issue and clarify whether the LTMP performance criteria should apply to all the downgradient performance wells. Accordingly, Army and Shell propose sampling well 36566 and a new well (36569) quarterly, and extraction well 36302 semiannually, for one year to assess the contaminant concentration trends and system performance.

5.1.1.6 Groundwater Mass Removal Project

A Resolution Agreement was reached with the Regulatory Agencies in 2005 to implement short-term groundwater mass removal remedies within the STF Plume and the former Lime Basins areas (Washington Group International 2005a). These remedies entailed the extraction of groundwater from the STF Plume and the Lime Basins areas with treatment of the extracted groundwater to reduce the contaminant mass within the respective plumes.

The changes to the RMA On-Post ROD groundwater remedy resulting from the implementation of this project were documented in the Explanation of Significant Differences for Groundwater Remediation and Revegetation Requirements (Tetra Tech 2006b).

The STF and Lime Basins groundwater extraction/recharge and monitoring systems of the GWMR Project were installed and became operational in 2006. The GWMR Project continued until the end of May, 2010. The GWMR Project Operations Reports are referenced for information regarding the effectiveness of the STF and Lime Basins mass removal systems (URS Washington Division 2009b, 2010a, 2010b). The information in the annual reports is summarized for each system in the following sections. Annual operations costs for the GWMR Project during this FYR were $945,000 in FY10.

5.1.1.6.1 South Tank Farm System

The STF System consisted of seven extraction wells, 12 recharge wells, seven new monitoring wells, 18 piezometers, and associated piping and controls connecting the system to the CWTF. Figure 5.1.1.6-1 shows the well locations for the STF System. Because the recharge wells were irreversibly fouled and recharge capacity was lost, two recharge trenches (RT-1 and RT-2) were installed in October 2007, and became operational in November 2007. The changes to the design were documented in Design Change Notice (DCN)-GWMR-032 (Washington Group International 2007).

During operation of the extraction system, free product that was confirmed to be exclusively benzene was discovered in extraction wells DW-1 (01311), DW-2 (01312), and DW-3 (01313). Of these wells, only DW-2 (01312) and DW-3 (01313) exhibited sufficient accumulation to allow recovery of the free product. Free product removal pumps were installed in these wells and were operated periodically to remove the free product once sufficient quantities accumulated in the well. A total of 120.7 gallons (402.5 kilograms [kg]) of free product was removed during the previous FYR period. No free product was removed in 2010.

Although a large spill of benzene (approximately 100,000 gallons) in the STF area was documented during the RI, and benzene was a small component of the LNAPL during the STF soil vapor extraction treatability study conducted during the FS, LNAPL that was exclusively benzene had not previously been detected in recoverable quantities. Consequently, the discovery was an event during the previous FYR period.

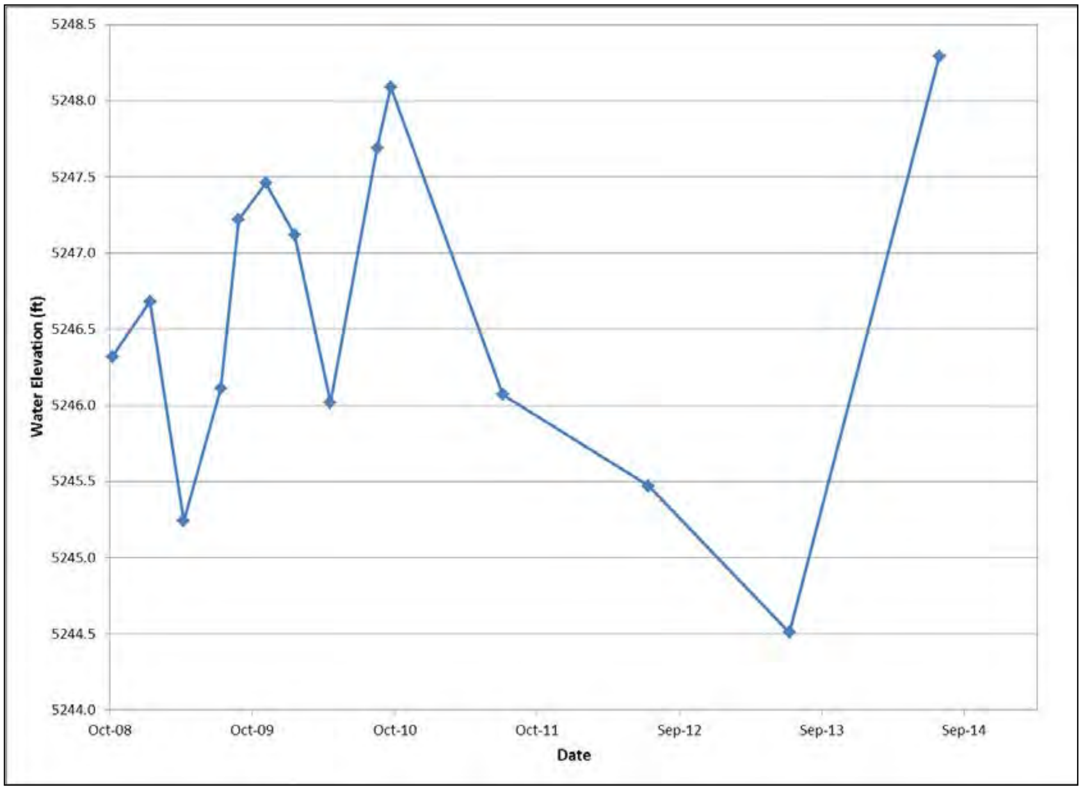
Table 5.1.1.6-1 summarizes the volumes of groundwater treated, free product removed, total mass removed, and the mass removal rate for the STF System during the FYR period. The mass removal rate for groundwater treated was consistent, averaging 1.1 kg removed/1,000 gallons treated, indicating that the dissolved concentrations in the center of the plume remained similar to the baseline concentrations and were not significantly affected by rising and falling of the water table. The water table varied approximately 8 ft in the center of the plume during the previous FYR period, but the variation was only 3.8 ft in well 01534 during this FYR period, which included the September 2013 and May 2014 storms (Figure 5.1.1.6-2). The reduced variability in the water levels during this FYR period likely is due to reduced recharge caused by the South Plants cover.

Table 5.1.1.6-1. STF Mass Removal Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Volume of Groundwater Treated (gal)	Free Product Removed	Total Mass of Contaminants Removed	Mass Removal Rate (kg removed/ 1,000 gal treated)*	Major Contaminants Removed
2010	1.26	482,900	0 gal 0 kg	598.6 kg 1319.7 lbs	1.2	Benzene DCPD TCE Chloroform
Total (2006-2010)	0.95 (avg.)	2,180,900	120.7 gal 402.5 kg	2863.5 kg 6312.9 lbs	1.1	

*The Mass Removal Rate equals the Total Mass of Contaminants Removed minus the Free Product Removed divided by the Volume of Groundwater Treated.

Figure 5.1.1.6-2. South Tank Farm Well 01534 Hydrograph



The mass removed was lower than estimated in the design document (Washington Group International 2006) (8,700 kg per year [kg/year]) because the actual flow rates were significantly lower than the flow rate of 7 gpm assumed in the design. The actual flow rates were constrained by the capacities of the treatment system and extraction and recharge systems. The mass removal was maximized by keeping the flow rates as high as possible, and installation of the recharge trenches provided sufficient recharge capacity. The flow rate was limited to approximately 1.5 gpm, however, by the treatment process to allow sufficient contact time for ex-situ biodegradation.

Within the primary objective of the project to remove contaminant mass, the project focused on the operation of the STF System to prevent the adverse migration of the contaminant plume. As stated in the design and project plans, such adverse migration would consist of the migration of the plume towards the lakes to the south of the project site. It should be noted that adverse migration of the plume refers to the high-concentration portion of the plume defined by the 2004/2005 100,000-µg/L contour shown on the GWMR Project maps for the STF. This portion of the plume has been extremely stable and has not moved appreciably toward the lakes since the 1990s or earlier, due to intrinsic aerobic biodegradation of the benzene plume, which is most effective at the edges of the high-concentration plume. This biodegradation mechanism was demonstrated during the RI/FS and STF IRA and was critical in selecting monitoring for the STF plume in the On-Post ROD. There is evidence that the high-concentration plume was receding prior to operation of the GWMR Project. For example, the benzene concentration in well 02522 was 470,000 µg/L in 1993 and had decreased to 2,900 µg/L in 2006, prior to startup of the STF System (Table 5.1.1.6-2). The benzene concentrations in well 02522 ranged from less than 0.2 µg/L to 5,530 µg/L during the operation of the GWMR system, but still have been at least two orders of magnitude below 100,000 µg/L. The additional wells installed near the edges of the plume during the GWMR Project showed that small lobes of the plume extend outside the 2004/2005 100,000-µg/L contour. These lobes are localized effects related to the groundwater mound on the eastern side of the plume, but the high-concentration plume is not moving toward the lakes. The historical data also show that the leading edge of the detectable plume has receded away from the lakes. The benzene concentrations in well 02505 decreased to below the CSRG and consistently have been below reporting limits since 1989. Since both the high-concentration portion and the downgradient extent of the detectable plume were stable or likely receding prior to startup of the GWMR system, operation of the system was not required to protect the lakes.

Monitoring of the downgradient monitoring wells to assess plume migration indicated a decrease in the concentrations of benzene below historical maximum and baseline levels (Table 5.1.1.6-2). To provide additional historical data, the highest benzene concentrations in the closed wells adjacent to the four existing downgradient wells are shown in Table 5.1.1.6-2 for comparison with the recent concentrations during mass removal system operation. The decrease in the benzene concentrations in downgradient wells indicates the STF System was successfully operated in a manner that prevented the adverse migration of the high-concentration plume. In fact, the system appears to have reduced plume migration in the downgradient direction in several wells (e.g., 01604, 01605, 02522, and 02684).

Consequently, additional downgradient monitoring was not necessary according to criteria in the GWMR Project plans. Wells closer to the lakes are monitored under the site-wide monitoring component of the LTMP, and benzene was not detected in these wells during the FYR period. These data are discussed in Section 5.1.3.1. GWMR Project post-shut-off monitoring in the STF was conducted during this FYR period and is discussed in Section 5.1.5.2.

Table 5.1.1.6-2. South Tank Farm System Comparison of Historical High and Baseline Benzene Concentrations to Operational Data in Downgradient Wells in FY09 and FY10

Well	Test Name	Sample Date	Boolean	Value	Units	Comment
01560 (closed)	Benzene	1990-03-29		47,000	µg/L	Historical High
01604	Benzene	2006-04-05		2.04	µg/L	Baseline
01604	Benzene	2009-02-23	LT	0.2	µg/L	
01604	Benzene	2009-09-23	LT	0.2	µg/L	
01604	Benzene	2010-02-15	LT	0.2	µg/L	
01587 (closed)	Benzene	1988-04-12		2,600	µg/L	

Table 5.1.1.6-2. South Tank Farm System Comparison of Historical High and Baseline Benzene Concentrations to Operational Data in Downgradient Wells in FY09 and FY10 (Concluded)

Well	Test Name	Sample Date	Boolean	Value	Units	Comment
01605	Benzene	1994-04-19		11,000	µg/L	Historical High
01605	Benzene	2006-04-05		3.42	µg/L	Baseline
01605	Benzene	1008-11-03		6.29	µg/L	
01605	Benzene	2009-02-24	LT	0.2	µg/L	
01605	Benzene	2009-05-18	LT	0.2	µg/L	
01605	Benzene	2009-09-23	LT	0.2	µg/L	
01605	Benzene	2009-11-16		0.277	µg/L	
01605	Benzene	2010-02-15		0.212	µg/L	
01605	Benzene	2010-04-27	LT	0.2	µg/L	
02584 (closed)	Benzene	1990-03-27		85,000	µg/L	
02522	Benzene	1993-04-28		470,000	µg/L	Historical High
02522	Benzene	2006-04-06		2,900	µg/L	Baseline
02522	Benzene	2009-02-23	LT	0.2	µg/L	
02522	Benzene	2009-09-23	LT	0.2	µg/L	
02522	Benzene	2010-01-26	LT	0.2	µg/L	
02575 (closed)	Benzene	1988-05-04		1,300	µg/L	Historical High
02684	Benzene	2006-04-05		13,800	µg/L	Baseline
02684	Benzene	2009-02-23		0.759	µg/L	
02684	Benzene	2009-09-24		0.333	µg/L	
02684	Benzene	2010-01-26		0.561	µg/L	

5.1.1.6.2 Lime Basins Groundwater System

The Lime Basins Groundwater System consisted of four extraction wells, three recharge trenches, 12 recharge trench piezometers, associated piping and controls, and a monitoring network consisting of pre-existing wells. Figure 5.1.1.6-3 is the well location map for the Lime Basins Groundwater System. Both the Lime Basins mass removal system and Lime Basins slurry wall project dewatering system wells are shown on the map. Because the mass removal and dewatering systems are intended to operate concurrently, and share some of the same monitoring wells and the recharge system, both extraction systems and the associated monitoring networks are shown on the same map. The Lime Basins slurry wall project dewatering system is discussed in Section 5.1.2.3.

Table 5.1.1.6-3 summarizes the volumes of groundwater treated, total mass removed, and mass removal rate for the Lime Basins mass removal system during the FYR period. The total mass removal during the FYR period was 1059.8 kg (2336.5 lbs). Dense non-aqueous phase liquid was discovered in the Lime Basins slurry wall project dewatering wells in August 2009. This event is addressed in Section 4.1.

Table 5.1.1.6-3. Lime Basins Mass Removal Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Volume of Groundwater Treated (gal)	Total Mass of Contaminants Removed	Mass Removal Rate (kg removed/ 1,000 gal treated)	Major Contaminants Removed
2010	0.56	241,387	167 kg 368.2 lbs	0.7	Chloroform Arsenic 1,2-dichlorobenzene 1,4-dichlorobenzene Chlorobenzene
Total (2006-2010)	0.55 (avg.)	1,213,710	1059.8 kg 2336.5 kg	0.9 (avg.)	

The mass removal rate was consistent while the system was operating, averaging 0.9 kg removed/1,000 gallons treated. The annual mass removal was lower than estimated in the design document (2,210 kg/year) because the actual flow rates were significantly lower than the flow rate of 3 gpm assumed in the design. The average flow rate for the FYR period was 0.55 gpm. The aquifer is stratified and the pumping tests used in the design calculations occurred when water levels were higher and in a more permeable sand zone. A clay zone is present in the lower portion of the alluvium, and with lower water levels, most of the flow comes from the clay zone. The Lime Basins mass removal was also reduced because of shutdown of the system to allow construction of the RCRA-equivalent cover construction in the Lime Basins area and because DNAPL was discovered.

Water level monitoring was conducted in the Lime Basins network wells and water quality monitoring was conducted in the four mass removal system extraction wells and four monitoring wells to assess the effects of the system on groundwater levels and water quality and assess the capacity of the recharge trenches. No significant changes in groundwater levels occurred during the review period. The capacity of the recharge trenches decreased slowly, but excess capacity was adequate for the duration of the project. Use of the recharge trenches was discontinued in 2010 when the mass removal system was shut down and treatment of the groundwater extracted by the Lime Basins slurry wall project dewatering wells was transferred to the BANS. At the BANS, the extracted groundwater was treated to below CSRG concentrations and reinjected by the BANS recharge system.

Based on criteria in the Resolution Agreement, Design Document (Washington Group International 2006), and ESD (TtEC 2006b), the GWMR Project functioned as intended in the Decision Documents. The GWMR Project CCR was approved by the EPA on May 16, 2012.

5.1.1.7 CERCLA Wastewater Treatment Facility

The CWTF supported various RMA remediation projects. The facility operated in batch mode in compliance with all On-Post ROD specifications. Treated water from the CWTF was previously conveyed to the Basin A Neck treatment plant by an underground pipeline, combined with effluent from the plant at a maximum rate of 5 gpm, and reinjected in the Basin A Neck recharge trenches. From 2006 to 2010, the CWTF was used for treatment of water extracted under the GWMR Project (STF and Lime Basins mass removal) and the Lime Basins Slurry Wall Dewatering Project, and this water was reinjected in the STF and Lime Basins areas under a reinjection exemption that allowed recharge of groundwater at concentrations that exceed the CBSGs (Washington Group International 2005a). The CWTF was decommissioned in 2010 and a CCR was issued (TtEC 2011i). After the GWMR Project ended, and the CWTF was decommissioned, Lime Basins dewatering continued, and treatment of the extracted groundwater was transferred to the BANS. The water is treated to meet the BANS CSRGs/PQLs, and is then recharged in the BANS recharge trenches.

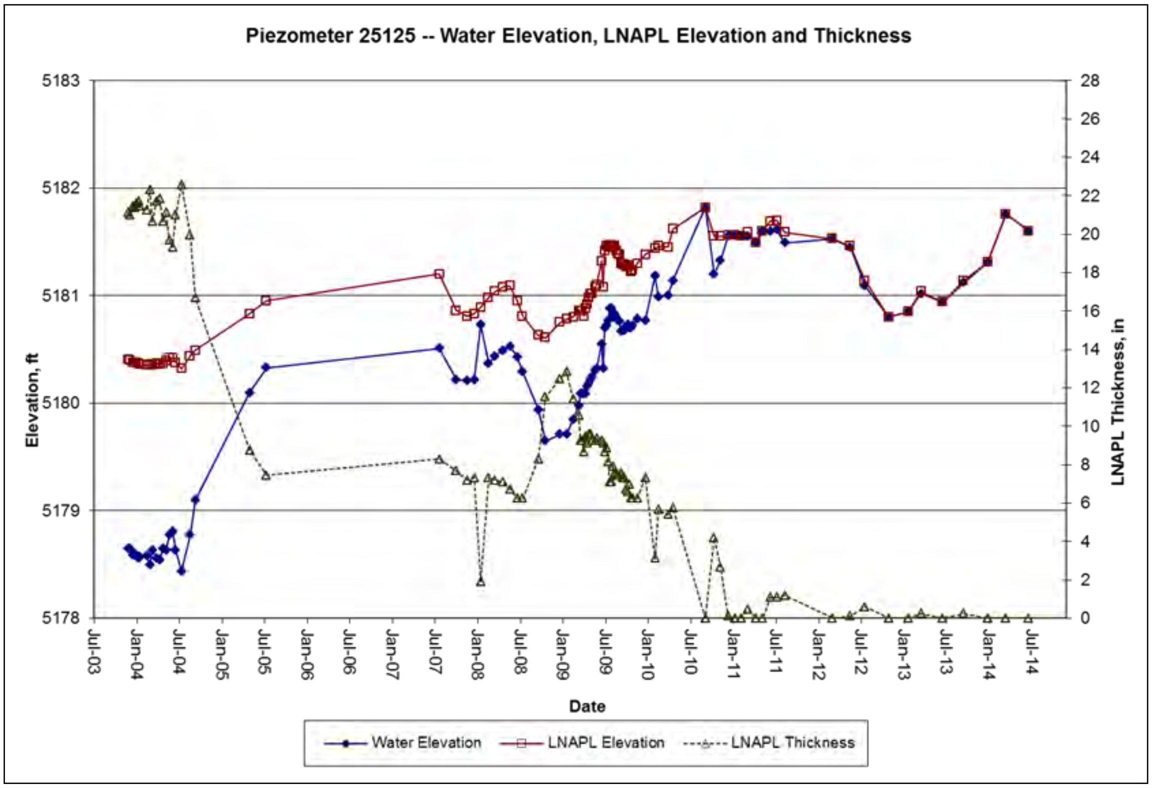
The CWTF met all applicable provisions of the On-Post ROD. All liquid discharges to the Basin A Neck recharge trenches met standards. All wastes generated were properly disposed of off-site in a fully permitted and CERCLA Off-Site Rule-approved facility.

5.1.1.8 North Plants LNAPL

In February 2009, the North Plants LNAPL Removal Pilot Study Action Plan was issued to evaluate actions for LNAPL removal (URS and TtEC 2009). The LNAPL consists of fuel oil that migrated to the water table from historical leaks from storage tanks in North Plants. LNAPL is a separate-phase liquid that does not mix or dissolve readily in water and is less dense than water, so it floats on the top of the water table.

During the FYR period, water levels and LNAPL thickness were monitored. Figure 5.1.1.8-1 is a well location map for North Plants that shows 12 original piezometers, 10 new piezometers, and 2 new recovery wells that were installed in 2009. Water level and LNAPL thickness monitoring has been conducted since 2003. Figure 5.1.1.8-2 shows the water elevations, LNAPL elevations, and LNAPL thickness for piezometer 25125. The figure shows that the LNAPL thickness increases and decreases in response to changes in water elevations. Since 2004, the LNAPL thickness in piezometer 25125 decreased from 22 inches to zero, likely in response to the rising water table. Figure 5.1.1.8-3 shows the LNAPL extent in 2004, 2007, and 2010 and groundwater elevations in July 2014.

Figure 5.1.1.8-2. Piezometer 25125—Water Elevation, LNAPL Elevation and Thickness



In 2005, the North Plants LNAPL and groundwater were sampled and analyzed to characterize the LNAPL and determine the impact of the petroleum release on the groundwater. A sample of the LNAPL was collected from piezometer 25125. Two piezometers downgradient of the LNAPL pool (25126 and 25133) and monitoring wells farther downgradient (25054, 25059, and 25091) were sampled to characterize the groundwater constituents potentially associated with the LNAPL. In 2007, piezometers 25132 and 25133 were sampled to further characterize the groundwater immediately downgradient of the LNAPL accumulation. The locations of the piezometers are shown on Figure 5.1.1.8-1. The results were reported in the North Plants Soil Remediation Project Interim Free Product and Groundwater Characterization Data Summary Report (TtEC 2007b). The groundwater results were compared to the Colorado Department of Labor and Employment Office of Public Safety Tier 1 Standards. These standards are the same as the Colorado Water Quality Control Commission (CWQCC) CBSGs. All results were below these standards. Reporting limits for certain analytes were above the standards; however, they were below the PQLs established for these compounds in the CWQCC PQL guidance (CDPHE 2008).

Monitoring of water levels and LNAPL thickness in the new and existing wells began in March 2009 to determine when the LNAPL thickness would stabilize in the new wells so that bail-down testing and the pilot study could begin. Monitoring was conducted weekly from March 2009 through the end of October 2009, and LNAPL was not detected in any of the new recovery wells and piezometers. Additionally, the LNAPL thickness decreased in the existing piezometers during the same time period. The water levels and LNAPL thickness were monitored monthly in FY10 and FY11. After LNAPL did not accumulate in the wells sufficiently to begin removal through the end of FY11, the pilot study was reassessed and quarterly monitoring from FY12 through the end of the FYR period was agreed upon by Army and Shell and the Regulatory Agencies.

Table 5.1.1.8-1 shows the LNAPL thickness at the end of each fiscal year from 2009 through 2014. The LNAPL thickness decreased in all the wells and was not detected at the ends of FY13 and FY14. Figure 5.1.1.8-4 shows that water levels rose overall with lower water levels during FY13. The rise in the water table may be reducing the mobility of LNAPL into the new wells, and likely caused the apparent LNAPL thickness in the piezometers to decrease. LNAPL removal will commence if LNAPL migrates into the recovery wells with a sufficient thickness for recovery.

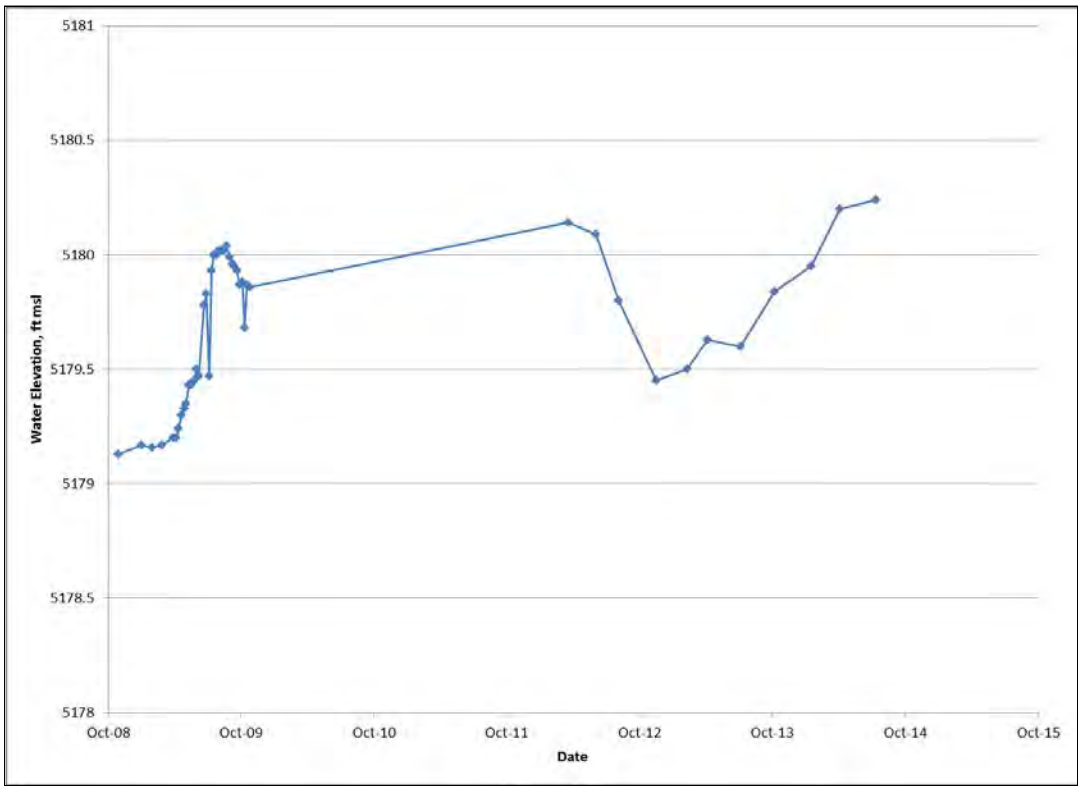
Table 5.1.1.8-1. LNAPL Thickness at the end of FY09, FY12, FY13, and FY14

Piezometer	Measurement Date	LNAPL Thickness, ft
25125	09/28/09	0.61
	7/10	0
	7/11	0
	08/08/12	0.05
	07/10/13	0
	07/17/14	0
25130	09/28/09	0.43
	7/10	0
	7/11	0
	08/08/12	0
	07/10/13	0
	07/17/14	0

Table 5.1.18-1. LNAPL Thickness at the end of FY09, FY12, FY13, and FY14 (Concluded)

Piezometer	Measurement Date	LNAPL Thickness, ft
25132	09/28/09	0.06
	7/10	0
	7/11	0
	08/08/12	0
	07/10/13	0
	07/17/14	0
25134	09/28/09	0.15
	7/10	0
	7/11	0
	08/08/12	0.02
	07/10/13	0
	07/17/14	0

Figure 5.1.1.8-4. North Plants Well 25132 Hydrograph



Except for an LNAPL thickness of 0.24 inch (0.02 ft) measured in well 25125 in October 2013, no measurable LNAPL was detected in the North Plants wells during FY14. A rising water table prior to and during the pilot study likely caused the apparent thickness and extent of LNAPL to decrease, and explains the lack of entry of LNAPL into the recovery wells. The thickness of LNAPL in the formation probably is insufficient to overcome the entry capillary pressure. A falling water table may cause the apparent thickness of LNAPL in the wells to increase if sufficient potentially mobile LNAPL is still present in the formation. Based on the previous data, a decrease in water elevations of a least one foot for six months or longer may be required for the apparent thickness of LNAPL in the wells to increase significantly (URS 2012). Since this scenario was approximated during 2012/2013, yet the LNAPL thickness did not increase appreciably, potentially mobile LNAPL may no longer be present. A minimum apparent thickness of six inches is needed in the recovery wells for bail-down testing to be conducted, which would precede recovery operations. An apparent thickness of six inches was last measured in a piezometer in 2010. Thus, it is extremely unlikely for this to occur in the larger diameter recovery wells. The Colorado Department of Labor and Employment Division of Oil and Public Safety Petroleum Storage Tank Owner/Operator Guidance Document (CDLE 2005) requires that LNAPL be removed to the extent practicable. The monitoring data demonstrate that removal of LNAPL no longer appears feasible.

Figure 5.1.1.8-3 shows the area of stained soil, which was much larger than the maximum extent of LNAPL measured in the piezometers in 2004. Most likely, LNAPL caused the staining of the soil at the water table. Thus, the extent of the stained soil likely was the maximum extent of the LNAPL before the piezometers were installed to characterize the LNAPL extent. This decrease in the extent of the LNAPL over time likely has been caused by a combination of factors including a fluctuating water table and by biodegradation. The weekly, monthly, and quarterly monitoring data indicate that potentially mobile LNAPL no longer appears to be present, and it likely has become trapped by capillary pressures. Aerobic biodegradation of fuel oil is a known attenuation mechanism and would affect the residual fuel oil in the soil. To confirm that potentially mobile LNAPL does not accumulate in the piezometers and recovery wells in a sufficient thickness for recovery operations, the piezometers and recovery wells will be monitored annually during the next FYR period and the LNAPL project will be reviewed again during the 2020 FYR. If LNAPL is found in sufficient thickness for removal, Army and Shell have an ongoing commitment for additional action, and LNAPL removal operations will commence.

5.1.2 On-Post Containment Remedy

5.1.2.1 Complex (Army) Disposal Trenches

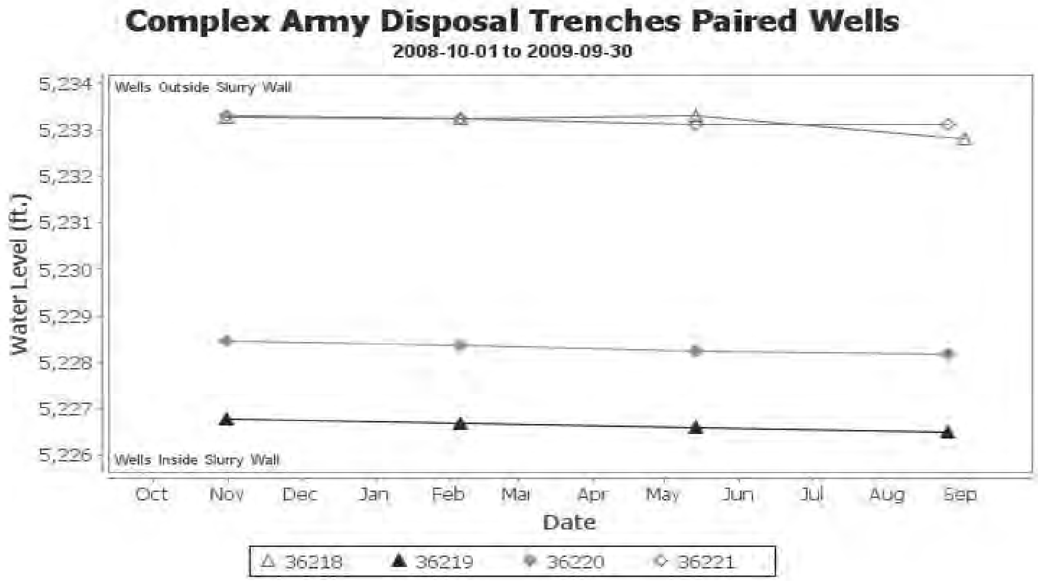
Installation of the CADT slurry wall began in 1998 and construction of the project was completed in 2000. Testing of the groundwater extraction trench was completed in February 2000 and operation of the dewatering system began in March 2001. Figure 5.1.2.1-1 is the well location map for the CADT.

The head differential across the slurry wall is monitored to ensure that the groundwater extraction system does not induce differentials that would affect the stability of the wall, and to show whether an inward hydraulic gradient is maintained. Also, for compliance purposes, water levels adjacent to disposal trenches are monitored to confirm the dewatering objective of lowering the water table below the bottom of the trenches that was identified in the CADT and Shell Section 36 Trenches Groundwater Barrier Project 100 percent design document (RVO 1997). The design dewatering goal is derived from the On-Post ROD goal (FWENC 1996) of "dewater as necessary to ensure containment."

The performance criteria for the CADT system are to demonstrate that water levels in compliance monitoring wells 36216 and 36217 are below the target elevations of 5226 ft and 5227 ft, respectively, and that the water levels inside the slurry wall are lower than the water levels outside the slurry wall (i.e., maintain an inward gradient). The target elevations correspond to the disposal trench-bottom elevations.

The maximum hydraulic gradient across the barrier wall during the FYR period was 3.5 ft per foot (ft/ft), which is well below the upper safe limit of 10 ft/ft, cited in the design document. An inward hydraulic gradient was also present at the two well pairs adjacent to the slurry wall (Figure 5.1.2.1-2). Maintenance of an inward hydraulic gradient across the slurry wall indicates that hydraulic containment has been achieved.

Figure 5.1.2.1-2. Complex (Army) Disposal Trenches Well Pair 36218/36219 and 36220/36221



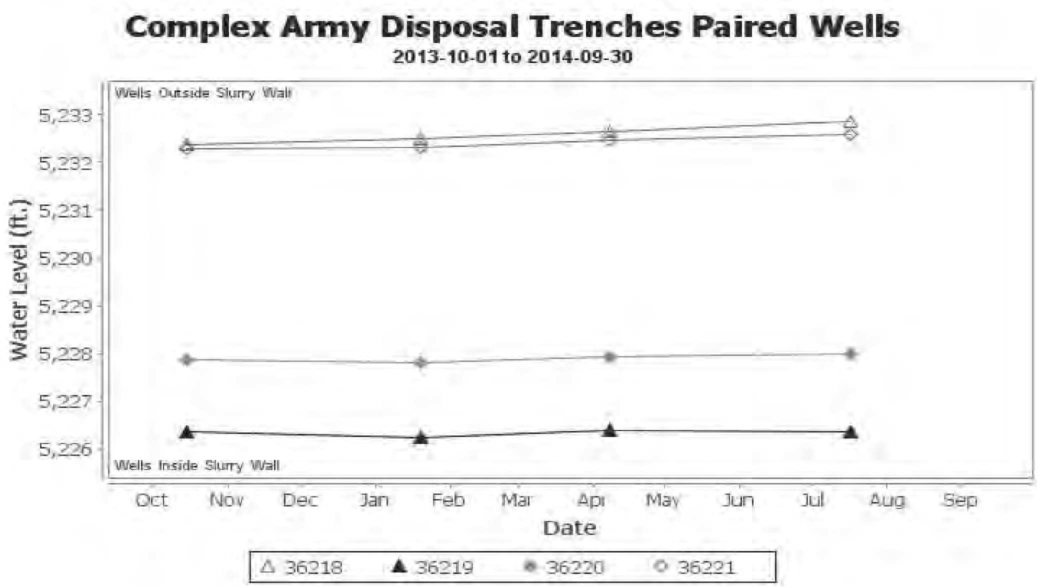


Figure 5.1.2.1-3 shows the quarterly water levels for wells 36216 and 36217 since system startup in 2001. Water levels in the two compliance wells have dropped 2 to 5 ft since dewatering commenced. The water elevations in well 36216 were below the target throughout the FYR period except when the dewatering well was shut down temporarily in FY11. The quarterly water levels for well 36217 remained above the target elevation, but are trending lower, with the elevation less than one foot above the target elevation in FY14. The water elevation in well 36217 was only 0.66 ft above the goal before the effects of the September 2013 and May 2014 storms caused the water level to rise.

The 2010 LTMP determined a time frame for meeting the CADT dewatering goals based on the influence of the Integrated Cover System on the groundwater levels. For cover compliance, the vegetation is expected to be established five years after the cover is constructed and seeded. Consequently, the 2010 LTMP stated that achievement of the dewatering goals is expected to occur by September 9, 2014, after the five-year period required to establish vegetation. The unprecedented 500- to 1000-year storm event in September 2013, followed by heavy May 2014 rainstorms, affected the groundwater elevations within the CADT slurry wall, such that the dewatering goals were not attained by September 2014. On September 29, 2014, the Regulatory Agencies were notified about the non-attainment of the dewatering goals. In well 36217, both the short-term (FY10-FY14) and long-term water elevation trends are decreasing, and indicate that progress toward meeting the dewatering goal in well 36217 is being made, even with the September 2013 and May 2014 storms. Consequently, no further action besides continued quarterly monitoring was proposed, and progress toward meeting the goals will be reported in the quarterly effluent reports and ASRs. A summary of the operational data for the FYR period is provided below.

Figure 5.1.2.1-3. Complex (Army) Disposal Trenches Compliance Well 36216 and 36217 Hydrograph

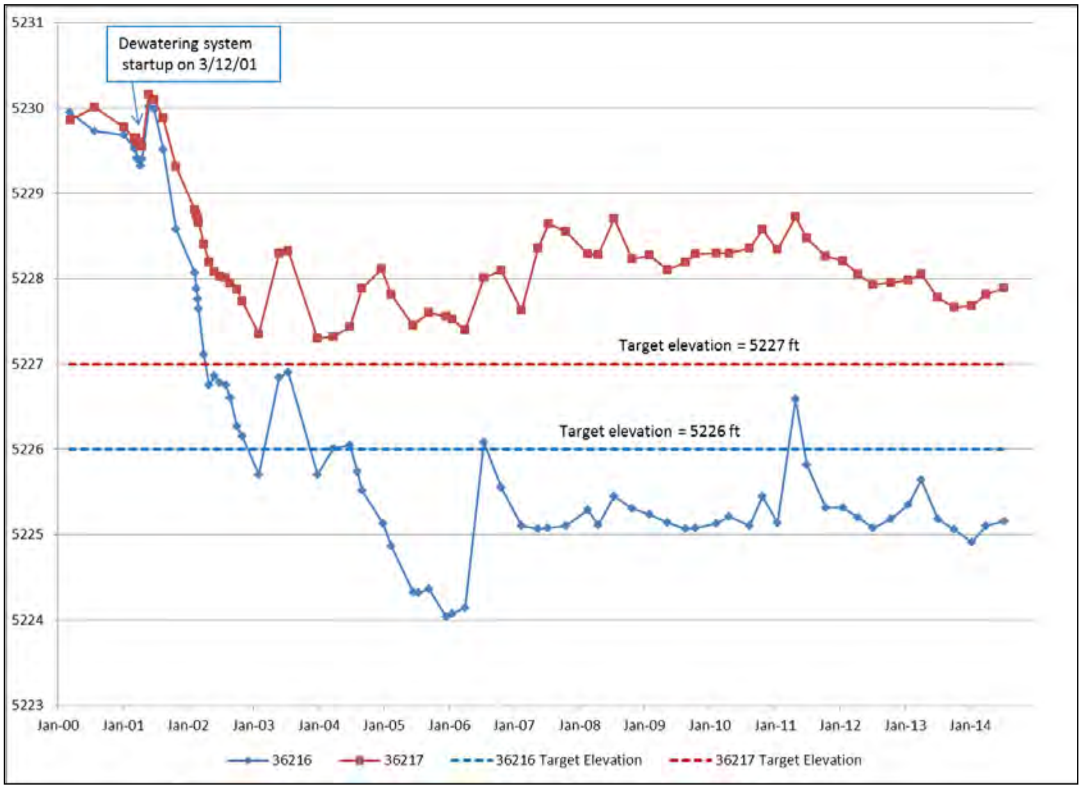


Figure 5.1.2.1-4 shows the flow rate for the CADT dewatering well. The average flow rate was 1.68 gpm during this FYR period, which is lower than the previous FYR period (2.1 gpm). The flow rate has been optimized to reduce cycling of the dewatering well pump on and off, and shows a decreasing trend for the FYR period. Figure 5.1.2.1-5 shows the water elevations in the dewatering well (36305) and in the piezometer in the dewatering trench (36215). The water level in the dewatering trench has been maintained at an elevation of about 5220 ft during this FYR period and during the previous period. Maintaining the water level at this elevation minimizes cycling of the pump. The short-term rises in the water elevations on Figure 5.1.2.1-5 during 2011 were caused by temporary shutdowns of dewatering-well pumping. Even though the flow rate has decreased somewhat, the water elevation in the dewatering trench has been maintained at the desired operational level, which is six to seven feet below the compliance well target elevations. The stable water levels in the dewatering trench since 2005 suggest that the dewatering capacity is not declining and there is no plugging of the gravel in the trench. The lower flow rate likely is caused by less saturated thickness in the alluvial aquifer near the dewatering trench, but that indicates that dewatering is successfully occurring.

Figure 5.1.2.1-4. Complex (Army) Disposal Trenches Dewatering Well 36305 Flow Rate

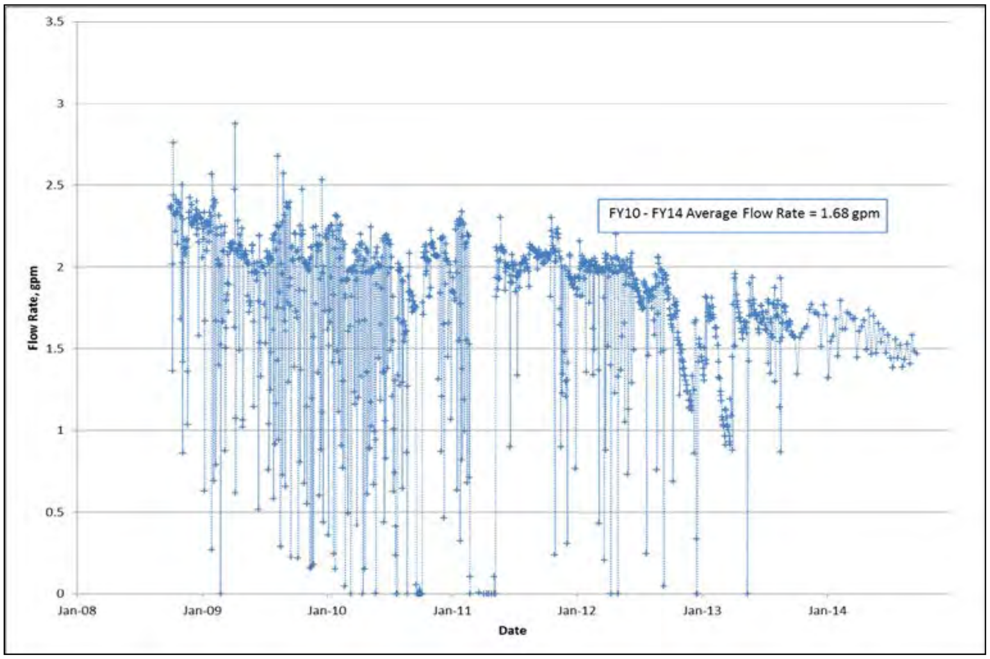
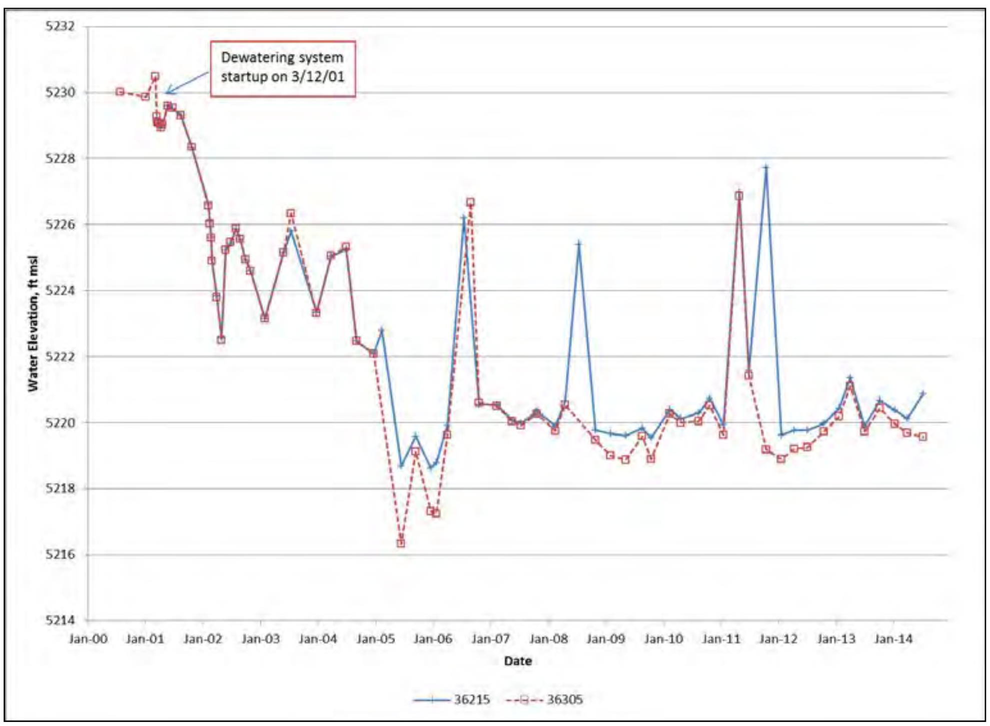


Figure 5.1.2.1-5. Complex (Army) Disposal Trenches Dewatering Well 36305 and Trench Piezometer 36215 Hydrographs



Based on criteria in the Design Document (RVO 1997), On-Post ROD, and 2010 LTMP, the CADT dewatering system is not performing as expected in the Decision Documents. The inward hydraulic gradient has been maintained and the dewatering goal has been attained in one of the two compliance wells. Although the dewatering goal of lowering the water level below the trench bottom elevation in the second compliance well has not been met, it is within one foot of meeting the goal and progress is being made toward the goal. There is a decline in the water elevations during the five years since the ICS construction was completed. Army and Shell believe that the progress toward meeting the goal will continue and progress toward meeting the dewatering goal will be evaluated further during the next FYR period. A cost-benefit evaluation for installing dewatering wells in the CADT to supplement the existing dewatering trench will also be conducted.

In the meantime, there is no adverse impact to the protectiveness of the remedy because the CADT groundwater contamination is contained within the slurry wall. Additionally, significant contaminant mass removal is occurring because of continued operation of the dewatering trench and treatment of the groundwater to meet CSRGs at BANS. For example, over 200 lbs of contaminant mass was removed during the FYR period for just three of the 37 analytes detected in well 36305 (i.e., DIMP, dithiane, and TCE). For comparison, contaminant removal for the NWBCS and NBCS combined was 63.8 lbs for the FYR period. When the CADT dewatering goal of lowering water levels below the disposal trench bottoms is achieved and can be maintained without pumping, the groundwater treatment and associated mass removal will end.

5.1.2.2 Shell Disposal Trenches

The Shell Disposal Trenches slurry wall remedy includes installation of a slurry wall encircling the disposal trenches as shown in Figure 5.1.2.2-1. The 2-ft-thick slurry wall, installed in 1999**,** surrounds the 6-inch-thick slurry wall installed during the Shell Disposal Trenches IRA in 1991.

The purpose of groundwater level monitoring, specified in the combined Complex (Army) Trenches and Shell Section 36 Trenches 100 percent design document (RVO 1997), is to measure water level differentials across the barrier wall to obtain information on the direction (i.e., inward or outward) of gradients across the barrier. Monitoring is also conducted to obtain information on the water level differentials that could affect barrier wall stability. The design document stated that dewatering inside the Shell Disposal Trenches slurry wall was not necessary at that time because water levels were already below the bottom of the trenches. As such, the dewatering goal was redefined as "lowering the water table below the trench bottom." Thus, the performance criteria for the Shell Disposal Trenches are based on achieving water elevation goals (i.e., below the bottoms of the disposal trenches) (RVO 1997). Quarterly water level monitoring is conducted in 14 wells to monitor the hydraulic gradient across the slurry wall, and water levels inside the slurry-wall enclosure, to assess progress toward meeting the dewatering goals.

The improved effectiveness of the ROD slurry wall compared to the IRA slurry wall is demonstrated by a reduction in the northerly hydraulic gradient inside the slurry-wall enclosure and larger head differences across the slurry wall on the northern side, especially at the northeastern corner where leakage of the IRA slurry wall was suspected. Between 1997 (before the ROD slurry wall was constructed) and January 2013, the northerly gradient decreased from 0.0047 ft/ft to 0.00095 ft/ft (80 percent decrease) in January 2013 on the western side. On the eastern side, well 36535 is dry, so the gradient cannot be determined.

In the northeastern corner, the head difference was only 0.23 ft in December 1997 before the ROD slurry wall was constructed; it was 1.29 ft in August 2009; and 1.57 ft in July 2014. Outward gradients were present in the north-side well pairs and inward gradients were present in the south-side well pairs throughout the FYR period. The head differences averaged 1.5 ft in the northeast corner, 3.1 ft in the northwestern corner, 3.9 ft in the north-central well pair, and 1.3 ft in the southwest corner during the FYR period. An inward gradient probably was present in the southeast corner, but the head difference cannot be determined because well 36535 is dry. Since active dewatering was not required in the original design, creating or maintaining an inward hydraulic gradient also is not required. The maximum hydraulic gradient across the slurry wall was 1.6 ft/ft, which is well below the upper safe limit of 10 ft/ft.

The performance requirement for Shell Disposal Trenches is to demonstrate that groundwater elevations are below the disposal trench-bottom elevations within the slurry-wall enclosure shown in Figure 5.1.2.2-1 and Table 5.1.2.2-1 below. Table 5.1.2.2-1 lists the bores drilled through the disposal trenches where the trench-bottom elevations were determined. The elevation of the water level at each bore location was interpolated using the July 2014 water table and bore locations in Figure 5.1.2.2-2. As shown in Table 5.1.2.2-1, the water elevations were below the bottom of the trenches in all of the bores except at Bore 3453 in July 2014. The July 2014 water elevation is estimated to be 0.4 ft above the trench-bottom elevation at Bore 3453.

The 2010 LTMP determined a time frame for meeting the dewatering goals based on establishment of the Integrated Cover System vegetation. The target goals were required to be achieved by October 2, 2012, after the five-year period required to establish cover vegetation. The Regulatory Agencies were notified on October 3, 2012 that the goal was not met. The notification indicated that meeting the goal was expected to be achieved during calendar year 2013 based on the water elevation trends in the associated wells. The dewatering goal was first met in July 2013 and continued until October 2013. The September 2013 500- to 1000-year storm, followed by heavy rains in May 2014, caused water levels to rise inside the Shell Disposal Trenches slurry wall. The water elevation at Bore 3453 was above the trench-bottom elevation in January, April, and July 2014. The Regulatory Agencies were notified that the dewatering goal was not met after the quarterly monitoring results were reviewed.

The September 29, 2014 notification occurred after the third consecutive quarter of loss of the dewatering goal and stated that after the effects of the September 2013 and May 2014 storm events have passed, the water elevations inside the slurry wall should decrease and the dewatering goal will be re-attained. Thus, continued quarterly water level monitoring was proposed. Additional notifications will be discontinued, unless it becomes apparent that the dewater goal will not be re-attained, and the status will be reported in the Quarterly Effluent Reports and ASRs.

Figure 5.1.2.2-2 depicts groundwater elevations in July 2014. Based on these water-level data, it appears that the groundwater elevations were below the bottom of the trenches except at one location (i.e., Bore 3453). This finding is based on six borings where the trench bottom elevations were determined during the RI (see Table 5.1.2.2-1), and the groundwater elevations were below the trench bottom elevations at five of the six locations during this FYR period.

Table 5.1.2.2-1. Shell Disposal Trenches Boring Water Elevations (July 2014) and Trench Bottom Elevations

Bore ID	FY14 Water Elevation (interpolated from Figure 5.1.2.2-2) (ft)	Trench Bottom Elevation (ft)	Bore Water Level Above or Below the Trench Bottom
3178	5239.9	5242.0	Below
3444	5237.8	5244.1	Below
3445	5238.0	5240.5	Below
3446	5237.9	5240.6	Below
3453	5238.1	5237.7	Above
3457	5239.1	5240.8	Below

Table 5.1.2.2-1indicates that the water table elevation was above the trench bottom at boring 3453 by approximately 0.4 ft.

Figure 5.1.2.2-3 shows the water elevations in wells 36226, 36529, 36536, and 36537 from 2004 through the FYR period. Wells 36226, 36536, and 36537 are located at the southwestern corner of the slurry-wall enclosure and well 36529 is located at the northwestern corner. Well 36226 is located outside the ROD slurry wall, well 36537 is between the two slurry walls, and wells 36529 and 36536 are inside the IRA slurry wall.

The water elevations in wells 36536 and 36537 track each other and are consistently lower than well 36226. This shows that the 2-ft-thick ROD slurry wall is more effective than the 6-inch thick IRA slurry wall. The water elevations for wells 36536 and 36537 declined from 2010 through 2013, and then increased after the September and May 2014 storms.

Figure 5.1.2.2-3. Shell Disposal Trenches Hydrographs for Wells 36226, 36529, 36536, and 36537

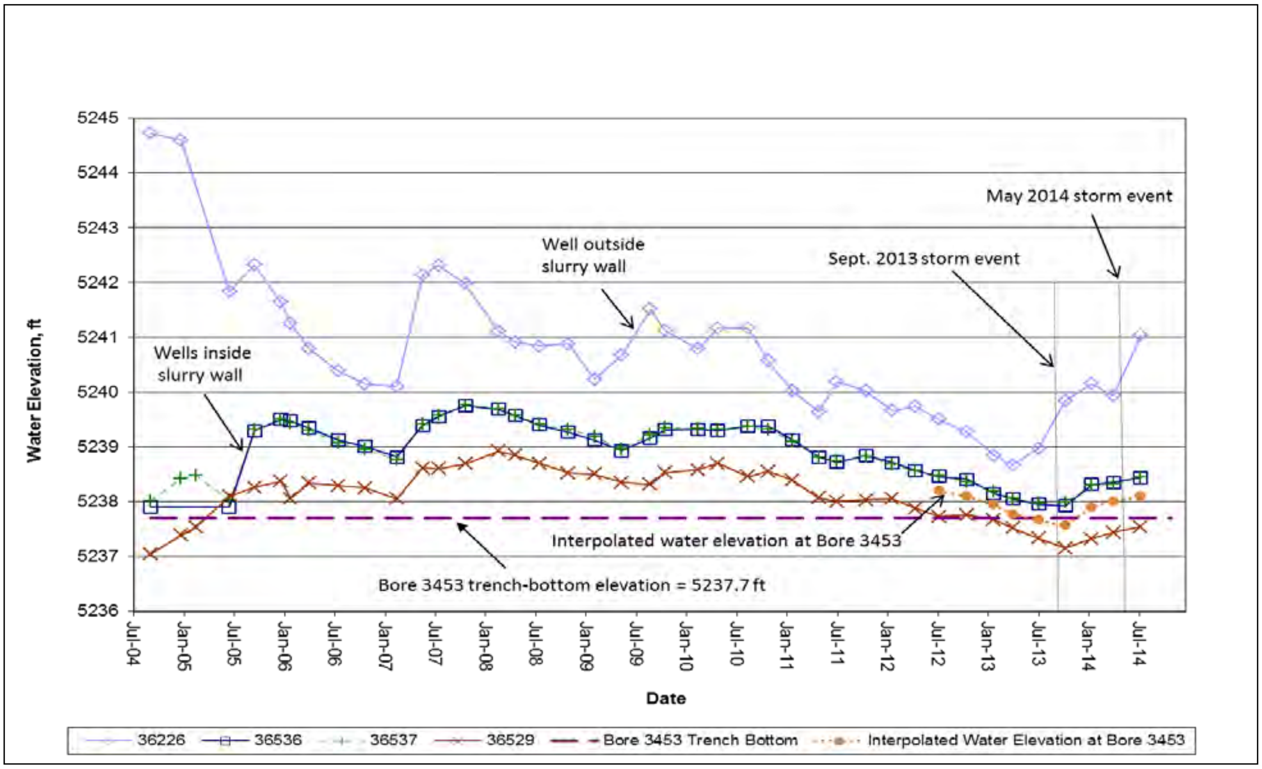


Figure 5.1.2.2-3 shows that the interpolated water elevation at boring 3453was above the disposal trench bottom of 5237.7 ft during most of the FYR period.

Based on criteria in the Design Document (RVO 1997), On-Post ROD, and 2010 LTMP, the Shell Disposal Trenches slurry wall and cover performed as expected in the Decision Documents during part of the FYR period. The goal of maintaining water levels below the bottom of the disposal trenches was achieved in all of the six boring locations in parts of FY13 and FY14. The combined effects of the historic flood event in September 2013 and May 2014 rainstorms caused water levels to rise inside the slurry wall and were above the trench bottom at one of the six borehole locations at the end of the FYR period. The protectiveness of the remedy is not significantly affected because much of the Shell Disposal Trenches groundwater contamination is contained within the dual slurry walls. Additionally, downgradient of the Shell Disposal Trenches, the groundwater is extracted by the BRES and BANS, and treated to meet CSRGs. Thus, the remedy contains multiple layers of protectiveness. After the effects of the 2013 and 2014 storms have passed, water levels are expected to stabilize then fall, and the dewatering goal will be re-attained. Progress toward meeting the dewatering goal will be evaluated further during the next FYR period. Since the ability to meet the dewatering goal in the Shell Disposal Trenches has been negatively affected by the recent heavy rainfall events, a cost-benefit evaluation for installing dewatering wells in the Shell Disposal Trenches will be conducted during the next FYR period.

5.1.2.3 Lime Basins Slurry Wall Dewatering

An encircling slurry wall and dewatering system were installed to contain Lime Basins contamination (TtEC 2005, 2007c). Extracted water was treated at the CWTF until it was decommissioned in 2010. After that, treatment occurred at the BANS. The Lime Basins slurry wall dewatering system was independent of the Lime Basins groundwater mass removal system (Section 5.1.1.6.3).

Figure 5.1.1.6-3 (first cited in Section 5.1.1.6.2, and provided at the end of the report) is the well location map for the Lime Basins Groundwater Systems. The Lime Basins slurry wall dewatering system consists of six dewatering wells located inside the slurry-wall enclosure, 11 new monitoring wells, and two existing monitoring wells. Water levels are monitored inside and outside the slurry wall at six well pairs, which consist of the 11 new monitoring wells (36231 through 36241) and one previously existing well (36054).

Baseline water levels for the slurry-wall project wells were measured on March 25, 2009, and the system started up on March 30, 2009. Figure 5.1.2.3-1 shows the reverse gradient plots for the north side wells in FY09 and FY14, and Figure 5.1.2.3-2 shows the reverse gradient plots for the south side wells in FY09 and FY14. Figure 5.1.2.3-3 shows the water level trends for the wells inside the slurry-wall enclosure and the total flow rate for the six dewatering wells between March 2009 and September 2014. Figure 5.1.2.3-3 also shows the shutdown periods for 1) evaluating DNAPL, 2) decommissioning the CERCLA Wastewater Treatment Facility, and 3) modifying BANS. FY12 was the first full year of operation of the LB.

In August 2009, monitoring of the Lime Basins dewatering wells indicated the potential presence of DNAPL. A RI/FS was conducted and three suspected DNAPL source zones were identified in the Lime Basins area (refer to Section 5.1.2.4 for discussion of the Lime Basins DNAPL Remediation Project). During the RI, in April of 2010, deterioration was observed of the polyvinyl chloride (PVC) piping components associated with dewatering well DW-10. Deterioration in the form of softening was observed of the down-well pump discharge pipe, strainer cage, and ball valve. The piping associated with the other dewatering wells was also inspected for similar deterioration but none was observed, either with the PVC or high-density polyethylene (HDPE) piping components. The deterioration of the piping associated with DW-10 appears to be a function of the specific high concentration of compounds (mostly isomers of dichlorobenzene and chloroform) associated with this well. Details of the investigation were summarized and presented to the Regulatory Agencies during a DNAPL project meeting conducted on April 21, 2010. In accordance with the corrective actions proposed during that meeting, the RVO prepared a DCN detailing the modifications to address the material incompatibility. This DCN was reviewed and approved by the Regulatory Agencies (TtEC 2010d). To summarize, the proposed modifications to the Lime Basins slurry wall dewatering system included:

- The PVC piping components associated with DW-10 that were located in the Lime Basins meter building were replaced with Type 316L stainless-steel components as detailed in the DCN.
- The down-well PVC discharge pipe associated with DW-10 was replaced with Type 316L stainless-steel piping as detailed in the DCN.
- The existing piping from the dewatering well to the edge of the RCRA equivalent Cover (including runout area) was modified by replacing the transition piping from the pitless adapter to the HDPE piping and the HDPE piping below the biota barrier was replaced with a new HDPE pipeline that was installed above the biota barrier layer near the bottom of the soil cover. The existing piping below the biota barrier layer was abandoned in-place after it had been rinsed. This modification was performed for dewatering wells DW-5 through DW-10 as detailed in the DCN.

In addition to the above modifications, the PVC/HDPE piping components associated with dewatering wells DW-5 through DW-10, and located in the Lime Basins meter building, are inspected on a quarterly basis to detect any deterioration resulting from contact with organic compounds (TtEC 2010c).

On May 28, 2010, dewatering wells DW-1 through DW-10 were shut down to allow for the decommissioning and demolition of the CWTF and the Groundwater Mass Removal Project. The dewatering wells of the Lime Basins slurry wall (DW-5 through DW-10) were restored to operation when the Lime Basins Groundwater Treatment Relocation Project was completed and commissioned to receive and treat the Lime Basins groundwater from slurry wall dewatering operations.

As discussed in Section 1.4.1.9, eight new monitoring wells (four well pairs adjacent to the slurry wall) were installed for the Lime Basins DNAPL Remediation Project in late FY12. FY13 and FY14 water quality data were collected to accommodate the LB and DNAPL Remediation Project monitoring objectives. Since the LB does not have water quality performance criteria, the data are discussed in Section 5.1.2.4.

Regulatory goals and conditions for termination of the Lime Basins dewatering system were established in the Amendment to the ROD (TtEC 2005). The dewatering goals/standards are summarized as follows:

- Standard: Dewater as necessary to maintain a positive gradient from the outside to the inside of the slurry wall and maintain groundwater level below the level of the LB waste for as long as the surrounding local groundwater table is in the alluvium.
- Standard: Monitor to ensure that the dewatering standard is met. If the groundwater table drops below the level of the alluvium inside the slurry wall, monitor annually thereafter to check that the groundwater table remains below the alluvium inside the wall.

- Standard: Capture and treat contaminated groundwater to meet CSRGs as specified in the ROD. This standard applies to the dewatering system after the CERCLA Wastewater Treatment Facility is decommissioned, and the extracted groundwater is diverted to BANS for treatment. At this point, the contaminated groundwater will be treated to meet the BANS CSRGs.

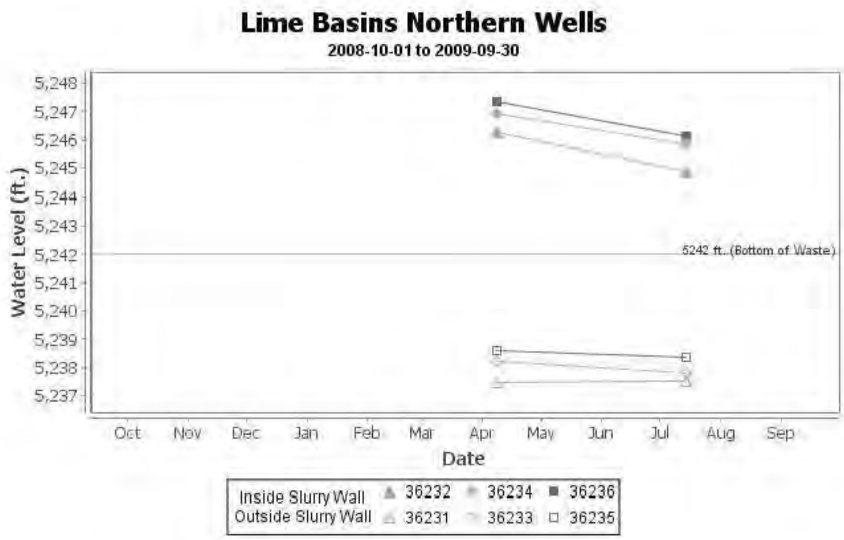
Establishing an inward hydraulic gradient across the slurry wall is one objective of the dewatering system. Figures 5-1.2.3-1 and 5.1.2.3-2 show the water elevation data for the northern and southern well pairs during FY09 and FY14. At baseline (March 25, 2009), an outward gradient was present at all six well pairs. The baseline average head differentials were 9.2 ft in the well pairs on the northern side, and 2.4 ft on the southern side. In the fourth quarter of FY14 (September 18, 2014), an outward gradient was present at all the well pairs on the northern side and, for the first time, an inward gradient was present in all well pairs on the southern side. The average head differentials were 4.5 ft (outward) on the northern side and -0.44 ft (inward) on the southern side of the slurry-wall enclosure. Thus, significant progress was made toward meeting the dewatering goal in FY14.

The second dewatering objective is to lower the water levels inside the slurry-wall enclosure below the bottom of the waste, which is at an elevation of 5,242 ft. The average water elevation inside the slurry-wall enclosure decreased from 5,247.6 ft at baseline, which is 5.6 ft above the base-of-waste elevation, to 5242.5 ft at the end of FY14, which is only 0.5 ft above the bottom of the waste. For the first time, the water elevation in one well (36232) was below the waste elevation. Thus, progress also was made toward lowering the water levels below the waste.

With modification of the BANS in FY11, the Lime Basins groundwater has been extracted and treated in batch mode. Figure 5.1.2.3-3 shows the intermittent nature of the dewatering system flow rates. The LTMP for Groundwater and Surface Water (TtEC and URS 2010) established a time frame for meeting the Lime Basins dewatering goals based on the time required to establish cover vegetation. Although achieving the Lime Basins dewatering goals does not rely on installation of the Integrated Cover System, the associated revegetation and irrigation may affect the timeframe for meeting the dewatering goals. Due to a variety of factors (discussed below), achievement of the dewatering goals did not occur by the target date of September 9, 2014, after the five-year period required to establish vegetation. The Regulatory Agencies were notified on September 29, 2014, and the corrective action is to operate the dewatering and treatment systems in a more continuous manner instead of in batch mode.

The factors that prevented meeting the dewatering goals by 2014 include the following: 1) higher initial water levels inside the slurry wall than in the design document, 2) the pumping rates were significantly lower than the design flow rate of 1.2 gpm, 3) the dewatering system was operated in batch mode, not continuous operation, and 4) extended shut-down periods occurred in 2009 (6 months) and 2010 (one year). The water levels were up to four feet higher at startup in 2009 than when the system was designed in 2005/2006. This created a much larger volume of water that must be pumped to meet the goals. The design flow rate of 1.2 gpm was based on the average flow rate for the GWMR Project wells of 0.28 gpm/well. As water levels have fallen inside the slurry wall due to dewatering, the flow rate has decreased because of less saturated thickness and because the lower part of the alluvial aquifer is less permeable (clay/clayey sand) than the upper part (silty sand). For example, in FY14 the total flow rate was only about 0.2 gpm. The dewatering operation changed from continuous flow in 2009/2010 to batch mode when treatment at BANS began in 2011. The initial batch-mode operation was dictated by the need to demonstrate that the treatment requirements could be met before the water was recharged. The intermittent operation occurred because of the turnaround time needed for the analytical data to be obtained. The shut-down periods for the DNAPL investigation and BANS modifications were not foreseen in the design document or when the LTMP dewatering goal compliance date was determined.

Figure 5.1.2.3-1. Lime Basins Monitoring Well Water Elevations (FY09 and FY14) North Side Wells



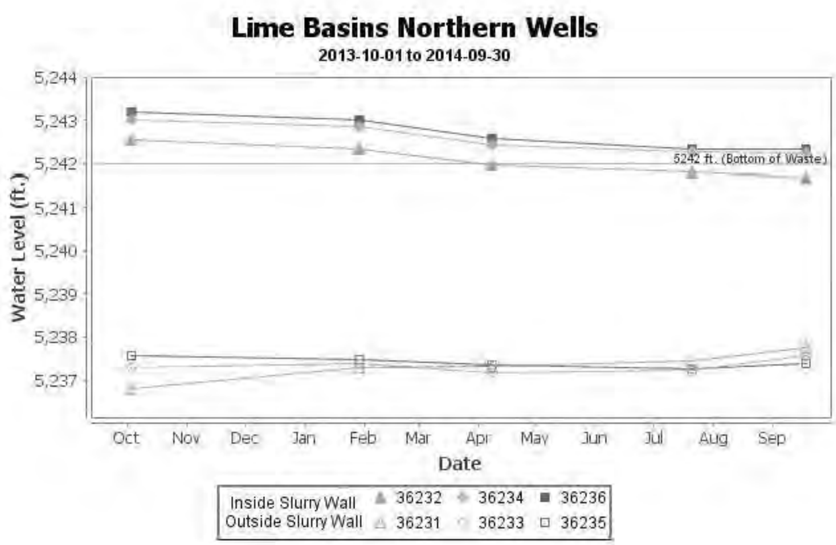
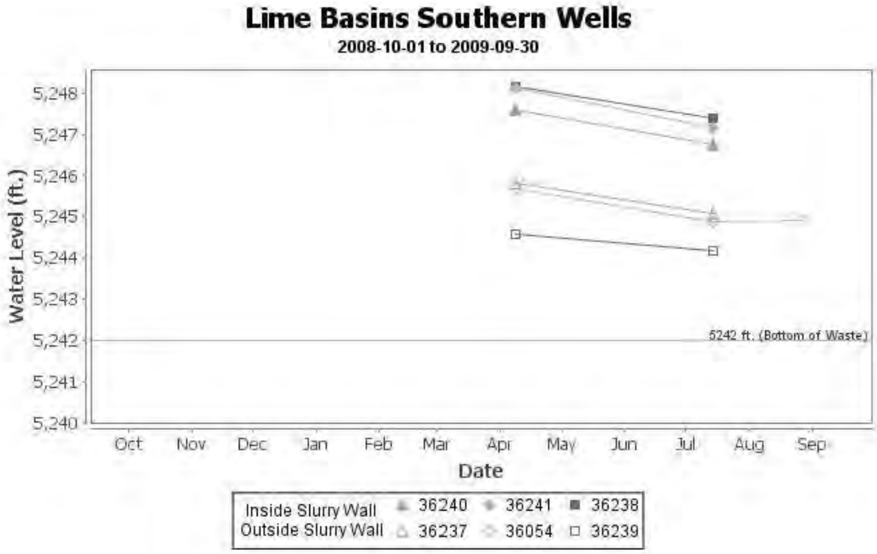


Figure 5.1.2.3-2. Lime Basins Monitoring Well Water Elevations (FY09 and FY14) South Side Wells



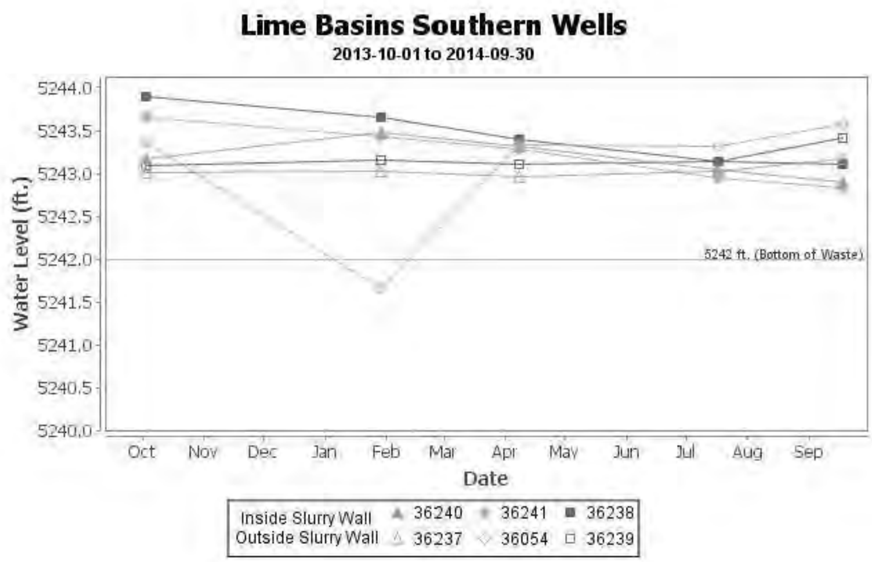
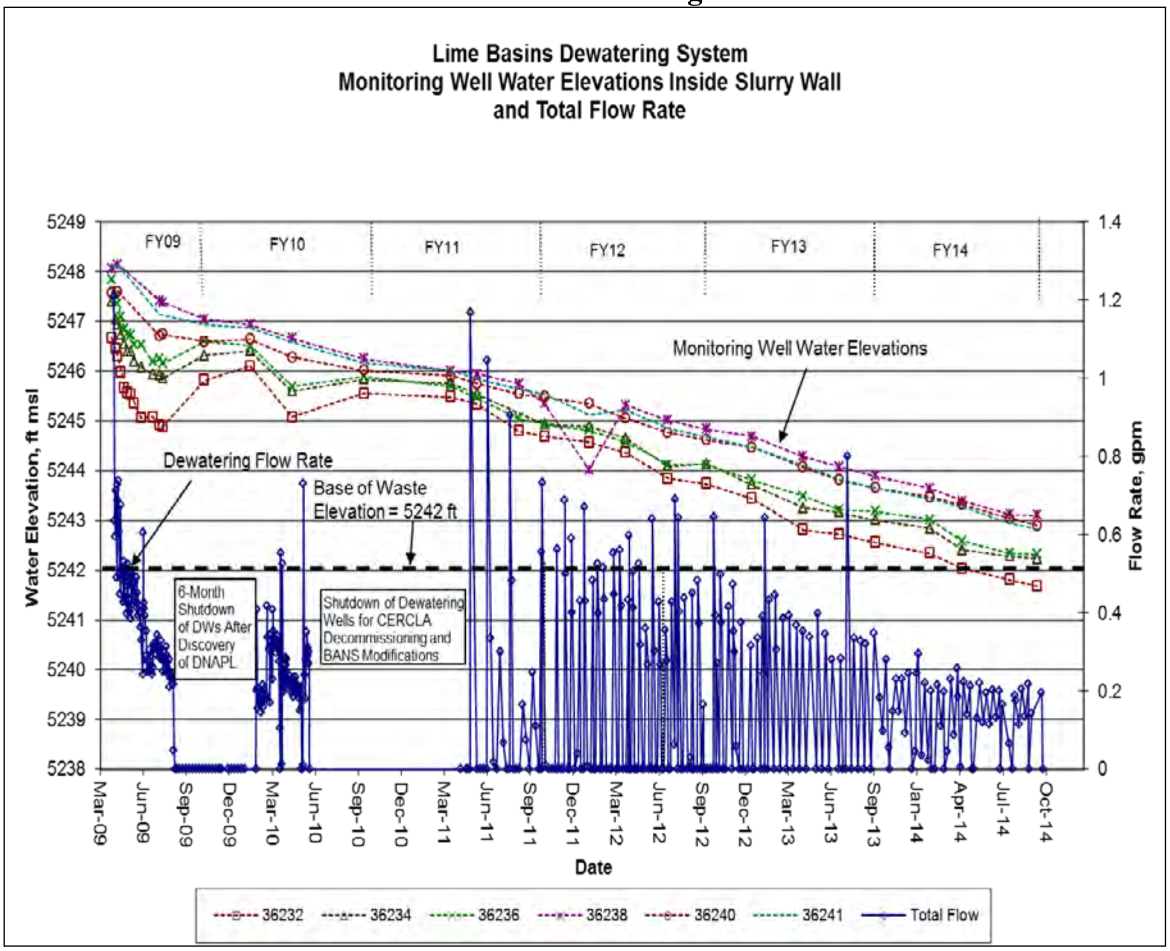


Figure 5.1.2.3-3. Lime Basins Monitoring Well Hydrographs and Total Dewatering Flow Rate



Based on criteria in the Design Document (TtEC 2007c), ROD Amendment (TtEC 2005), and 2010 LTMP, the Lime Basins dewatering project is not functioning as intended in the Decision Documents because the dewatering goals were not met within the time frame established in the 2010 LTMP (September 2014). Significant progress was made toward meeting the dewatering goals, however. An inward gradient has been established in the south-side well pairs, and the water levels are expected to decrease to below the waste elevation during the next FYR period. More continuous operation of the dewatering and treatment systems may help reduce the time frame for meeting all of the dewatering goals. In the meantime, the protectiveness of the remedy is not adversely affected because the Lime Basins contamination is contained within the slurry wall. Progress toward meeting the dewatering goals will be evaluated further during the next FYR period. Revised compliance dates will be developed and documented in the LTMP with an OCN.

5.1.2.4 Lime Basins DNAPL Remediation Project

In August 2009, monitoring of the Lime Basins dewatering wells indicated the potential presence of DNAPL. A RI/FS was conducted and three suspected DNAPL source zones were identified in the Lime Basins area (Refer to Section 1.4.1.9). The selected remedy consists of DNAPL source containment, removal of DNAPL to the extent practicable, and DNAPL thickness and groundwater monitoring (Tetra Tech and URS 2012).

Operation of the Lime Basins dewatering wells will continue according to the goals and standards for the Lime Basins Slurry Wall Dewatering System. The groundwater will be treated at the BANS to meet CSRGs. Eight new monitoring wells (four well pairs adjacent to the slurry wall) were installed in late FY12, and data collection specified in the Design Analysis Report (DAR) (TtEC and URS 2012) began in FY13 and continued in FY14. The Lime Basins DNAPL Remediation Project FY13 Monitoring Results, Conclusions, and Recommendations (Department of the Army 2015) were presented to the Regulatory Agencies on November 20, 2013. The FY13 and FY14 results are summarized in this section.

Figure 5.1.1.6-3 is the well location map for the Lime Basins area. In the Lime Basins DNAPL RI Summary Report (TtEC 2010c), the percent of relative aqueous solubility (PRAS) of the DNAPL compounds was used as a screening tool to assess the potential presence of DNAPL source zones using water quality data. The PRAS is calculated by dividing the aqueous solubility of an analyte by the dissolved concentration of the analyte. A PRAS greater than or equal to 75 percent, either for an individual analyte or for the sum of the five analytes, was considered the threshold for potential DNAPL source zone presence. The results for FY14 are provided in Table 5.1.2.4-1 below.

Table 5.1.2.4-1. FY14 DNAPL Thickness, PRAS, and FY13/FY14 DNAPL Removal

Well	Maximum DNAPL Thickness, ft	Maximum Analyte, PRAS, % (≥75% bold)	Maximum Summed PRAS, % (≥75% bold)	DNAPL Removed, gallons. (date)
Monitoring Wells				
36054	0	CLC6H5, 0.5	0.5	
36212	0.08 (9/18/14)	14DCLB, 24.0	38.1	
36231	0.17 (1/29/14)	14DCLB, 57.7	**95.6**	
36232	0	14DCLB, 67.1	**111.4**	
36233	0	14DCLB, 34.5	53.7	
36234	0	14DCLB, 12.0	16.8	
36235	0	DCPD, 26.7	55.0	
36236	0	14DCLB, 23.3	39.9	
36237	0	14DCLB, 14.0	21.6	
36238	0	All LT MRL	All LT MRL	
36239	0	All LT MRL	All LT MRL	
36240	0	14DCLB, 15.1	23.2	
36241	0	14DCLB, 5.6	6.9	
36242	0	14DCLB, 54.2	**85.1**	
36243	0	14DCLB, 71.1	**117.8**	

Table 5.1.2.4-2. Lime Basins DNAPL Remediation Project. FY14 DNAPL Thickness, PRAS, and FY13/FY14 DNAPL Removal (Concluded)

Well	Maximum DNAPL Thickness, ft	Maximum Analyte, PRAS, % (≥75% bold)	Maximum Summed PRAS, % (≥75% bold)	DNAPL Removed, gallons. (date)
36244	0	14DCLB, 47.5	73.0	
36245	0	14DCLB, 38.1	56.6	
36246	0	14DCLB, 22.5	25.4	
36247	0	CLC6H5, 5.8	5.8	
36248	2.0 (4/8/14)	CLC6H5, 5.2	5.2	3.75 (4/22/14)
36249	0	All LT MRL	All LT MRL	
Dewatering Wells				
36315	0.67 (2/19/14)	14DCLB, 42.1	62.9	
36316	0	14DCLB, 3.7	4.4	
36317	0	14DCLB, 3.3	3.3	
36318	0	14DCLB, 8.1	8.1	
36319	1.5 (4/8/14)	DCPD, 23.3	50.7	4.8 (10/1/12, 5/23/13) 2.08 (4/22/14)
36320	0.75 (3/13/14)	14DCLB, 6.17	**106.0**	

The observed presence of DNAPL, PRAS greater than 75 percent for individual compounds, and summed PRAS greater than 75 percent in the wells in Table 5.1.2.4-1 are consistent with the FY13 results, and indicate that additional suspected DNAPL source zones are present in the vicinity of some of the monitoring wells installed in FY12. The suspected DNAPL source zone on the west side of the Lime Basins is larger than the RI/FS data indicated based on PRAS greater than 75 percent in new wells 36242, 36243, 36244, and 36245. Additionally, DNAPL was detected in new well 36248, which is located inside the slurry wall on the east slurry-wall segment. The data for the previously existing wells are consistent with the suspected DNAPL source zones characterized in the RI Summary Report. The suspected DNAPL source zones based on the FY13 data are shown on Figure 5.1.2.4-1.

Generally, the DNAPL-related compound concentrations were lower in FY14 than in FY13, with no wells above 75 percent PRAS for individual compounds (five wells were above 75 percent in FY13), and three fewer wells were above 75 percent for summed PRAS (eight wells were above 75 percent Summed PRAS in FY13).

The water quality data for the western DNAPL source zone are consistent with the composition of the DNAPL found in dewatering well 36320. In FY13, the DNAPL found in new well 36248 was analyzed and contained four of the five DNAPL-related compounds. Additionally, the concentrations were above 75 percent PRAS for benzene, ethylbenzene, toluene, tetrachloroethylene, trichloroethylene, and xylenes. The DNAPL composition in well 36248 is different than the DNAPL analyzed previously in dewatering wells 36319 and 36320.

DNAPL was not detected in the well adjacent to well 36248 that is located on the outside of the slurry wall (36249), and the concentrations of DNAPL-related compounds in well 36249 were below reporting limits in FY13 and FY14. Thus, future increases in concentrations of the DNAPL-related compounds in well 36249 potentially may be an indicator of impacts to the slurry wall from the DNAPL found in well 36248. Assessment of potential impacts to the slurry wall will also include evaluation of water level data according to the criteria in the DAR.

Figure 5.1.2.4-2 is the Lime Basins water-table map for September 2014. The hydraulic gradient is very flat inside the slurry wall, ranging from 0.0022 to 0.0043 ft/ft. The maximum head differential from the southeast corner to the northwest corner has decreased from 1.86 ft in April 2009 to 1.43 ft in September 2014. There are no depressions in the water table other than those created by the dewatering wells. Additionally, there is no apparent deviation of water levels in the wells adjacent to the slurry wall that would indicate an impact to the performance of the slurry wall.

In FY13, a total of 4.8 gallons of DNAPL was removed, and during FY14 a total of 5.8 gallons of DNAPL was removed. Modification of the Lime Basins DNAPL monitoring program for FY14 and subsequent years is documented in OCN-LTMP-2014-001 and incorporated into the 2010 LTMP.

The water level data indicate that the slurry wall has not been impacted by DNAPL according to criteria in the DAR. Consistent head differentials across the slurry wall have been maintained for all the well pairs.

Based on criteria in the Design Document (TtEC and URS 2012), ESD (TtEC 2011b), and 2010 LTMP, the Lime Basins DNAPL Remediation Project is functioning as intended.

5.1.3 On-Post Groundwater Site-Wide Monitoring Programs

The on-post site-wide water quality programs are the on-post groundwater monitoring programs addressed by the LTMP. They include water level tracking, water quality tracking, and CFS monitoring.

5.1.3.1 Water Level and Water Quality Tracking

Water level and water quality monitoring are conducted in areas upgradient from the containment systems to track changes in groundwater flow and contaminant migration within the UFS. Delineation and characterization of groundwater contaminant plumes were completed during the RI/FS and used to describe baseline conditions at the time of remedy selection. Remedies implemented within designated source areas were assumed to have short-term and long-term effects on water levels and water quality. Through implementation of long-term monitoring, the effects of these remedies will be substantiated by tracking water levels and the resulting groundwater flowpaths and associated water quality over time. The objective of long-term monitoring is to detect any changes in groundwater conditions that are indicative of remedy performance after implementation. To meet the primary objective of long-term monitoring, a limited number of wells located proximal and downgradient to source areas and upgradient of the boundary containment systems are sampled for indicator analytes that represent constituents of the major plumes on post.

Water level tracking wells are used to monitor water levels and track groundwater flowpaths between individual on-post remedies and the RMA boundary. Water levels are measured annually in wells completed within the UFS and CFS across RMA. Water level data are used to develop site-wide groundwater contour maps. Comparison of these maps year to year provides insight into the groundwater flowpaths and whether any changes have occurred over time. Table 5.1.3.1-1 provides a list of wells used to track water levels and determine flowpaths under the 2010 LTMP. The table is updated from the 2010 LTMP well network to include revisions made in the Well Networks Updates included in the ASRs for fiscal years 2010 through 2014 RVO 2011, 2012, Army and Shell 2013, Navarro 2015a and 2015b).

Table 5.1.3.1-1. Water Level Tracking Wells (2010 LTMP and Well Networks Update Revisions)

Section 1										
01001	01021	01024	01033	01041	01044	01047	01049	01063	01068	01069
01078	01101	01312	01407	01408	01517	01525	01534	01582	01583	01600
01605	01656	01669	01670	01681	01685	01686	01687	01702		
Section 2										
02011	02014	02023	02026	02034	02041	02043	02052	02056	02058	02065
02505	02512	02515	02520	02522	02523	02524	02525	02576	02580	02597
02683										
Section 3										
03002	03005	03008	03012	03013	03014	03015	03016	03503	03523	
Section 4										
04014	04020	04021	04024	04029	04038	04040	04076	04080	04082	04525
04528	04035									
Section 5										
05001	05005									
Section 6										
06002	06003									
Section 7										
07001	07032	07033	07139							
Section 8										
08003	08026	08027*								
Section 11										
11002	11023									
Section 12										
12001	12002	12005								
Section 19										
19001	19004	19007	19015	19017						
Section 20										
20002										

Table 5.1.3.1-1. Water Level Tracking Wells (2010 LTMP and Well Networks Update Revisions) (Concluded)

Section 22										
22001	22006	22007	22052	22053	22054	22081	22505			
Section 23										
23002	23004	23008	23029	23040	23053	23095	23096	23135	23140	23142
23160	23182	23185	23196	23198	23199	23211		23227	23253	23548
Section 24										
24006	24080	24081	24092	24094	24096	24098	24106	24107	24108	24109
24112	24124	24126	24135	24158	24162	24163	24164	24166	24187	24201
Section 25										
25001	25011	25015	25022	25041	25048	25054	25059	25091	25126	25129
25133	25500	25502								
Section 26										
26006	26015	26016	26017	26020	26040	26049	26061	26071	26083	26094
26097	26154	26157	26158	26160	26163	26170	26500			
Section 27										
27002	27003	27018	27025	27035	27037	27043	27049	27051	27053	27060
27063	27066	27072	27077	27078	27079	27082	27083	27084	27091	27500
27522										
Section 28										
28004	28012	28022	28024	28027	28520	28522				
Section 29										
29002										
Section 30										
30004	30006	30009	30020							
Section 31										
31005	31012	31014	31016	31537						
Section 32										
32001	32004	32005								
Section 33										
33001	33025	33043	33061	33081	33341	33510	33514	33533		
Section 34										
34005	34008	34014	34015	34017	34018	34019	34020	34503	34508	
Section 35										
35013	35023	35037	35058	35061	35065	35069	35087	35093	35504	35512
Section 36										
36052	36054	36069	36077	36087	36089	36092	36094	36112	36120	36123
36142	36157	36158	36168	36169	36181	36186	36200	36201	36210	36212
36502	36521	36538	36541	36552	36575	36594	36595			
36216	36217	36627	36628	36629	36630	36631	36632	36633		
*08027 is destroyed.										

The water quality tracking program focuses on tracking changes in indicator analyte concentrations in plume source areas, along the edges of plumes, and across transects of major plumes. Water quality data collected for these areas are used to confirm that groundwater conditions remain consistent with the initial assumptions used at the time of remedy selection. Water quality data collected in areas upgradient from the containment systems are used in combination with more extensive water level monitoring data to track the effects of the remedies on groundwater. The evaluation of water level and water quality conditions is intended to answer the following questions related to remedy performance (FWENC 1999):

- Have conditions changed since remedy selection?
- Is there new information about conditions that could affect remedy performance?
- Is any change needed in the monitoring program used to track these conditions?

Table 5.1.3.1-2 provides a list of water quality tracking wells with their respective indicator analytes for the specific source areas and boundary containment systems monitored under the 2010 LTMP. The table is updated from the 2010 LTMP well network to include revisions made in the ASRs (RVO 2011, 2012, Army and Shell 2013, Navarro 2015a and 2015b).

Table 5.1.3.1-2. Water Quality Tracking Wells and Indicator Analytes (2010 LTMP and Well Networks Update Revisions)

Well ID	Sampling Frequency	Indicator Analytes
Upgradient of NWBCS		
03005	Twice in 5 years	Chloroform, dieldrin
03015	Twice in 5 years	Dieldrin
03016	Twice in 5 years	Dieldrin
22001	Twice in 5 years	DIMP, OCPs
22002	Twice in 5 years	Chloroform, dieldrin
27025	Twice in 5 years	Arsenic, Chloroform, dieldrin, DIMP, NDMA
27037	Twice in 5 years	Chloroform, dieldrin
27043	Twice in 5 years	Dieldrin
27079	Twice in 5 years	Arsenic, Chloroform, dieldrin, DIMP
27082	Twice in 5 years	Arsenic, Chloroform, dieldrin, DIMP, NDMA
27083	Twice in 5 years	Chloroform, dieldrin,
27091	Twice in 5 years	Chloroform, dieldrin
34005	Twice in 5 years	Chloroform, dieldrin
34008	Twice in 5 years	Dieldrin
34015	Twice in 5 years	Dieldrin
34017	Twice in 5 years	Chloroform, dieldrin
34020	Twice in 5 years	Chloroform, dieldrin
34508	Twice in 5 years	Chloroform, dieldrin
35058	Twice in 5 years	Chloroform, dieldrin

Table 5.1.3.1-2. Water Quality Tracking Wells and Indicator Analytes (2010 LTMP and Well Networks Update Revisions) (Continued)

Well ID	Sampling Frequency	Indicator Analytes
Section 36 Bedrock Ridge		
25502	Twice in 5 years	Carbon tetrachloride , chloroform, DIMP, PCE
36552	Twice in 5 years	Benzene, chloroform, TCE
36594	Twice in 5 years	Carbon tetrachloride, chloroform, dieldrin, DIMP, tetrachloroethylene, TCE
Basin A/Basin A Neck		
26006	Twice in 5 years	Arsenic, DIMP, dieldrin, dithiane, NDMA, DDT
35065	Twice in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
Basin A Source		
36627	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
36629	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
36630	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
36631	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
36632	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
36633	Once in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
Lime Basins/Basin A		
36210	Twice in 5 years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
South Plants/South Plants Central Processing Area		
01078	Once in 5 years	Arsenic, benzene, chloride, chloroform, dieldrin
01525	Once in 5 years	Arsenic, benzene, chloroform, dieldrin
02065	Once in 5 years	Benzene, chloroform, dieldrin
36181	Once in 5 years	Arsenic, benzene, chloride, chloroform, DBCP, dieldrin
South Lakes/South Tank Farm		
01312	Twice in 5 years	Benzene, chloride, chloroform
02034	Twice in 5 years	Benzene, chloroform, dieldrin
02505	Twice in 5 years	Benzene, chloroform
02512	Twice in 5 years	Benzene, dieldrin
02523	Twice in 5 years	Benzene, chloroform, dieldrin, TCE
02524	Twice in 5 years	Benzene, chloroform, dieldrin
02525	Twice in 5 years	Benzene, chloroform, dieldrin

Table 5.1.3.1-2. Water Quality Tracking Wells and Indicator Analytes (2010 LTMP and Well Networks Update Revisions) (Concluded)

Well ID	Sampling Frequency	Indicator Analytes
02597	Twice in 5 years	Benzene, chloroform, dieldrin
South Plants SPSA-2d Ditch Source		
01044	Once in 5 years	Aldrin, dieldrin
01047	Once in 5 years	Aldrin, dieldrin
01101	Once in 5 years	Aldrin, dieldrin, chloride
01582	Once in 5 years	Aldrin, dieldrin
01669	Once in 5 years	Aldrin, dieldrin
01670	Once in 5 years	Aldrin, dieldrin
Upgradient of NBCS		
23095	Twice in 5 years	Arsenic, chloride, chloroform, dieldrin, DIMP, fluoride, NDMA, sulfate
23096	Twice in 5 years	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA, sulfate
23142	Twice in 5 years	Chloride, chloroform, dieldrin, DIMP, fluoride, sulfate NDMA
23548	Once in 5 years	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA
24092	Twice in 5 years	Chloride, chloroform, DIMP, fluoride, sulfate, NDMA
24094	Twice in 5 years	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, sulfate
Rail Yard		
03523	Twice in 5 years	DBCP
Motor Pool		
04535	Twice in 5 years (until MCR approved)	TCE
North Plants		
24081	Twice in 5 years	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, tetrachloroethylene
25059	Twice in 5 years	Chloride, chloroform, DIMP, fluoride, tetrachloroethylene

Water Level Tracking

Under the water level tracking program, water level monitoring is used to track the effects of the source area remedies and boundary containment systems in the On-Post and Off-Post OUs. Water level data from water level tracking wells are used to develop groundwater flowpaths between individual on-post remedies and the RMA boundary, and support the evaluation of flowpaths. By evaluating on-post flowpaths over the course of the FYR period, the effects of remedies implemented across the facility can be assessed and used to support optimization of the monitoring program in the future.

This report presents data for the fourth FYR period from October 1, 2009, through September 30, 2014, and water level tracking was conducted in accordance with the 2010 LTMP objectives. Several soil remedies were completed during this FYR period and their impact on groundwater was evaluated and the results are provided in this section of the report.

There were only a few deviations from the On-Post Water Level Tracking program established by the 2010 LTMP (and subsequent Well Network Update revisions) during this FYR period and these are as follows:

- Well 01312 was added to the water level tracking network, but was not monitored for water levels and LNAPL thickness in FY13.
- Well 08027 was destroyed by subcontractors of Denver Water in July of 2013. The well was cancelled in the RMAED (Navarro 2015a). This well was replaced in May of 2015, but was unavailable for monitoring during FY13 and FY14.

The On-Post ROD identified five plume groups consisting of 15 contaminant plumes on post. The on-post plume groups that were included in the water level tracking during the FYR period include the following:

- North Boundary Plume Group, upgradient of NBCS
- Northwest Boundary Plume Group, upgradient of the NWBCS
- Western Plume Group, upgradient of RYCS and ICS
- Basin A Plume Group, upgradient of BANS
- South Plants Plume Group, which includes plumes emanating in the South Plants Central Processing Area

Source monitoring is conducted in the South Plants and Basin A to evaluate effectiveness of the remedies. The objectives of the source-monitoring component of on-post water level and quality tracking are as follows:

- Conduct water level monitoring to assess the impact of the on-post remedy implementation on water levels, flow, and contaminant migration pathways in plume source areas.
- Conduct water quality monitoring for key indicator compounds to support contaminant concentration tracking in source areas where human health exceedance soils are left in place.

Source and remedy areas addressed under the water level tracking program, include the following:

- Former Basin F/Basin F Wastepile
- Basin A

- Complex (Army) Disposal Trenches and Shell Disposal Trenches
- South Plants and South Lakes

The water level tracking program described in this report addresses the site-wide remedy impacts and associated water level trends. Project-specific details are provided in the monitoring reports for the individual remedies that require monitoring.

From July through September each year Army and Shell collect water level data and uses these data to construct a site-wide water level map of the RMA. The water level map is used to determine groundwater flowpaths and identify changes in groundwater flow directions within the UFS that could affect contaminant plume migration. Figure 5.1.3-1 provides a comparison between on-post water levels measured in 2009 and 2014, which reflects the overall changes in water levels during the FYR period. Individual water-level maps for 2010, 2011, 2012, 2013, and 2014 are presented in Figures 5.1.3-2 through 5.1.3-6. Figure 5.1.3-7 illustrates the change in water elevations between 2009 and 2014. The wells used to draw the contours for each year are shown on all seven maps. On Figure 5.1.3-7, the contour interval is 2 ft; elevation increases are shown with purple contours and decreases are shown with green contours. Some of the larger changes in water elevations shown on Figure 5.1.3-7 occur where no wells exist or where wells were not measured in both years. Significant changes that are shown in areas where no well data are available are likely related to differences in interpretation and may not be representative of actual changes. For example, the increase of 22 ft shown in western Section 35 likely did not occur.

Remediation activities, such as the installation of groundwater extraction and recharge systems, engineered caps and covers, and slurry walls, will have an effect on water levels in localized areas across the RMA. Precipitation events also affect water levels and are an important source of recharge to the shallow UFS at RMA. Army and Shell collect precipitation data on-post from two locations in Section 36, one at the Shell Disposal Trenches and one at the Lime Basins. There is variability between the stations, so both are discussed below.

The average annual water-year precipitation at RMA is 15.48 inches. Annual precipitation data from FY09 through FY14 showed a variable trend ranging from a low of approximately 12 inches in FY12 to a high of approximately 19 inches in FY14 at the Shell Disposal Trenches station and from 8.9 inches in FY12 to 20.6 inches in FY14 at the Lime Basins station. The FY13 total for the Lime Basins station was 18.65 inches. The Denver International Airport station total for 2013 was 25.04 inches, with 13.79 inches in September 2013. The annual precipitation totals are quite variable for these stations and may not reflect the magnitude of the September 2013 flood event. Mapping by NOAA (2013) determined the September 2013 storm event to be a 500- to 1000-year storm for some parts of RMA.

For this report, water level tracking data were evaluated by comparing water level contours year-to-year beginning with 2009 (the last year of the third FYR) through 2014. Precipitation events and remediation activities have caused some changes in groundwater levels at RMA over the past 5 years, especially the September 2013 500- to 1000-year storm event followed by heavy rains in May 2014. The combined effects of these two storms caused water levels to rise in non-cover areas and are at historic highs in several areas. Precipitation events at RMA generally result in increases in water level elevations while remedies, such as groundwater extraction and soil covers, have caused water levels to decrease over time. Overall, based on a year-to-year water level comparison for 2009 through 2014, groundwater flow directions and associated migration of contaminant plumes have not changed significantly.

The year-to-year comparison indicates that there were higher groundwater elevations in 2014 near BANS, NWBCS, NBCS, and RYCS (Figures 5.1.3-1 and 5.1.3-7). The historically high water levels at BANS caused the extent of the reverse hydraulic gradient to be reduced during part of FY14. Higher water levels at the NWBCS may have mobilized some residual contamination downgradient of the slurry wall that caused concentrations of dieldrin to increase in downgradient performance wells. The higher water levels at NBCS required more operational adjustments of recharge trench flow rates to maintain the reverse hydraulic gradient. No changes in the associated flow patterns occurred in the areas upgradient of the containment systems that could have affected the effectiveness of the systems during the FYR period, however. The 2009 water level contours, which are compared to those generated in 2014 in Figure 5.1.3-1, show water levels that depict similar groundwater flow directions. A more detailed evaluation of water level changes is presented below.

Water levels in the South Plants area have shown an overall decline since 2001, with decreased fluctuation within the soil cover areas because of the reduced infiltration and recharge. The water levels were relatively unchanged within the cover areas with higher water levels at the edges and outside the covers. The single groundwater mound present historically in South Plants in Section 1 no longer is present, and two smaller mounds exist in the west-central portion of Section 1 (STF) and at the junction of Sections 1, 2, 35, and 36. These mounds are indicated by the 5,250-ft elevation contours on the 2014 map. Localized flowpaths emanating from the remnant mounds have also changed, although the primary groundwater flow to the north from the South Plants area has remained consistent with historical flowpaths. The groundwater divide that separates the northern flow from South Plants from the flow to the south/southwest has remained in the same position. This divide is indicated by the parallel 5,245-ft elevation contours in the northwest part of Section 1 and the northeast part of Section 2. As of 2014, all flowpaths exiting the South Plants area continue to extend to either the NWBCS or through Basin A Neck as in previous years.

Stable conditions occurred during this FYR period in the former Basin F area with only minor variations near the center of Section 26. Water levels were lower to the west of former Basin F and higher to the north in Section 23, as shown in Figures 5.1.3-1 and 5.1.3-7. The groundwater levels were about two feet higher in Sections 23 and 24 near the NBCS where increased flow in First Creek has increased groundwater recharge. Recharge from the September 2013 and May 2014 rainstorms also caused higher groundwater levels near the NBCS. Although water levels varied in areas, the corresponding flowpaths in the vicinity the NBCS were stable compared to previous years.

Implementation of remedies such as installation of the Basin A covers; the Shell Disposal Trenches, CADT, and Lime Basins slurry walls, the CADT and Lime Basins dewatering systems; and the Bedrock Ridge extraction system have caused localized changes in water levels and localized flow directions. During the previous FYR period, increased recharge occurred in some of the cover areas due to increased infiltration of precipitation during construction of the covers and irrigation to establish the cover vegetation. Loading and compaction of the underlying aquifer by the placement of large volumes of contaminated soil, building debris, and fill for subgrade and Integrated Cover System construction in Basin A may also have caused groundwater levels to rise. The majority of the water level changes in and near Basin A occurred during the previous FYR period, but water levels were higher near the BANS during this FYR period and are at historical highs at the BANS since monitoring began in the 1980s.

Because cover construction has been completed and the cover vegetation has been established, Figure 5.1.3-7 shows relatively little change in the water elevations between 2009 and 2014 in the cover areas. This is remarkable given the unprecedented September 2013 storm/flood event followed by heavy rains again in May 2014. All major flowpaths originating north of the South Plants area and from Basin A continue to pass through or adjacent to Basin A and exit the area to the northwest through the Basin A Neck. Comparison of the 2004 and 2009 water-level maps shows that flow paths remained consistent with historical conditions for the major flowpaths upgradient and downgradient of the remedy areas, (Figure 5.1.3-1). Beginning in 2013, contouring of the water table at the west side of the HWL (western Section 25) was changed to include a well that previously had been excluded because the water in the well was considered perched (well 25194). The resulting interpretation shows a ridge in the water table east of the section line that coincides with the stormwater conveyance channel along the west side of the HWL. A 14-ft rise in the water elevation is indicated in this area on Figure 5.1.3-7 due to the inclusion of water level data for well 25194.

Within the Railyard area, water levels increased and are at historical highs because of the September 2013 and May 2014 storms. The corresponding flowpaths remain stable with only minor variations shown by the comparison of the 2009 and 2014 water-level maps (Figure 5.3.1-1). The water elevations were higher in 2014 than in 2009 in the entire Western Tier area (Figure 5.1.3-7).

Higher water levels by two to four feet were observed in the NWBCS area during the FYR reporting period because of the 2013/2014 rains. While water levels increased within the area, these changes did not significantly change the flowpaths towards the system.

Water Quality Tracking

On-post groundwater monitoring programs not directly associated with the containment and treatment systems were evaluated by comparing site-wide monitoring results from FY12 and FY14 with data collected during the last FYR review period in FY09. Sampling for indicator compounds was generally conducted twice during the FYR period, with a few wells sampled once during the period, to track plume migration from source areas downgradient to the groundwater containment and intercept systems. These data were also collected in areas upgradient of the containment systems to supplement the water level tracking data and are used to evaluate long-term trends in on-post groundwater quality.

The water quality tracking well network established for the 2010 LTMP is intended to monitor changes in water quality and assess the influence of the soil remedies on groundwater contaminant levels and plume migration. A map of the water quality tracking well network is presented in Figure 5.1.3-8. Water quality tracking data were used to assess potential changes in water quality related to source areas and associated remedies within the on-post plume areas by using indicator compounds identified in the 2010 LTMP. Table 5.1.3.1-2 provides a summary of the on-post wells included in the water quality tracking program during this FYR period. Table 5.1.3.1-2 identifies the monitoring well locations by source area and includes the indicator analytes and monitoring frequency for each well.

The water quality tracking network monitored during this FYR period included 59 wells located within source areas, the paths of historical contaminant plumes, and upgradient of the treatment and intercept systems. As required by the 2010 LTMP, sampling was conducted in 2012 and 2014. Data collected in 2009 were also used in this evaluation to facilitate trend assessments.

Monitoring was conducted in accordance with the 2010 LTMP, with the exceptions noted below:

- Well 01312 replaced well 01534 in 2012. Well 01312 was added to provide long term monitoring of benzene after the STF Mass Removal project ended.

The results of the site-wide water quality monitoring are presented for each source area included in the LTMP. Table 5.1.3.1-3 (included under Tables Tab) presents a summary of indicator analyte trends for each well by source area or boundary containment system.

The indicator analyte concentrations upgradient of the boundary containment systems show long-term decreases for several contaminants. Chloroform and DIMP levels have decreased or remained stable upgradient of the NBCS and NWBCS. Dieldrin concentrations at these systems have also been relatively stable.

Upgradient from NWBCS

The area upgradient of the NWBCS includes the Basin A Neck Plume, Sand Creek Lateral Plumes, and the chloroform and dieldrin plume that originates in the South Plants area. These plumes are in the Northwest Boundary Plume Group as shown in the On-Post ROD. Nineteen wells were monitored upgradient of the NWBCS where most indicator analytes show decreasing or stable trends since 2009.

Time-series plots for each of the 19 wells depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided in the text (Figures 5.1.3-9 through 5.1.3-13) to support the discussion of trends noted for groundwater upgradient of the NWBCS.

Concentrations of dieldrin have been stable or have decreased in 14 of 19 wells sampled upgradient of the NWBCS during the FYR period. The general decrease in dieldrin detected in LTMP samples indicates that source area remedies have been effective in reducing the contribution of contaminants to groundwater upgradient of the NWBCS. Higher water levels in 2014 may have caused some localized concentration increases.

Concentrations of chloroform were stable or decreasing in eight of the 13 wells analyzed for chloroform upgradient of the NWBCS (Appendix D).

DIMP concentrations in groundwater upgradient of the NWBCS were stable or decreasing in all four wells sampled for DIMP during the FYR period, and all were lower than the CSRG. A summary of noted trends in groundwater samples collected for this FYR is presented below:

- Well 27037, located more than one mile upgradient of the NWBCS, had increasing concentrations of chloroform and dieldrin during the FYR period (Figure 5.1.3-9). The dieldrin concentrations were above the PQL and were within the historical range for well 27037. The chloroform concentrations were below the CSRG, and the long-term trend (since 1994 and before) is downward.
- Chloroform concentrations increased in well 27079 from LT 0.2 µg/L in 2009 to 0.357 µg/L in 2014, which is well below the CSRG (Figure 5.1.3-10). The arsenic, dieldrin, and DIMP concentrations decreased overall.

Figure 5.1.3-9. Time Concentration Plot for Well 27037

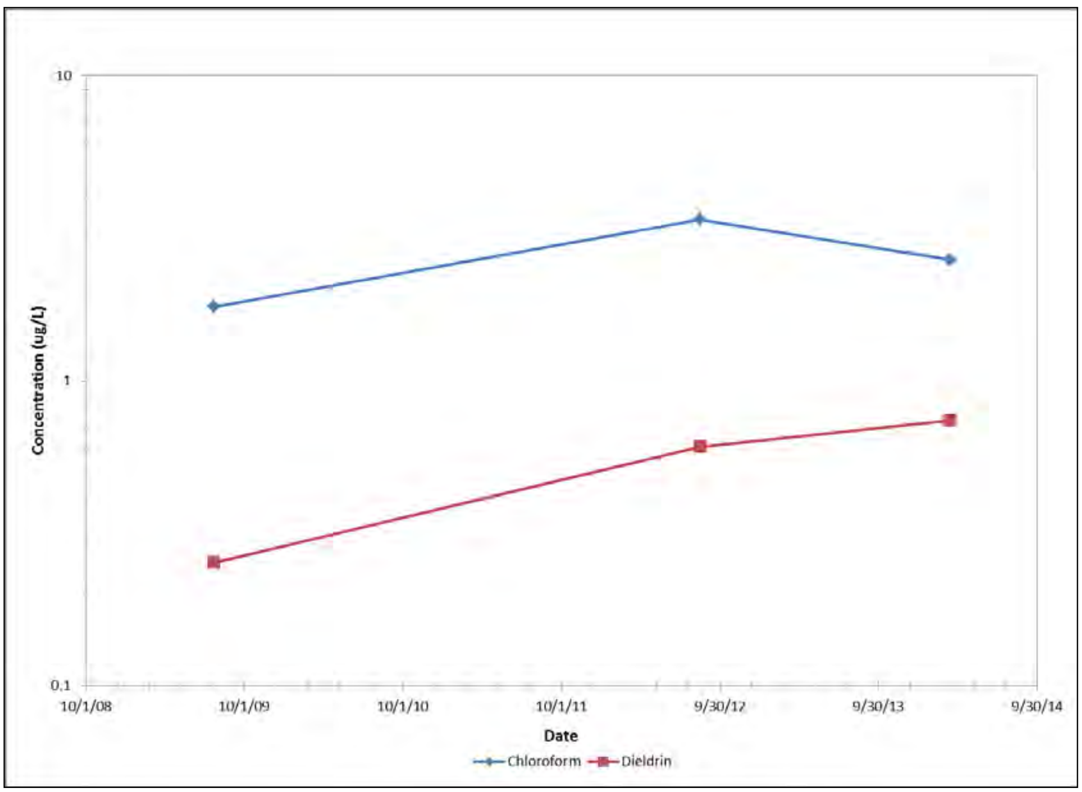
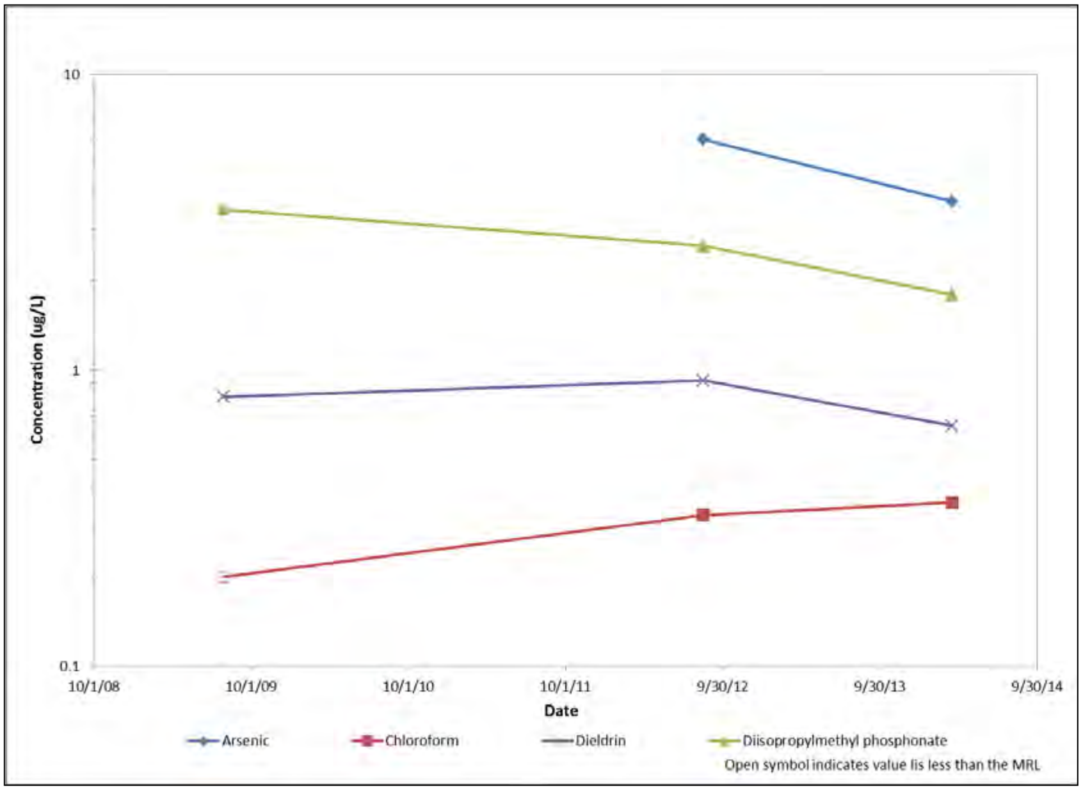


Figure 5.1.3-10. Time Concentration Plot for Well 27079



- In well 27025, the concentrations of arsenic, chloroform, dieldrin, DIMP, and NDMA decreased during the FYR period. All of the indicator analytes, except dieldrin, were below the CSRGs/PQLS in FY14 (Figure 5.1.3-11).
- Well 26006 is downgradient of the BANS and upgradient of well 27025. In Section 5.1.1.4, Figure 5.1.1.4-4 shows the dieldrin concentration trend for well 26006, which also decreased during the FYR period.
- The chloroform and dieldrin concentrations in well 35058 decreased in 2012 and increased in 2014 (Figure 5.1.3-12). The dieldrin concentrations are above the PQL and the chloroform concentrations are below the CSRG. The water levels in well 35058 were significantly higher in 2014 after the September 2013 flood event and May 2014 rainstorms, which may have caused the concentration increases.
- Near Lake Mary, the dieldrin concentration in well 03016 decreased from 0.083 to 0.051 µg/L, but is still above the PQL of 0.013 µg/L (Figure 5.1.3-13).

Figure 5.1.3-11. Time Concentration Plot for Well 27025

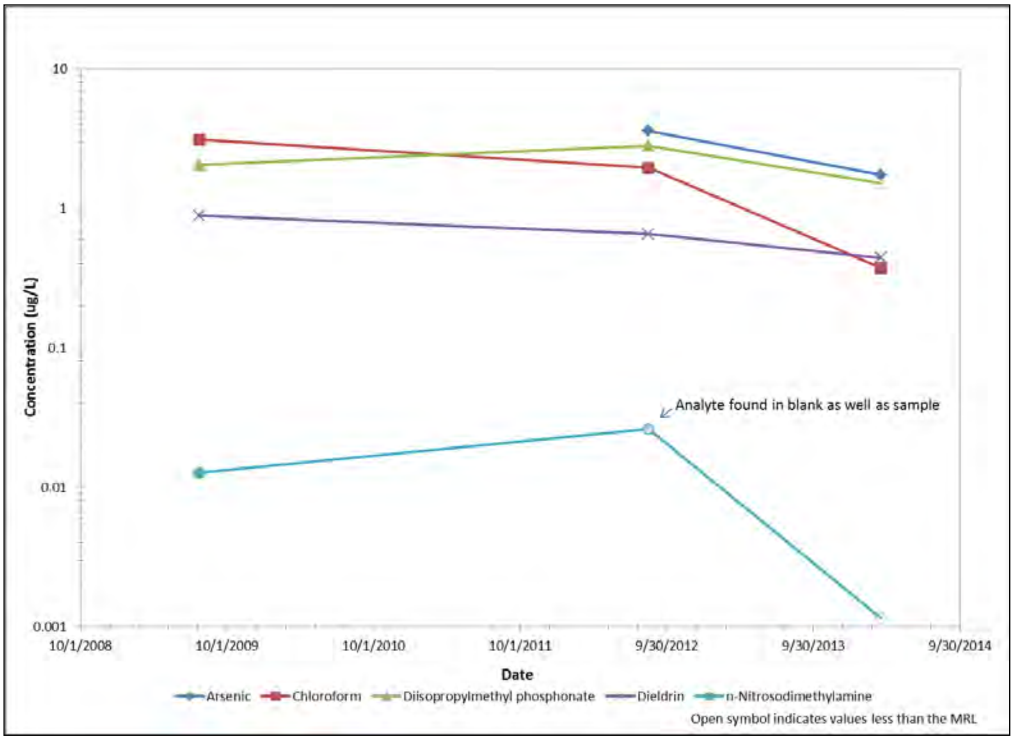


Figure 5.1.3-12. Time Concentration Plot for Well 35058

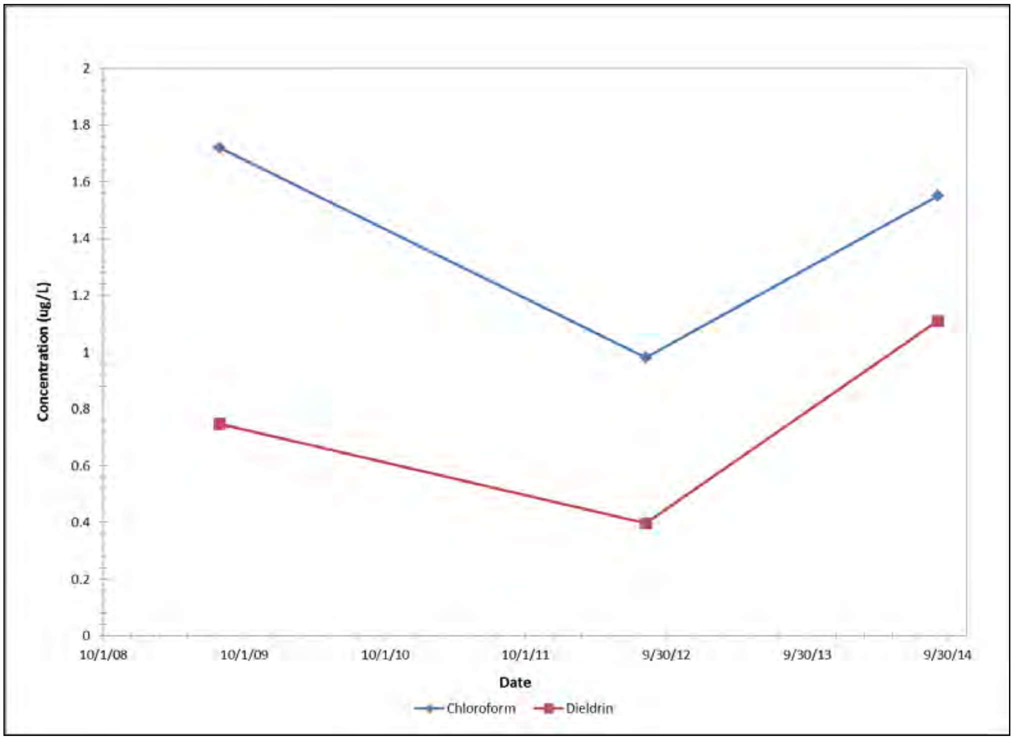
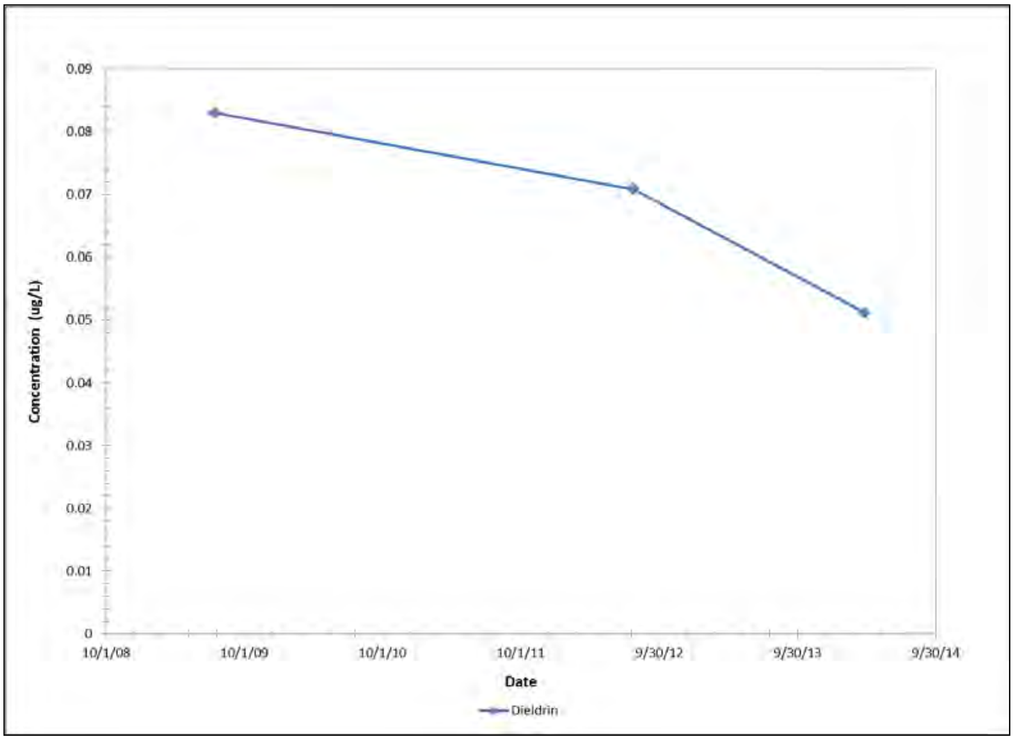


Figure 5.1.3-13. Time Concentration Plot for Well 03016



Basin A/Basin A Neck/Section 36 Bedrock Ridge
Basin A, the northern part of South Plants, and the Section 36 Bedrock Ridge area located northeast of Basin A are the plume source areas in the central portion of the RMA. Groundwater flows beneath Basin A and the associated source areas; the UFS groundwater flows to the northwest towards the BANS. A total of 12 wells located in Sections 25, 26, 35, and 36 were monitored within Basin A, the Basin A Neck, and Section 36 Bedrock Ridge areas upgradient and downgradient of the BANS and the BRES. Within these three source and remedy areas, most indicator analytes show decreasing or stable trends since 2009.

Time-series plots depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided in Figures 5.1.3-14 and 5.1.3-15 to support the discussion of trends noted for groundwater in the vicinities of the BANS.

A summary of noted trends in groundwater samples collected for this FYR is presented below:

- Well 35065 is located downgradient of Basin A and upgradient of BANS. Concentrations of indicator analytes, including arsenic, benzene, and chloroform, DBCP, NDMA, and TCE were relatively stable overall, except for dieldrin, which decreased to below the MRL, and chloride, DIMP, and dithiane concentrations increased (Figure 5.1.3-14). The other analytes were not detected or were below CSRGs/PQLs.
- Well 26006 is located downgradient of the BANS. Concentrations of indicator analytes arsenic, dieldrin, DIMP, dithiane, NDMA, and DDT decreased overall, except for NDMA, which increased in 2012 and 2014 (Figure 5.1.3-15). Dithiane was below the CSRG during the FYR period.

Figure 5.1.3-14. Time Concentration Plot for Well 35065

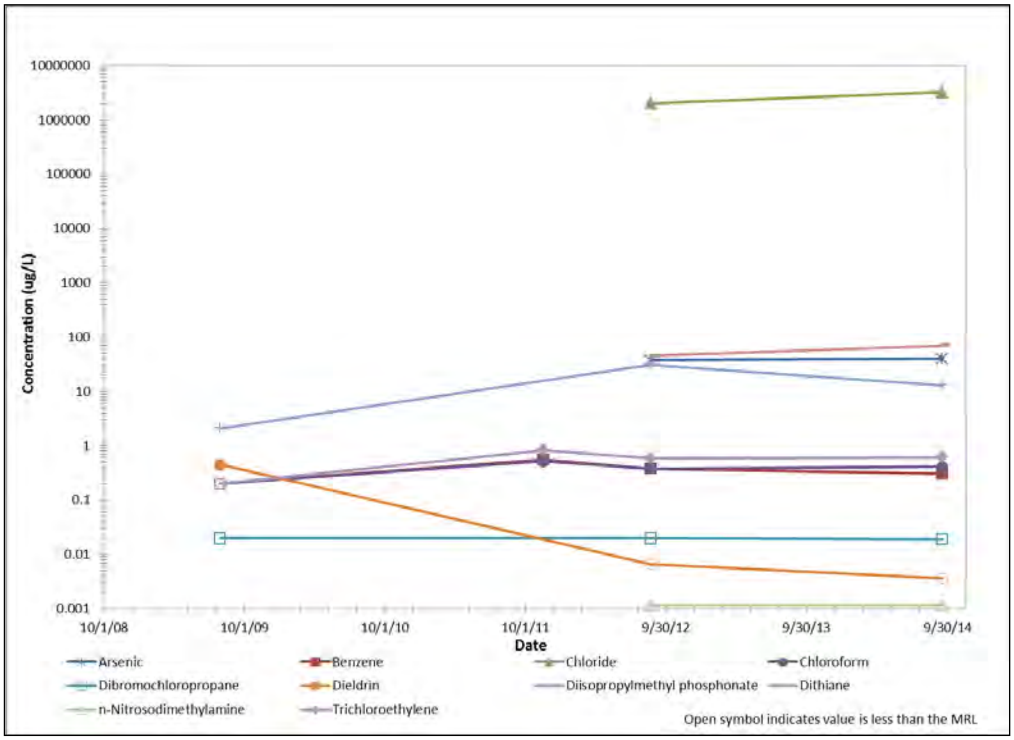
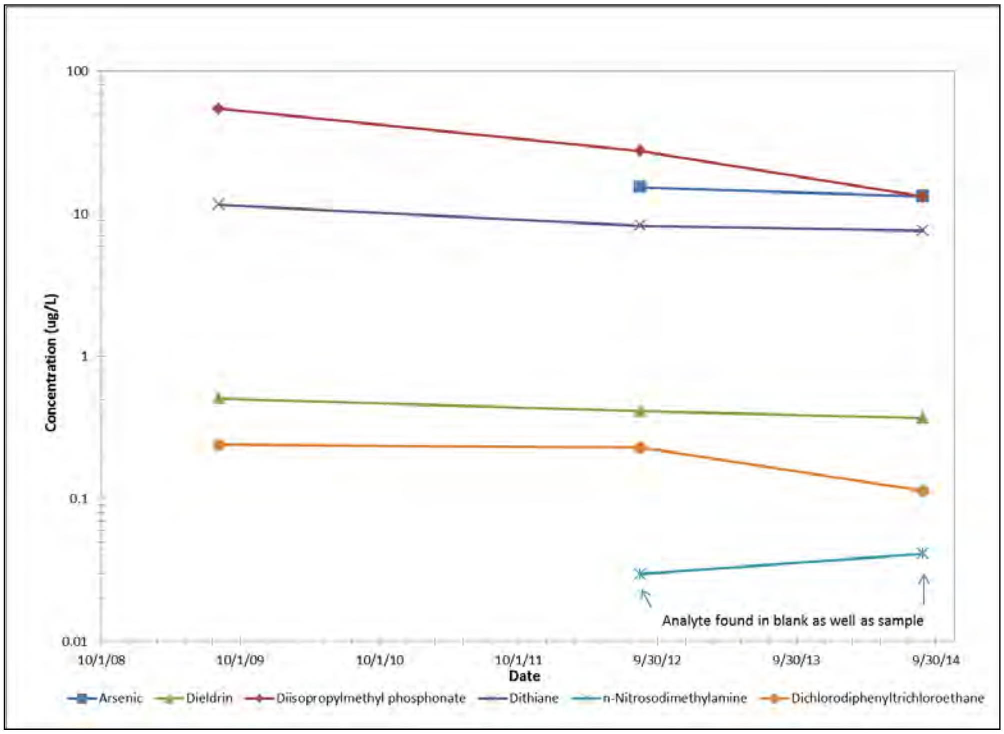


Figure 5.1.3-15. Time Concentration Plot for Well 26006



Time-series plots depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided in Figures 5.1.3-16 to 5.1.3-21 to support the discussion of trends noted for groundwater in the vicinity of Basin A.

Six wells located within Basin A represent relatively recent additions to the RMA groundwater monitoring network. The new wells were installed in October 2007 and May 2008, and replace older wells within Basin A. New wells 36627, 36629, 36630, 36331, 36332, and 36333 replace wells 36056, 36093, 36108, 36109, 36177, and 36599, respectively. Well 36627 is located downgradient of the Lime Basins. This well was not included in the water quality network in the 1999 LTMP, but was added to the 2010 LTMP, and baseline water quality data were collected during the previous FYR period. Wells 36629, 36630, and 36632 are located in northwestern portion of Basin A, and downgradient of sources areas. Well 36633 is located in the center of Basin A. Well 36631 is located east of and adjacent to the Lime Basins in the southern portion of Basin A, and is upgradient of Basin A source areas and downgradient of South Plants sources.

A summary of trends is provided in the following:

- Well 36627 (Figure 5.1.3-16) - Concentrations of benzene, chloride, chloroform, dieldrin, dithiane, and TCE were stable. Arsenic concentrations decreased from 1,900 µg/L in 2009 to 101 µg/L in 2014, possibly due to containment of the Lime Basins within a slurry wall. Changing flow patterns around the Lime Basins slurry wall may also affect the concentrations of some of the contaminants in this location. DIMP and NDMA concentrations were below the MRLs, and DBCP concentrations increased, but were below the CSRG.
- Well 36629 (Figure 5.1.3-17) - Concentrations of benzene, chloride, dithiane, DIMP, and TCE were stable. Arsenic concentrations decreased from 420 µg/L in 2008 to 93.4 µg/L in 2014, possibly due to containment of the Lime Basins within a slurry wall. Chloroform concentration decreased, and dieldrin and NDMA concentrations decreased to below the MRLs. DBCP concentrations increased, but were below the CSRG.
- Well 36630 (Figure 5.1.3-18) - All of the indicator analytes were stable during the FYR period.
- Well 36631 (Figure 5.1.3-19) - Concentrations of arsenic, chloride, dieldrin, and dithiane were stable. DIMP and TCE concentrations were below the MRLs, but the TCE MRLs were high (LT 5,000 µg/L and LT 10,000 µg/L). DBCP concentrations increased from 5.7 to 11. 8 µg/L, but were within the historical range. NDMA concentrations increased from LT 0.05 to 0.862 µg/L, likely due to a change in the flow patterns around the Lime Basins slurry wall. Benzene concentrations decreased from 32,800 µg/L in 2009 to 20,300 µg/L in 2014. Chloroform concentrations decreased from 1,050,000 µg/L in 2009 to 799,000 µg/L in 2014.
- Well 36632 (Figure 5.1.3-20) - Concentrations of arsenic, benzene, chloride, dithiane, and TCE were stable. DBCP concentrations were below the MRL. Chloroform, dieldrin, DIMP, and NDMA concentrations decreased, with chloroform below the CSRG. NDMA decreased from 0.0238 µg/L in 2009 to LT 0.00115 µg/L in 2014.
- Well 36633 (Figure 5.1.3-21) - Concentrations of arsenic, benzene, chloride, chloroform, and DIMP were stable. DBCP concentrations were below the MRL. Dieldrin and TCE concentrations decreased, with TCE concentrations decreasing from 18.1 µg/L in 2009 to 9.6 µg/L in 2014. Dithiane increased from 98.5 µg/L in 2009 to 214 µg/L in 2014.

For the former Basin A wells, most of the indicator analyte concentrations were stable overall or decreasing. The arsenic concentrations appear to be decreasing downgradient of the Lime Basins, which may be caused by the Lime Basins remedy, but changes in groundwater flow directions around the Lime Basins slurry wall may also be affecting the concentrations. Changes in concentrations (both increasing and decreasing) of other analytes in wells near or downgradient of the Lime Basins may be related to the change in flow directions around the slurry wall.

Figure 5.1.3-16. Time Concentration Plot for Well 36627

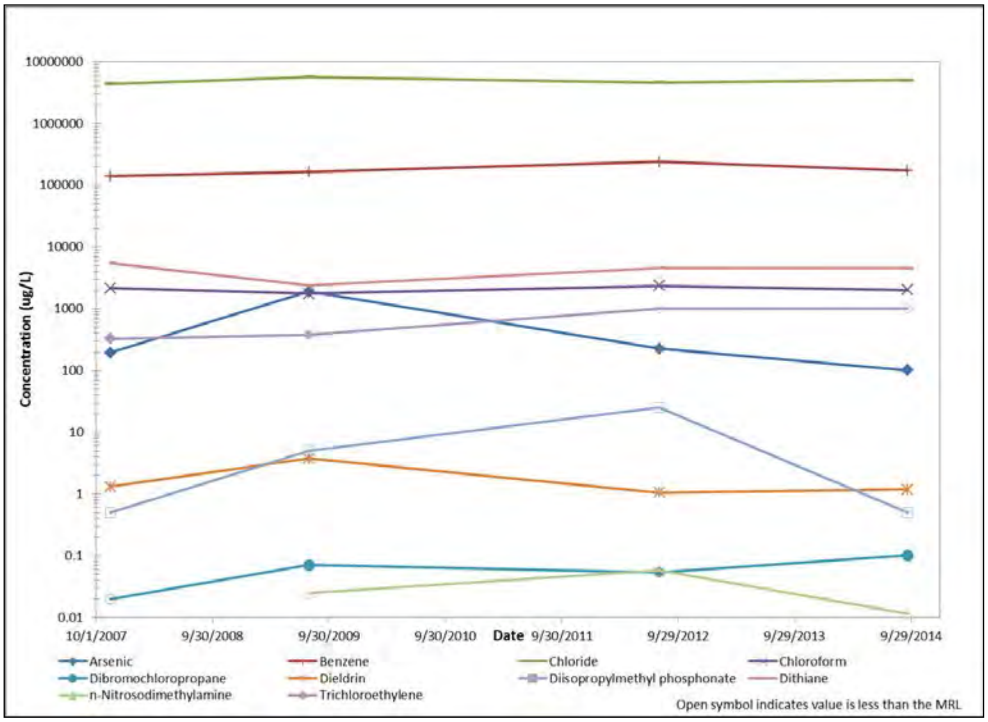


Figure 5.1.3-17. Time Concentration Plot for Well 36629

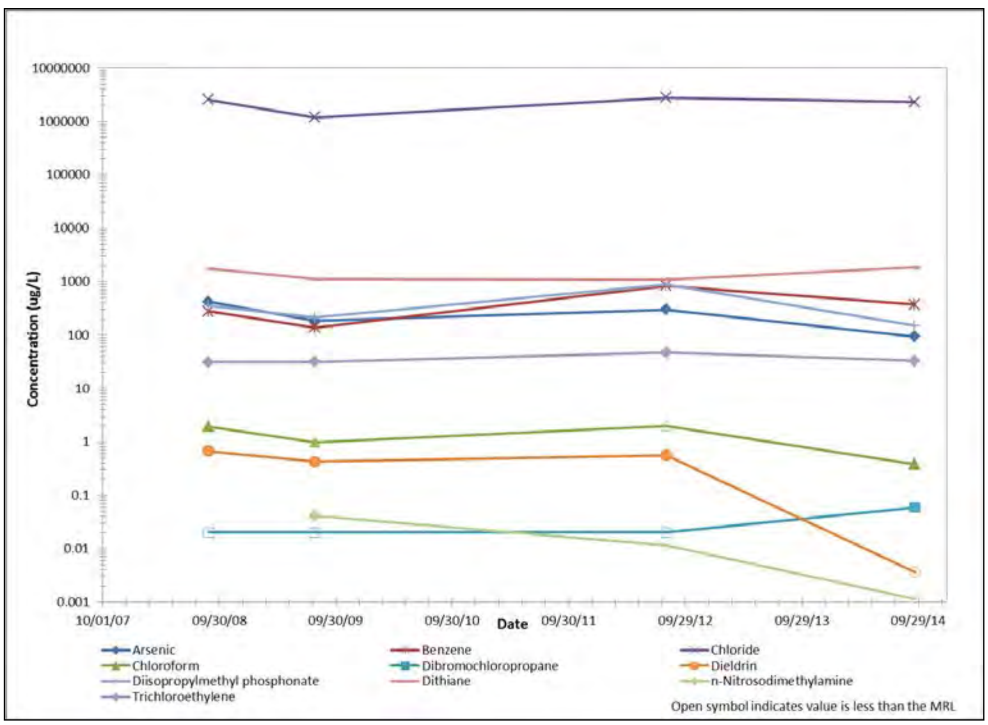


Figure 5.1.3-18. Time Concentration Plot for Well 36630

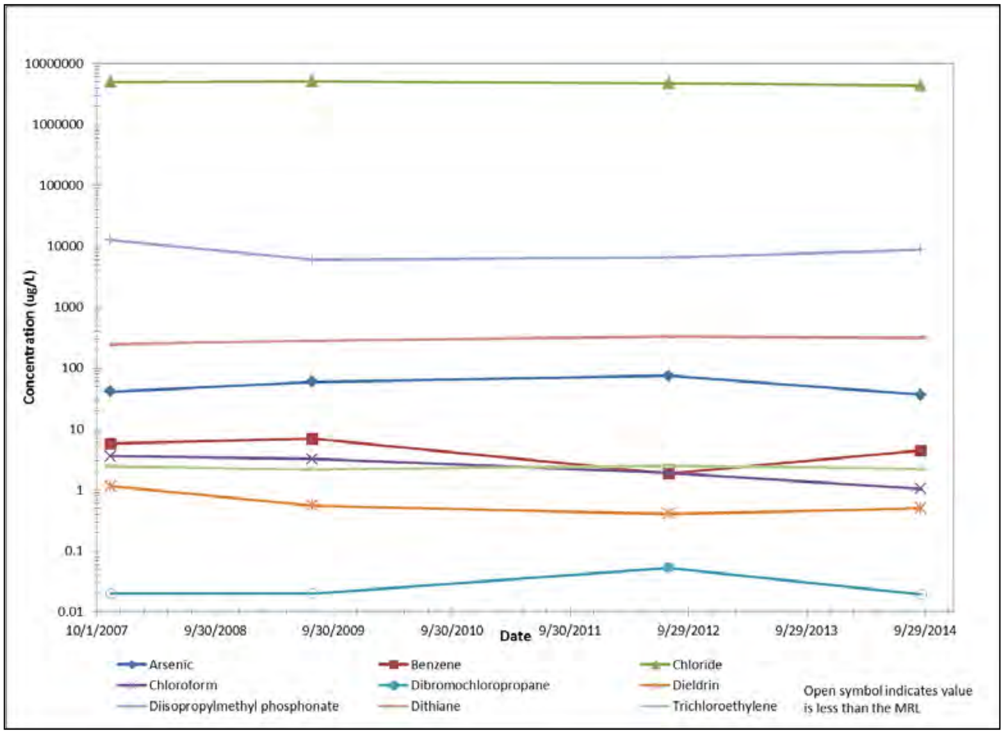


Figure 5.1.3-19. Time Concentration Plot for Well 36631

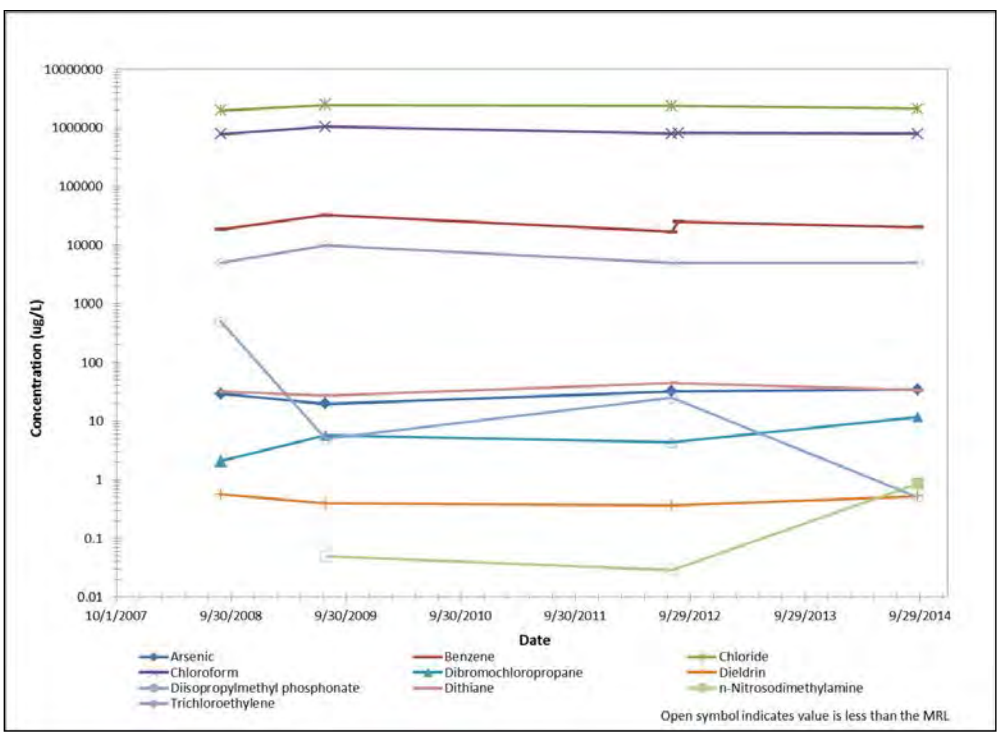


Figure 5.1.3-20. Time Concentration Plot for Well 36632

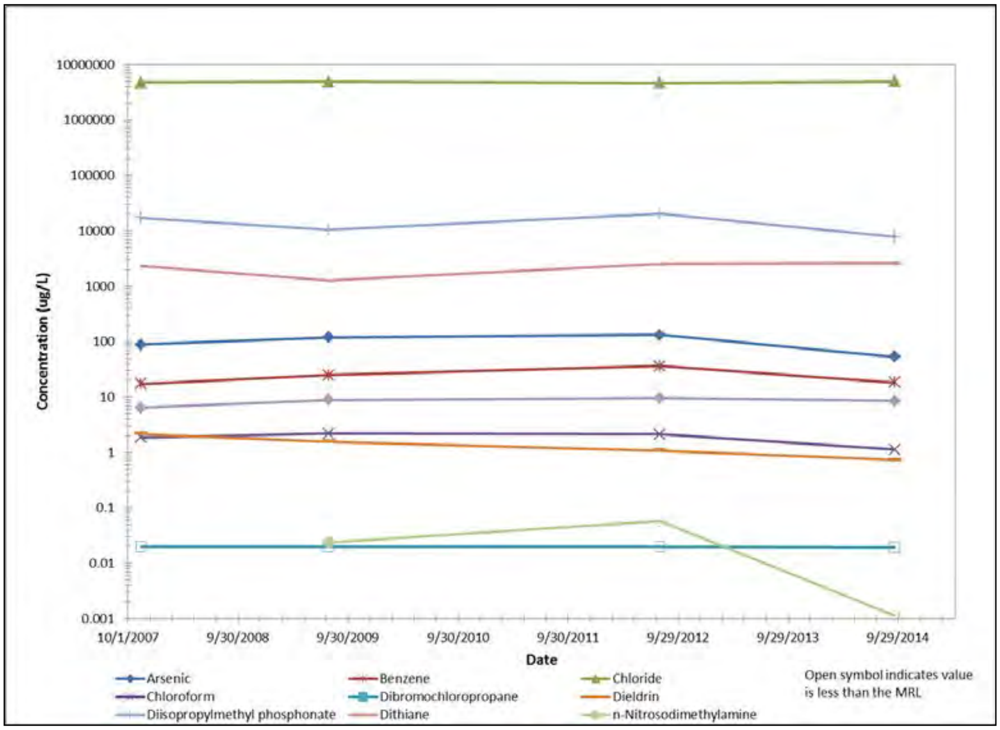
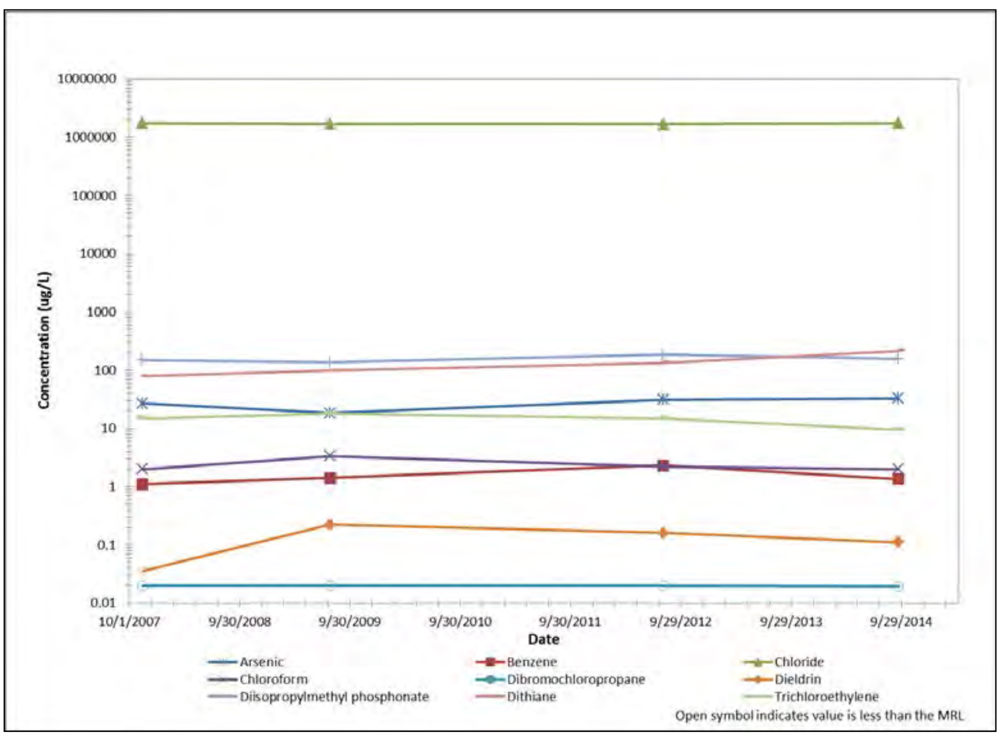


Figure 5.1.3-21. Time Concentration Plot for Well 36633



Variation in groundwater elevations up to several feet have occurred in the Basin A area during the past 10 years because covers, slurry walls, and recharge trenches have been installed within Section 36. The water levels in some of the wells in and downgradient of former Basin A are at historical highs. The 2013 and 2014 storm events also affected water levels in Section 36. With the completion of the Integrated Cover System in Basin A and establishment of the cover vegetation, it is anticipated that groundwater elevations will decrease and stabilize at a level that is lower than pre-construction conditions.

Three wells were monitored in the Section 36 Bedrock Ridge area. Well 25502 is downgradient of the BRES, and wells 36552 and 36594 are upgradient. The indicator analytes for these wells include benzene, chloroform, carbon tetrachloride, PCE, TCE, dieldrin and DIMP. Based on time-series plots for this FYR period and historical data, the concentrations of most of these indicator analytes are decreasing or have stabilized. A summary of trends is presented below:

- Indicator analytes for well 25502, located downgradient from the Section 36 BRES, include chloroform, carbon tetrachloride, DIMP, and PCE. All four analytes show steadily decreasing concentration trends during the FYR period, and either are at or below the CSRGS or were not detected. Only PCE was detected at the CSRG of 5 µg/L in 2014. The decreasing trends in this well are attributed to capture of the plumes by the BRES.
- TCE concentrations in well 36552 decreased from 139 µg/L to 60.5 µg/L (Figure 5.1.3-22). Benzene was not detected and chloroform was variable, with concentrations below the CSRG.
- TCE concentrations in well 36594 increased from 319 µg/L in 2009 to 406 µg/L in 2014 (Figure 5.1.3-23). PCE and dieldrin concentrations were stable, and CCL4, chloroform, and DIMP decreased (3.53 to 0.623 µg/L, 654 to 144 µg/L, and 789 to 24 µg/L, respectively).
- Wells 36552 and 36594 are upgradient of BRES and downgradient of the CADT. The decreases in concentrations of most of the indicator analytes in these wells likely are caused by the effects of the CADT remedy on the groundwater concentrations.

Figure 5.1.3-22. Time Concentration Plot for Well 36552

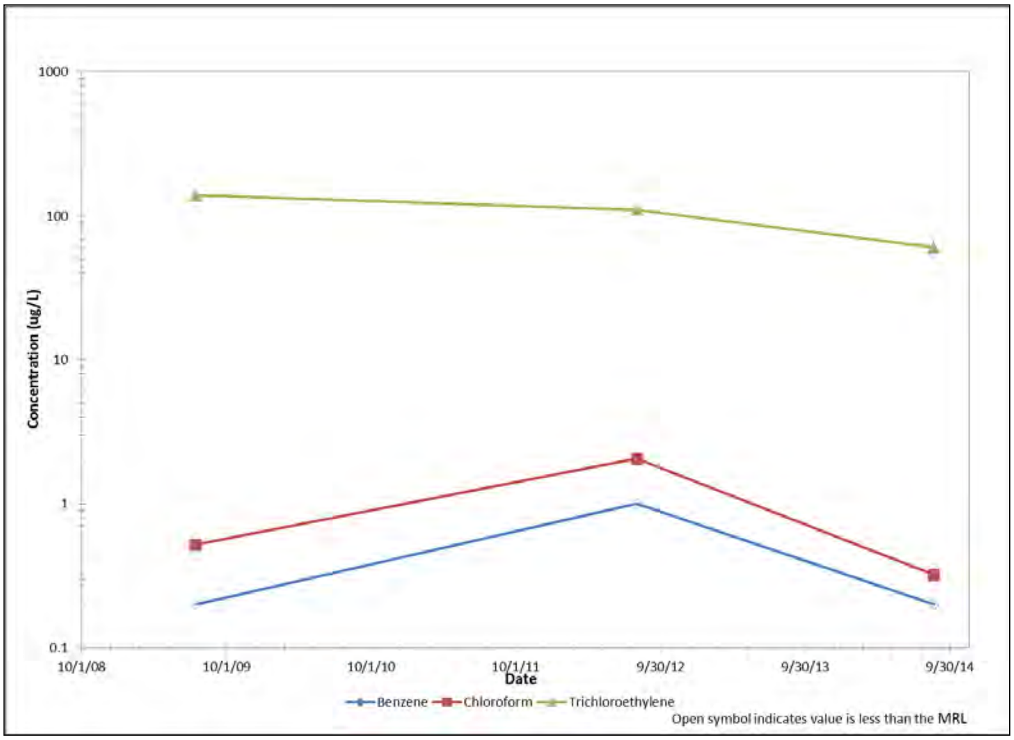
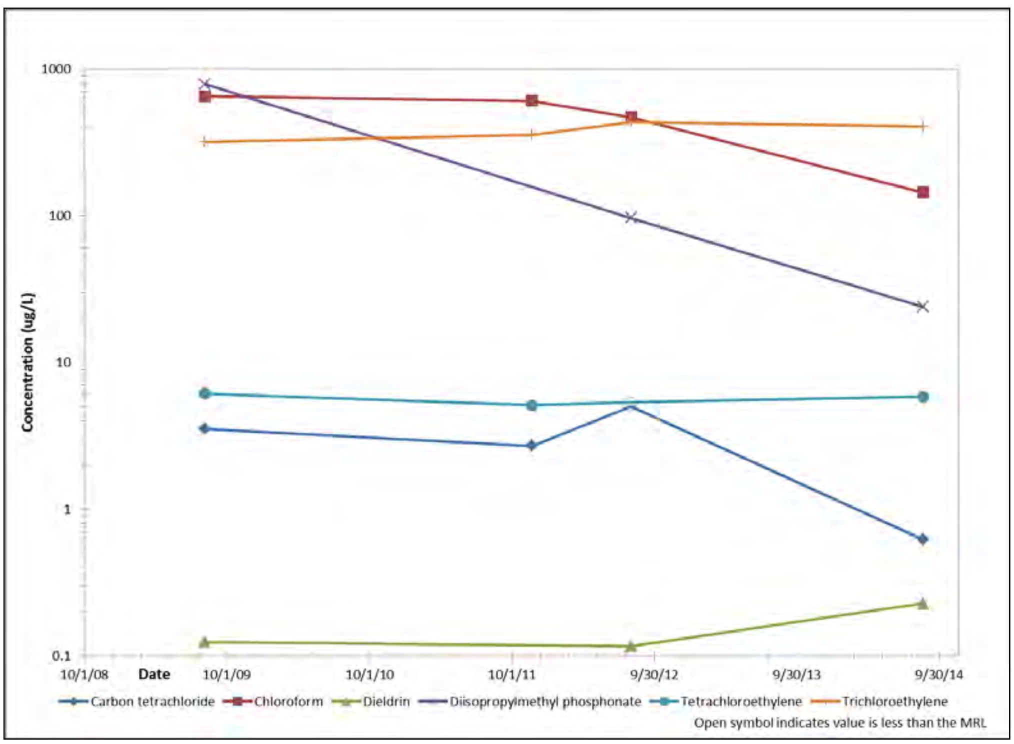


Figure 5.1.3-23. Time Concentration Plot for Well 36594



South Plants/South Lakes/South Tank Farm

Within the South Plants area, wells 01078, 01525, 02065, and 36181 are monitored for indicator analytes to evaluate trends supporting the effectiveness of source area remedies. In the vicinity of the South Lakes, wells 02034, 02505, 02512, 02523, 02524, 02525, and 02597 are monitored upgradient of Lake Ladora to evaluate water quality trends in this area. Well 01312 monitors the STF benzene plume source.

Time-series plots depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided as Figures 5.1.3-24 and 5.1.3-25 to support the discussion of trends noted for groundwater in the vicinities of the South Plants and South Lakes areas. A summary of noted trends in groundwater samples collected for this FYR is presented below:

- Arsenic and chloride concentrations remained stable in well 01078. Chloroform increased and dieldrin decreased.
- Benzene and chloroform concentrations in well 01525 were stable (Figure 5.1.3-24). Arsenic concentrations decreased slightly and dieldrin concentrations increased.
- In well 02065, benzene was not detected and chloroform was stable below the CSRG. Dieldrin decreased slightly.
- The arsenic concentrations in well 36181 were less than the CSRG and DBCP was stable. Benzene, chloroform, and dieldrin concentrations decreased, and chloride increased.
- In the South Lakes area, benzene was not detected in the seven wells monitored during the FYR reporting period.
- Chloroform concentrations decreased or were less than the CSRG in six of the seven South Lakes wells. Chloroform in well 02524 was variable above and below the CSRG (Figure 5.1.3-25).
- Dieldrin concentrations either decreased, remained stable, or were not detected in six of the seven wells upgradient of Lake Ladora. The dieldrin concentration in well 02523 increased slightly.
- Indicator analyte TCE was stable below the CSRG in well 02523.
- In the STF area, benzene concentrations in well 01312 were stable and were 1,320,000 µg/L in 2014. No benzene LNAPL was detected in well 01312 in 2012 or 2014. Chloroform was not detected (with MRLs of 5,000 and 10,000 µg/L), and chloride was stable.

Figure 5.1.3-24. Time Concentration Plot for Well 01525

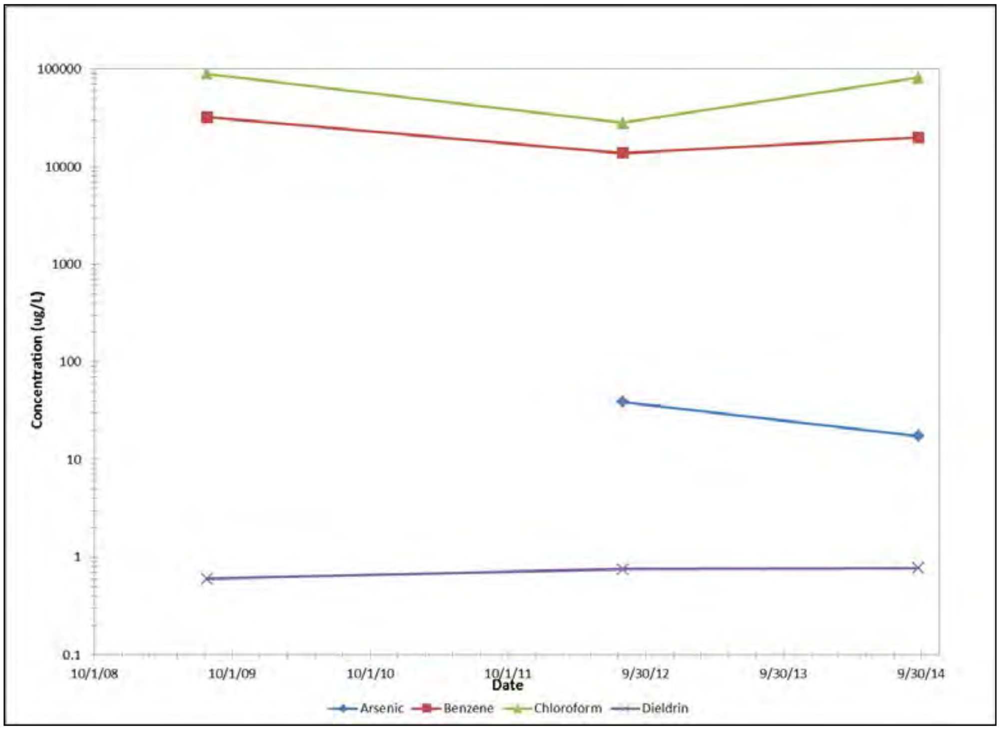
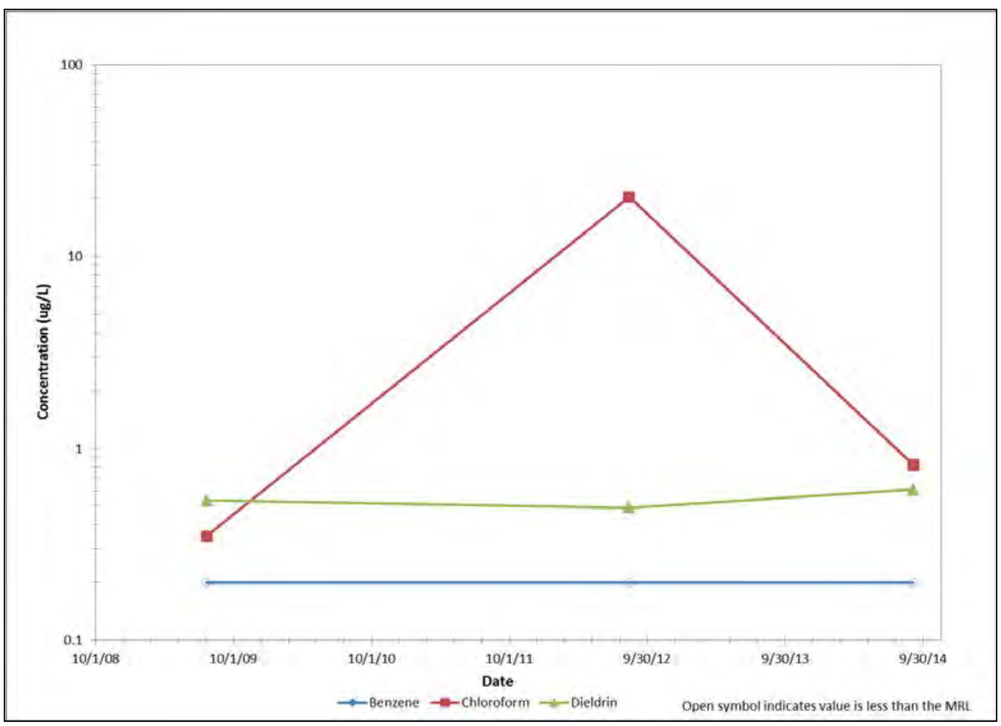


Figure 5.1.3-25. Time Concentration Plot for Well 02524



South Plants SPSA-2d Ditch

Six wells in the South Plants SPSA-2d Ditch source area were monitored for aldrin and dieldrin. According to the LTMP, the wells are sampled once in five years (which occurred in 2012), but were also sampled in 2014, as part of the 2014 On-post Plume Mapping task (see Section 5.1.5). Wells 01101, 01669, and 01670 are located upgradient and wells 01044, 01047, and 01582 are downgradient. Well 01101 is also sampled for chloride for comparison to adjacent CFS well 01109.

- Aldrin was detected in two of the upgradient wells (01669 and 01670), but not in well 01101, and not in the downgradient wells.
- Dieldrin was detected in all three upgradient wells at concentrations ranging from 0.0063 µg/L to 0.222 µg/L, and in two of the downgradient wells at lower concentrations (0.0146 µg/L in well 01044 and 0.126 µg/L in well 01582). Dieldrin was not detected in downgradient well 01047. The chloride concentration in well 01101 was stable, and was 335,000 µg/L in 2014.
- The 2012 and 2014 data indicate that five of the six wells are part of a larger dieldrin plume, and the South Plants SPSA-2d Ditch does not appear to be a source of aldrin or dieldrin to groundwater.

The South Plants SPSA-2d Ditch source area wells were added to the LTMP because human-health exceedance soil was found, and the South Plants 3-ft cover was extended to include this area. After two sampling events, the ditch does not appear to be a source of aldrin or dieldrin to groundwater. Based on the 2014 plume mapping results (Section 5.1.5.1), VOCs should be added to the indicator analyte list for wells 01044, 01047, 01101 and 01582.

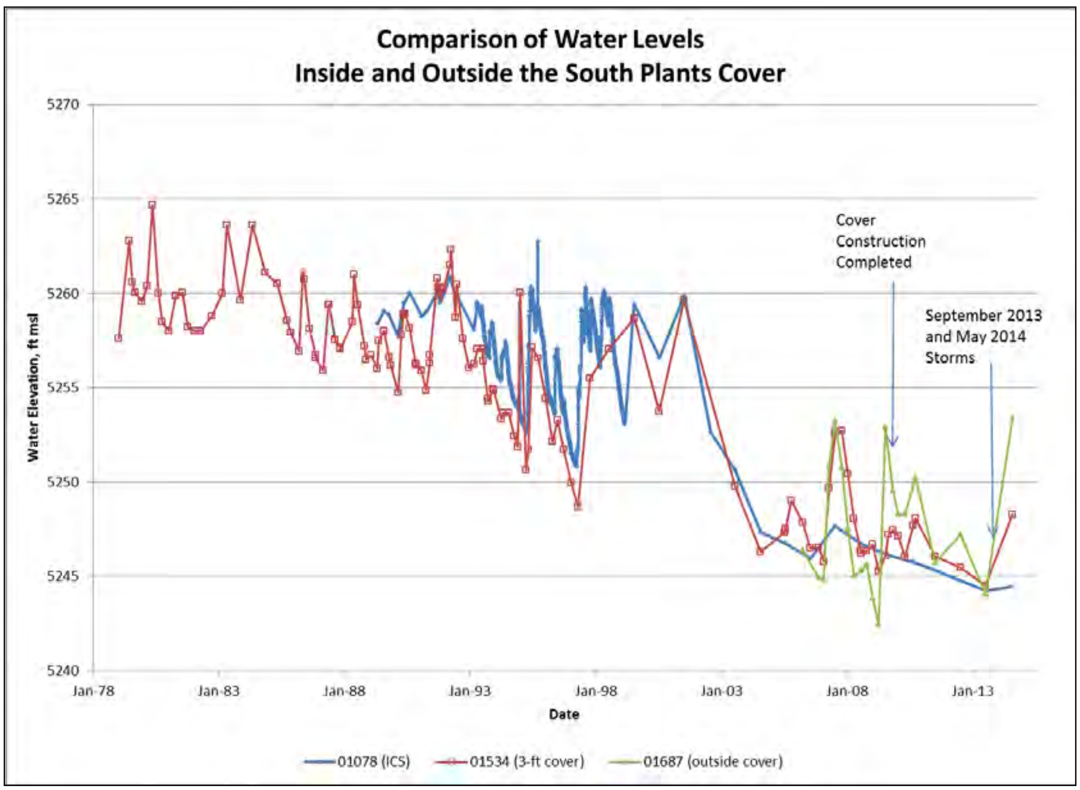
South Plants/South Lakes Water Level Changes

The variation in some indicator analyte concentrations in the South Plants/South Lakes area is likely attributable to the change in water levels and flowpaths in the area, which may have momentarily mobilized and introduced residual contamination to groundwater during soil cover construction. Water levels in the South Plants area have decreased overall since the 1990s, due to the elimination of leaking water pipes, remedy implementation, and installation of the soil cover across this area where localized groundwater recharge has been reduced. The historical groundwater mound in the South Plants area has subsided over most of its former extent, with smaller remnants remaining in the STF area and at the intersection of Sections 1, 2, 35, and 36. These changes are apparent in the vicinity of wells 01525, 02034, and 02524, thereby substantiating the nature of localized changes rather than a change on a regional scale. After the covers were installed and the cover vegetation established, groundwater level fluctuations have decreased, which should cause the groundwater contaminant concentrations to be less variable in the future.

Figure 5.1.3-26 shows the long-term water level changes inside and outside the South Plants cover. Well 01078 is inside the South Plants Integrated Cover System and the water levels have dropped over 15 ft since 2001and become very stable, including only a very small response (0.2-ft rise) after the September 2013 and May 2014 storms. Well 01534 is inside the South Plants 3-ft cover and shows decreasing variation in water levels since the cover was completed in 2009, with a 3.8-ft rise after the 2013 and 2014 storms. Well 01687 is outside the South Plants 3-ft cover and still shows considerable variation in water levels, including a 9.3-ft rise after the 2013 and 2014 storms.

Wells 01078 and 01687 are 2,230 ft apart and had essentially the same water elevations in 2013, before the September storm. Although these wells are not in the same flow path, and contamination at well 01078 migrates to the north not south toward well 01687, in 2013, the gradient was flat between the two wells. The lower water levels in South Plants, where some of the highest contaminant concentrations at RMA are present, reduce the lateral hydraulic gradients, thereby reducing the contaminant mobility. The water table in South Plants is in the weathered bedrock. Generally, the permeability of the weathered bedrock decreases with depth. As water levels fall in the bedrock, the contaminant mobility would be reduced further.

Figure 5.1.3-26. Comparison of Water Levels Inside and Outside the South Plants Cover



Former Basin F

Downgradient of former Basin F, groundwater flows north to the NBCS and northwest towards the NWBCS. Groundwater monitoring upgradient and downgradient of Basin F is conducted under the Basin F Post-Closure Groundwater Monitoring Plan (PCGWMP) and is evaluated in the Annual Covers Reports. For comparison to the previous FYSR, four downgradient wells are discussed in this section including 26015, 26017, 26157, and 26163. Wells 26028, 26073, 26128, 26133, and 26173 also are monitored under the PCGWMP. Based on data collected during this FYR reporting period, many contaminants display stable or decreasing trends in the area of former Basin F. A summary of noted trends in groundwater samples collected for this FYR is presented below:

- Chloroform was not detected or near the MRL in wells 26015, 26017, and 26163 and showed a decreasing trend in well 26157. Chloroform concentrations in well 26157 decreased from 1,950 µg/L in 2009 to LT 5 µg/L in 2014.
- Chloride concentrations decreased or were stable in wells 26015, 26157, and 26163. Chloride in well 26017 increased from 397,000 µg/L in 2009 to 1,250,000 µg/L in 2014 (Figure 5.1.3-27). The 2014 chloride concentration in well 26017 is within the historical range and similar to the other downgradient wells. Continued monitoring will help determine whether recent chloride results in well 26017 indicate a trend in water quality.
- The concentration of dieldrin in well 26015 decreased to below the MRL in 2014 (Figure 5.1.3-28). Dieldrin concentrations were lower in 2014 than in 2009 in all four wells (Figures 5.1.3-27 through 5.1.3-29). The dieldrin concentrations in well 26163 fluctuated from 1 µg/L and above to less than the MRLs during the FYR period (Figure 5.1.3-29). The water levels do not show similar fluctuations, so the cause of the variability in the dieldrin concentrations is unknown. Similar fluctuation in the dieldrin concentrations in well 26017 have occurred historically since monitoring of the well began in 1989.
- DIMP concentrations were stable or decreased in wells 26015, 26017, 26157, and 26163. DIMP concentrations in well 26157 decreased by an order-of-magnitude.
- NDMA concentrations were stable or decreasing in all four wells.

Time-series plots depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided in Figures 5.1.3-27 through 5.1.3-29 to support the discussion of trends noted for groundwater in the vicinities of the former Basin F.

Figure 5.1.3-27. Time Concentration Plot for Well 26017

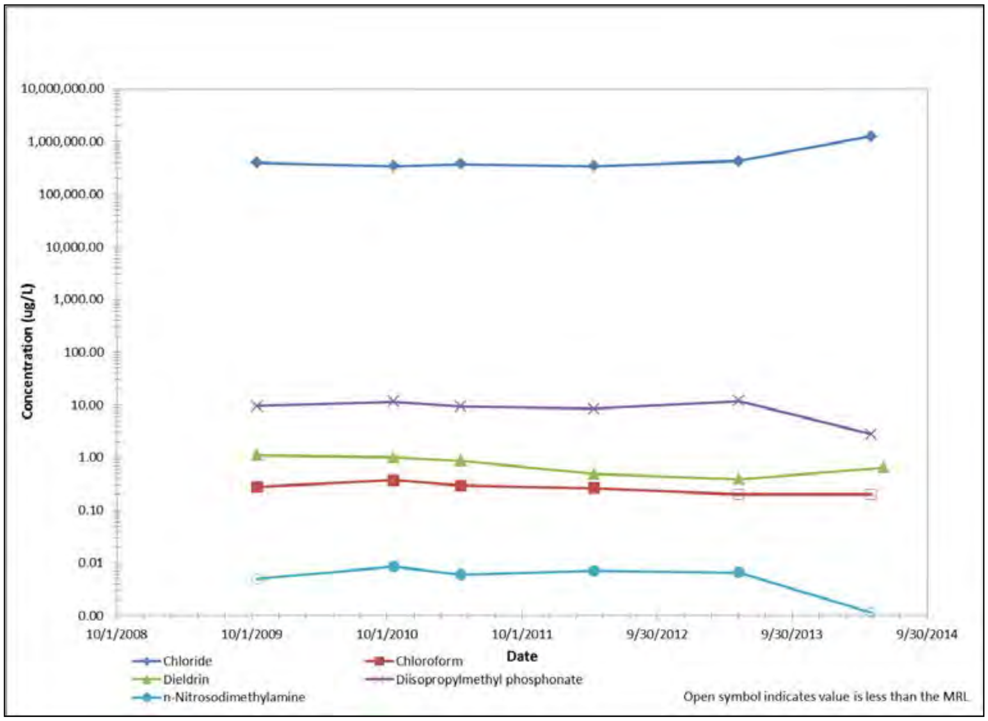


Figure 5.1.3-28. Time Concentration Plot for Well 26015

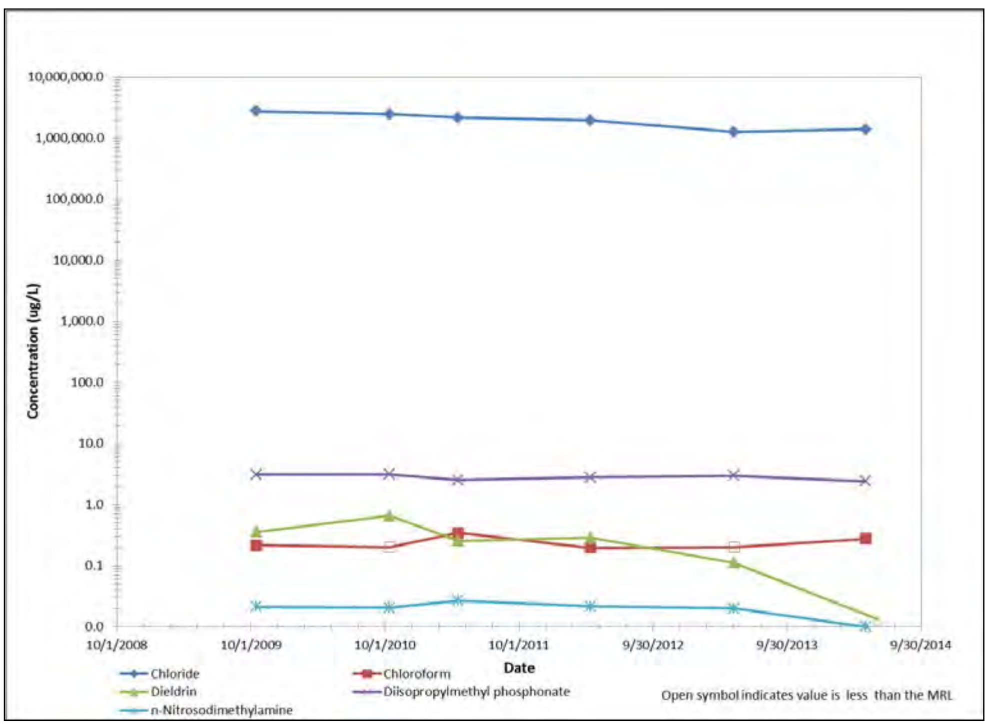
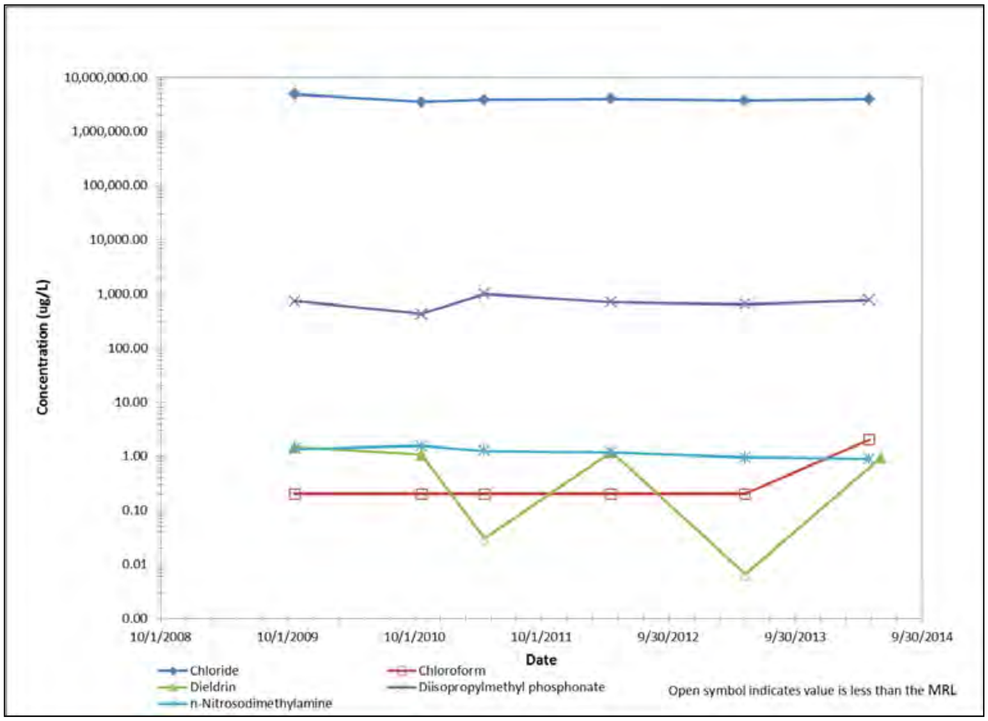


Figure 5.1.3-29. Time Concentration Plot for Well 26163



In 2007, during construction of the Basin F cover, a moat-like ditch was excavated along the perimeter of Basin F as a storm water control measure. Additional excavations to depths of up to 10 ft were also completed within the footprint of the former basin to remove localized zones of contaminated soil. Precipitation collected within these excavated areas and may have leached contaminants from the surrounding soils, subsequently contaminating groundwater. Excavation activities are likely the direct cause of the increased levels of indicator analytes in some of these wells during the previous FYR period. Continued monitoring of groundwater in the vicinity of the former Basin F will help to establish long-term trends now that the final remedies are in place.

Upgradient from NBCS

Downgradient of the former Basin F and Basin F Wastepile source areas and upgradient of the NBCS, six wells are monitored for water quality: 23095, 23096, 23142, 23548, 24092, and 24094. In this area, most indicator analytes show decreasing or stable trends since 2009. A summary of noted trends in groundwater samples collected for this FYR is presented below:

- Concentrations of indicator analytes in well 23096 are decreasing and signify the typical trend for the area upgradient of the NBCS (Figure 5.1.3-30). The 2012 sulfate concentration was anomalously high (4,700,000 µg/L), but was 360,000 µg/L in 2014 and similar to the historical trend. Chloride concentrations are stable in wells 23095 (Figure 5.1.3-32), 23096, and 24092 (Figure 5.1.3-33).

- Chloroform concentrations were below the CSRG in five of the six wells during the FYR period. The chloroform concentration in well 23096 decreased from 456 µg/L in FY09 to 108 µg/L in FY14 (Figure 5.1.3-30).
- Dieldrin concentrations decreased or were below the MRL in all six wells. Dieldrin is not an indicator analyte for wells 24092 and 24094, but they were sampled for dieldrin in 2009 and 2014 and were non-detect.
- DIMP concentrations decreased or were stable in five of six wells, and concentrations were variable in well 24092 (Figure 5.1.3-33). Well 23548 was not sampled for DIMP in 2009, but was sampled in 2007, and the concentration decreased from 1,040 µg/L in FY07 to 27.4 µg/L in FY14.
- Carbon tetrachloride was only detected in well 24094, and the concentration decreased from 5.22 µg/L in FY09 to 0.426 µg/L in FY14.
- NDMA is an indicator analyte for wells 23095, 23096, and 23548 and concentrations were stable or decreasing in all wells. NDMA is not an indicator analyte for wells 23142 (Figure 5.1.3-31) and 24092, but they were sampled for NDMA in 2009 and 2014 and were non-detect.

Time-series plots depicting the concentrations of indicator analytes relative to sample date are provided in Appendix D. Well-specific plots are provided in Figures 5.1.3-30 through 5.1.3-33 to support the discussion of trends noted for groundwater upgradient of the NBCS.

Figure 5.1.3-30. Time Concentration Plot for Well 23096

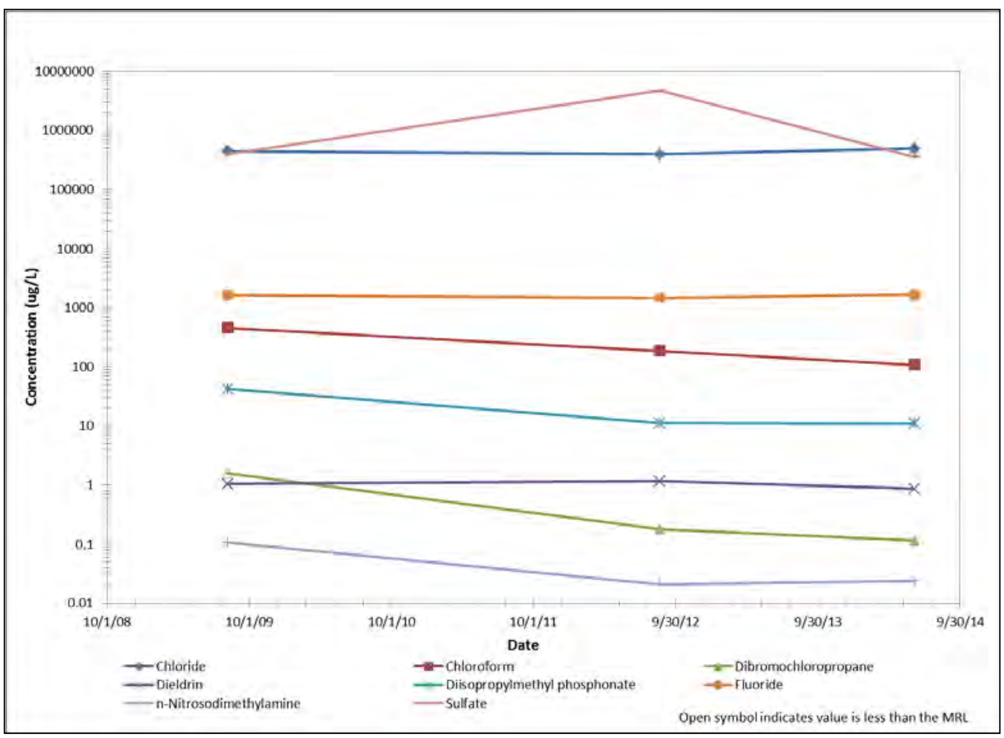


Figure 5.1.3-31. Time Concentration Plot for Well 23142

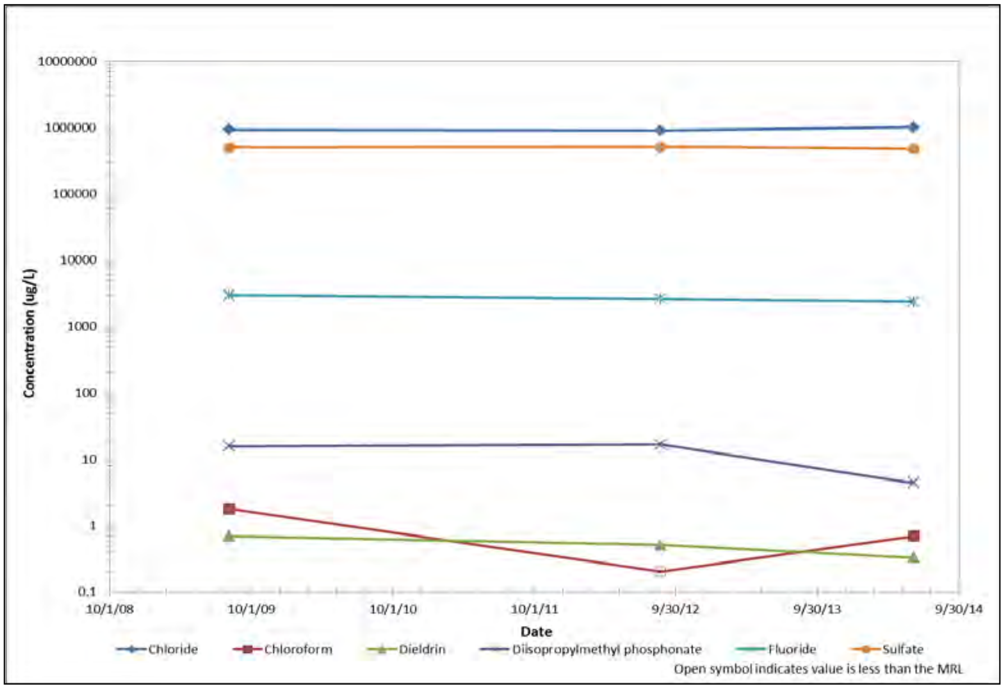


Figure 5.1.3-32. Time Concentration Plot for Well 23095

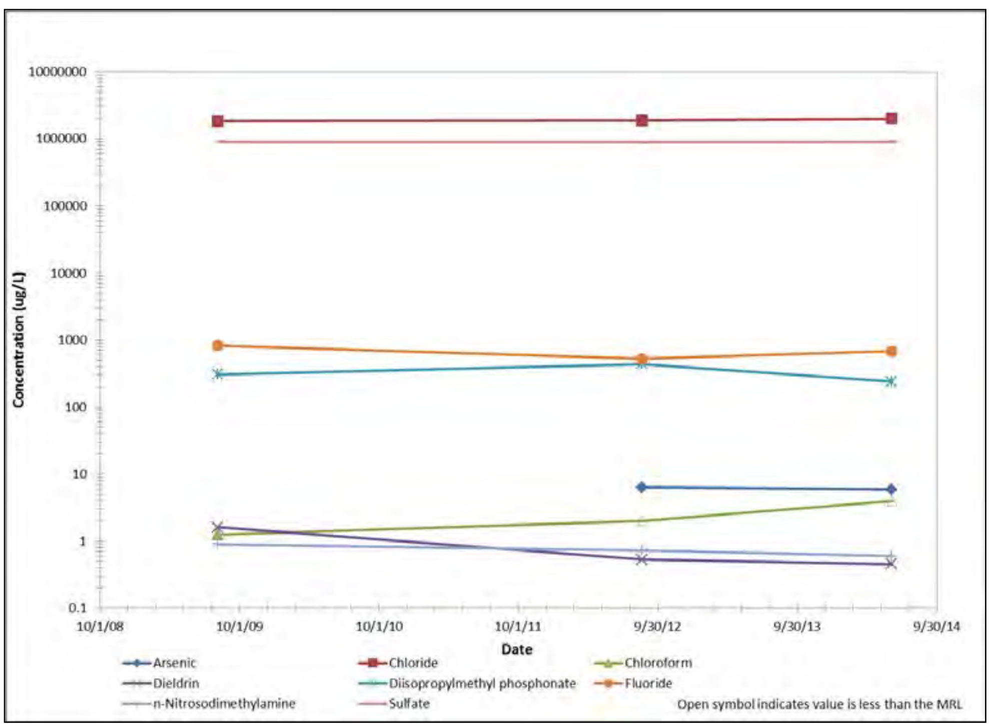
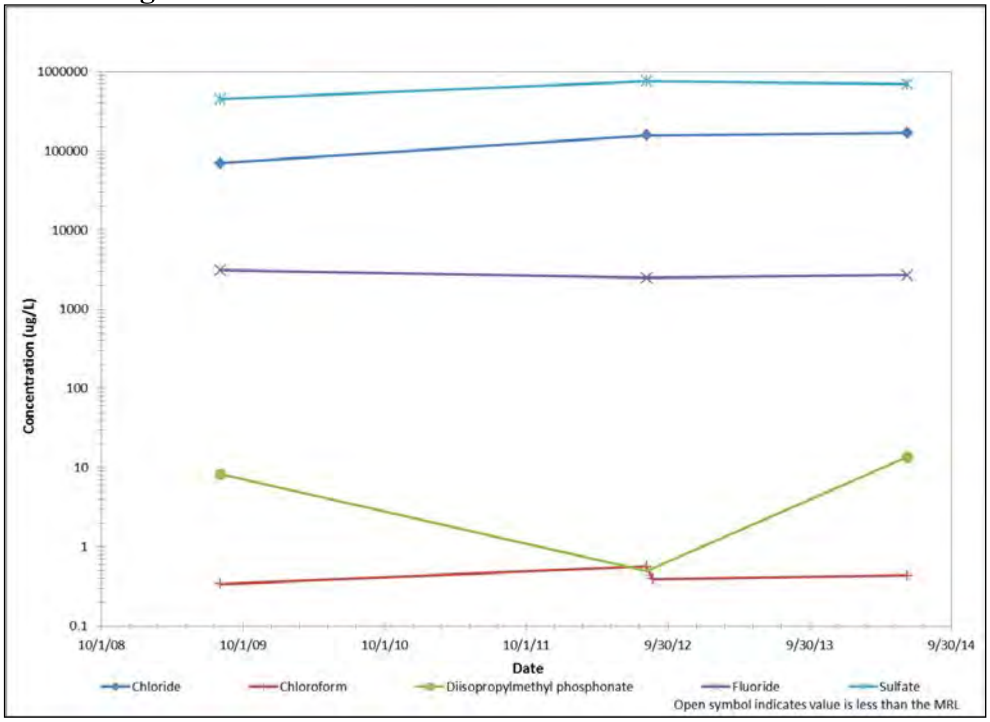


Figure 5.1.3-33. Time Concentration Plot for Well 24092



Railyard/Motor Pool

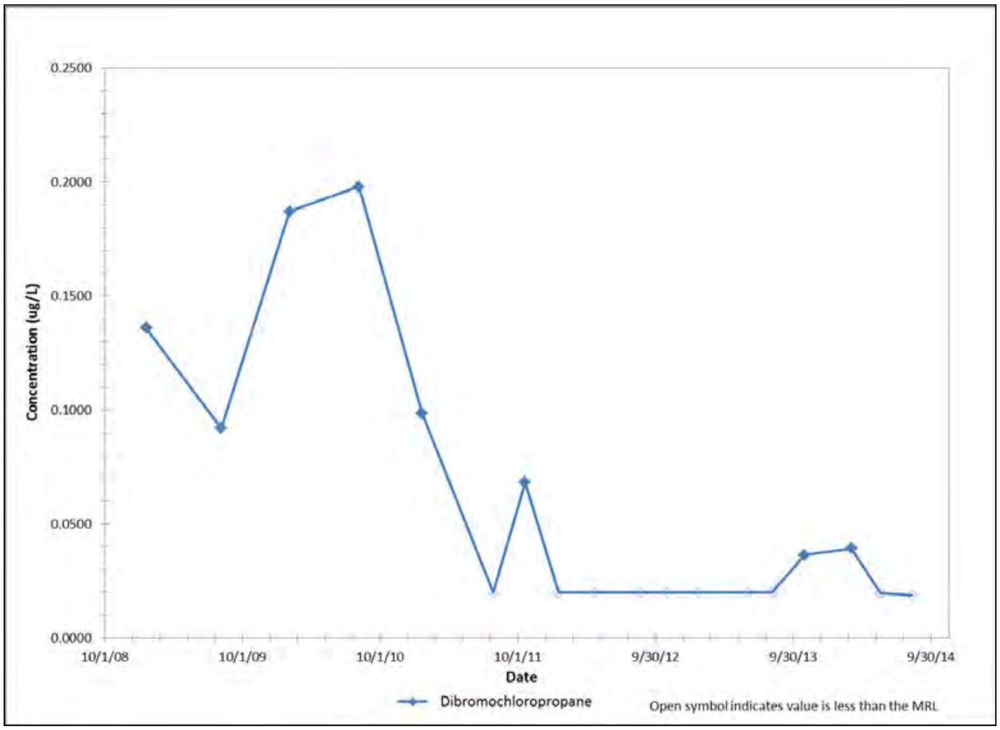
Well 03523 is monitored for DBCP in the Railyard area (Figure 5.1.3-34). Eighteen samples were collected and analyzed from well 03523 from FY09 to FY14. DBCP concentrations in well 03523 were below the CSRG in all samples, and the concentrations decreased overall from 2009 to 2014.

Well 04535 is monitored for trichloroethylene in the Motor Pool area. Beginning in FY12, it was monitored annually under the MP/ICS post-shut-off monitoring plan (see Section 5.1.5.2). The TCE concentrations were variable during the FYR period, and were below the CSRG in all four samples.

Irondale/Western Plume

ICS post-shut-off monitoring in well 33081 was conducted during the FYR period and is discussed in Section 5.1.5.2.

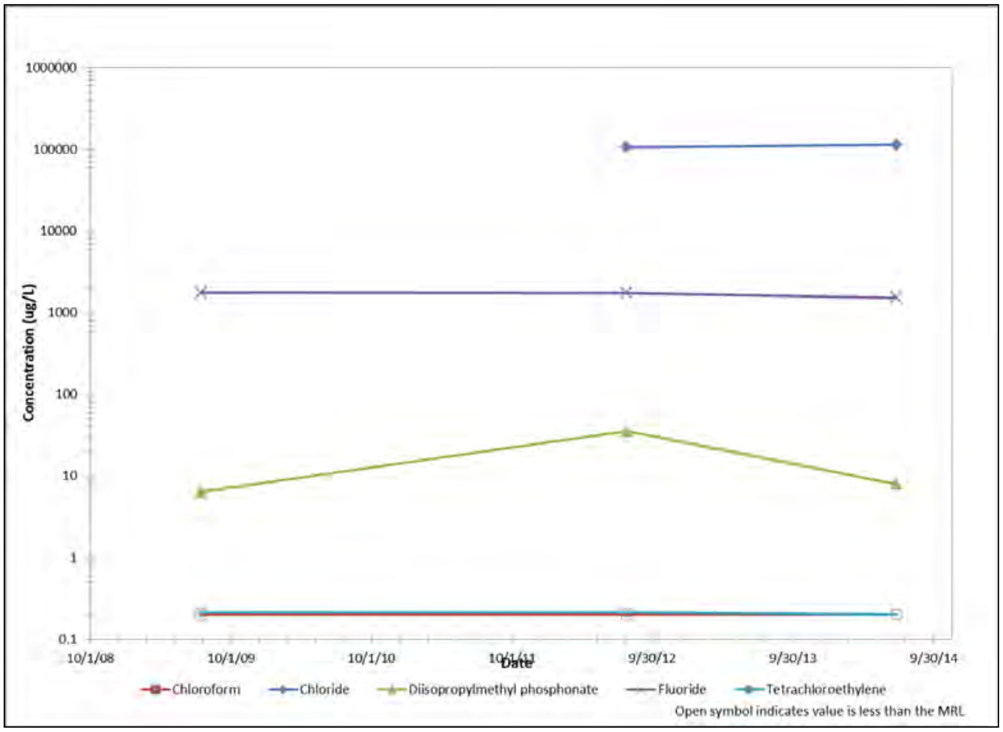
Figure 5.1.3-34. Time Concentration Plot for Well 03523



North Plants

In the North Plants and downgradient areas, wells 24081 and 25059 are monitored for carbon tetrachloride, chloride, chloroform, DIMP, fluoride, and tetrachloroethylene. In well 24081, carbon tetrachloride was below the CSRG and decreased to below the MRL of 0.263 µg/L in FY14. Chloroform and tetrachloroethylene concentrations were below the CSRGs and decreasing in well 24081. Only chloride, DIMP, and fluoride were detected in well 25059. DIMP concentrations showed a decreasing trend in well 24081 and were stable in well 25059 during the FYR reporting period (Figure 5.1.3-35). Chloride and fluoride concentrations were relatively stable for both wells.

Figure 5.1.3-35. Time Concentration Plot for Well 25059



Summary

Table 5.1.3.1-3 (provided under Tables Tab) provides a summary of the evaluations conducted for wells within each source and plume area monitored under the LTMP.

The water quality data collected in the areas upgradient from the containment systems and within source areas were used in combination with water level monitoring data to track the effects of the remedies on groundwater during this FYR period. The results of the evaluation of water level and water quality data indicates that conditions have generally not changed in the UFS relative to groundwater flow and indicator analyte concentrations. In many areas, contaminant concentrations generally decreased during the FYR period. For the water quality tracking wells where concentrations have increased, these short-term increases may be localized and less meaningful than the long-term trends. The overall change in plume extents and concentrations for nine indicator analytes between 1994 and 2014 is discussed in Section 5.1.5.1.

Groundwater flow has not changed in the UFS across most of RMA. Locally, groundwater flow has changed in areas where slurry walls were installed in the Lime Basins, CADT and Shell Disposal Trenches, and where infiltration is now limited due to the installation of covers within the vicinity of Basin A (Section 36), South Plants area, and former Basin F. Minor changes in groundwater flow have resulted, but flowpaths and associated plumes continue to migrate directly towards the containment systems. Within the South Plants area, the extent of the groundwater mound has decreased and evolved into two smaller mounds during the latter part of the previous FYR period and this FYR period. However, the overall groundwater flow directions have not changed.

The unprecedented 500- to 1000-year storm event in September 2013 followed by heavy rains in May 2014, caused groundwater levels to rise to historically high elevations in many areas of RMA. Infiltration of rainfall was greatly reduced in the Integrated Cover System, and the groundwater levels were much less affected. The high groundwater levels in 2014 affected operation of some of the groundwater extraction and treatment systems, but did not significantly affect the overall groundwater flow directions.

Based on the evaluation of water quality data, the remedies have affected the concentrations of indicator analytes within each area. For the most part, the concentrations of indicator analytes are remaining stable or decreasing. In a few instances, there are observed concentration increases that may be related to localized changes in flow directions or water levels. For each area addressed in the FYR, a summary is provided below with additional details presented in Table 5.1.3.1-3.

- **Upgradient of the NWBCS:** Concentrations of chloroform, dieldrin, and DIMP were stable or decreased in the majority of the wells.
- **Basin A/Basin A Neck/Section 36 Bedrock Ridge**: Concentrations of benzene, chloroform, DBCP, dieldrin, dithiane, PCE, TCE, 1,2-dichloroethane, NDMA, DIMP, carbon tetrachloride, and DDT demonstrate stable or decreasing trends for the wells sampled in this area. Only TCE in well 36594 shows a slight increase in concentration during the FYR period. Concentrations of arsenic were lower in wells downgradient of the Lime Basins. Concentrations of most analytes in wells downgradient of BANS, BRES, and CADT were lower.
- **South Plants/South Lakes**: The indicator analyte concentrations showed decreasing or stabilizing trends, and there were a few increases indicated in specific wells.
- **Former Basin F**: Concentrations of the indicator analytes were stable or decreased in most wells.
- **Upgradient of the NBCS**: Concentrations of indicator analytes are decreasing and signify the typical trend for the area upgradient of the NBCS.
- **Railyard**: DBCP concentrations decreased to below the CSRG in all samples during the FYR period within the Railyard area
- **North Plants**: Concentrations of the indicator analyte were decreasing or below CSRGs for most analytes, and a few were stable.

5.1.3.2 Confined Flow System Monitoring

CFS monitoring is required by the On-Post ROD to identify vertical or lateral migration of contaminants to or within the CFS in the Basin A**,** Basin F, and South Plants areas. The CFS well network is specified in the 2010 LTMP (TtEC and URS 2010); the CFS well locations are shown on Figure 5.1.3.2-1. Evaluations conducted for data collected during this FYR period included comparisons of CFS and UFS water level data and water quality data to assess the potential for downward contaminant migration. Comparisons of water level data are used to determine whether downward gradients, which indicate the potential for downward contaminant migration, are present. Water level data and hydraulic gradients for CFS and corresponding UFS wells are presented in Table 5.1.3.2-1 (included under the Tables Tab). Chemical data are used to determine whether contaminant concentrations in the CFS are changing or are indicating significant migration over time. Water quality trends for each well are summarized in Table 5.1.3.2-3. Nineteen wells are sampled for water quality within the on-post CFS well network. Well 23193 was part of the CFS water quality sampling network, and although water levels continue to be measured in this well, it has an obstruction that prevents sampling. Well 23193 has not been replaced because existing wells were to be used for the CFS network in the 1999 LTMP, and if a CFS well was damaged, existing alternate wells were to be selected as replacements. When the 2010 LTMP was developed, well 23193 was already obstructed and could not be sampled. Consequently, well 23193 was retained in the LTMP CFS network for water level monitoring. Additionally, the remaining wells in the CFS network near Basin F were considered adequate to meet the CFS monitoring objectives. Well 23193 was recently inspected with a downhole camera and sampling it may now be possible. If well 23193 cannot be sampled during the next scheduled sampling event, alternate CFS well 23230 will be sampled instead.

Water Level Monitoring Results

Comparisons of water levels in paired UFS and CFS wells generally indicate downward hydraulic gradients throughout the CFS monitoring network. An upward hydraulic gradient has been present in well pair 02057/02058 since July 2008 because UFS water levels in South Plants have been lower. An upward gradient was present during the FYR period until the September 2013 and May 2014 rainstorms caused the shallow (UFS) groundwater levels to rise. The water elevation in UFS well 02058 rose 5.7 ft between July 2013 and July 2014. Consequently, the July 2014 water elevations showed a small downward gradient. This well pair is located in the South Plants area, where the installation of soil covers has decreased infiltration of precipitation and recharge to the water table. Historically, prior to cover construction, downward hydraulic gradients were typical for this well pair. An upward gradient is desirable because the potential for downward migration is significantly reduced.

Although no other well pairs had upward gradients during this FYR period, the downward gradient head differentials have decreased in several well pairs in response to the reduced infiltration of precipitation and reduced recharge of the shallow groundwater in cover areas. A reduced head differential reduces the driving force for downward migration of dissolved contaminants. The vertical gradient head differentials were very consistent until about 2001, and then decreased in some of the well pairs. Table 5.1.3.2-2 provides the average head differentials prior to FY02 and the average head differentials for this FYR period.

Decreased head differentials occurred in all of the South Plants well pairs, with the largest decreases in UFS wells nearest the crest of the South Plants historical groundwater mound. Water levels have fallen approximately 15 ft in the area of the former groundwater mound. The decreases were less in wells on the flanks of the mound. The highest UFS contaminant concentrations in the vicinity of CFS wells occur in South Plants where the downward gradient decreased the most (i.e., well pairs 01102/01534, 01300/01078, and 36183/361981. Thus, the South Plants covers have reduced the potential for downward migration in these high concentration areas.

CFS well 01102 is located in the STF benzene plume where the concentrations exceed 1,000,000 µg/L. When well 01102 was first sampled in 1992, the benzene concentration was 8,800 µg/L. It was suspected that the contamination was introduced when drilling the well. The benzene concentrations subsequently decreased, and benzene has not been detected since 2004, including during this reporting period.

Most of the downward head differentials increased in the Basin A well pairs (Table 5.1.3.2-2). Higher water elevations have been present in UFS wells in and downgradient of Basin A after soil consolidation, re-grading, and cover construction were conducted in former Basin A. Water levels began rising in Basin A wells in 1998, when Basin A soil consolidation began, and likely was caused by a combination of: 1) increased infiltration/recharge during soil consolidation and cover construction activities; 2) irrigation of the cover to establish vegetation; and 3) loading/compaction of the underlying aquifer by the large volumes of contaminated soil, building debris, and fill placed in Basin A to facilitate re-grading and construction of the subgrade and ICS. Water levels in most wells in and downgradient of former Basin A currently are at historical highs since monitoring began in the 1980s. The September 2013 and May 2014 storms also caused the water levels in the Basin A wells to be higher in FY14 than in FY13. As this excess water dissipates, and the groundwater flows out of Basin A through the Basin A Neck channel, the UFS water levels should fall and the downward vertical gradient head differentials in the CFS wells would then decrease.

One exception to the increased downward vertical gradients in the Basin A wells is well pair 36159/36158. The head differential decreased by about three feet, likely because it is unaffected by the higher water levels in Basin A. The well pair is located northeast of the CADT slurry wall and northeast of a groundwater divide. Complex (Army) Disposal Trenches dewatering is occurring on the southwest side of the divide.

The Basin F well-pair head differential changes were more variable because some of the well pairs are downgradient of former Basin A (e.g., 26152/26154) and have higher UFS water levels. Additionally, some well pairs are not in soil cover areas, and are subject to more infiltration of precipitation and groundwater recharge than in the cover areas.

Table 5.1.3.2-2 CFS/UFS Vertical Gradient Head Differentials

Area	CFS Well	UFS Well	Pre-FY02 Average Head Differential, ft	FY10-FY14 Average Head Differential, ft
South Plants	01067	01068	14.4 (downward)	4.4 (downward)
	01102	01534	12.3 (downward)	5.8 (downward)
	01109	01101	42.2 (downward)	38.3 (downward)
	01300	01078	13.1 (downward)	3.7 (downward)
	02057	02058	3.8 (downward)	-2.3 (upward)
	35083	35013	51.4 (downward)	47.2 (downward)
	36183	36181	17.4 (downward)	8.0 (downward)
Basin A	35063	35061	24.3 (downward)	26.7 (downward)
	35067	35065	15.9 (downward)	17.9 (downward)
	35068	35065	25.6 (downward)	29.8 (downward)
	36113	36112	4.3 (downward)	4.8 (downward)
	36114	36112	27.3 (downward)	30.2 (downward)
	36159	36158	22.3 (downward)	19.2 (downward)
	36171	36169	32.9 (downward)	36.6 (downward)
Basin F	23187	23185	21.3 (downward)	25.9 (downward)
	23193	23191/23142	5.8 (downward)	10.7 (downward)
	26147	26146	2.2 (downward)	2.0 (downward)
	26150	26158	9.3 (downward)	7.2 (downward)
	26152	26154	16.7 (downward)	19.1 (downward)
	26153	26015	5.0 (downward)	5.6 (downward)

Water-Quality Monitoring Results

With the exception of chloride, only 1,1-dichloroethane (11DCLE), chlorobenzene, and dieldrin were detected in CFS wells during the FYR period (Table 5.1.3.2-3). 1,1-Dicholorethane (0.509 µg/L) was present in well 01067 for the first time, and was near the detection limit. The 11DCLE concentration in adjacent UFS well 01068 was 64.4 µg/L in FY14 and was higher than when it was last sampled in 1994. A questionable aquitard was noted for CFS well 01067 in the RMA Technical Report for Groundwater Data Evaluation (HLA 1994). Well 01067 was classified as a CFS well based on a pumping test in a well 1,200 ft to the west and may not have been sufficient for classifying well 01067. Consequently, well 01067 may actually be semi-confined. An increase in contaminant concentrations when the downward hydraulic gradient is decreasing (the head differential decreased from 14.4 ft before 2002 to 4 ft in FY14) would not be expected if the aquitard is effective. Well 01067 has only had a single detection of an indicator analyte near the MRL (11DCLE in FY14). The chloride concentrations in well 01067 are stable and equal to or lower than historical levels. Thus, monitoring of well 01067 should continue.

Chlorobenzene concentrations in well 02057 decreased from 1989 to 2007, but increased slightly from FY09 to FY14. The aquitard is questionable in well 02057 and it has no outer casing to seal off the alluvium. The top of the sandpack is in the weathered bedrock. Therefore, this well may actually be semi-confined, which likely explains why this well has historical contamination of several analytes that migrated downward to the well when a downward gradient was present from the UFS to the CFS.

1,1-Dichloroethane was detected at low concentrations in well 02057 during the past 10 years, but decreased since 1989, and it was not detected in well 02057 in FY09, FY12, or FY14. The decreasing 11DCLE trend coincides with the decrease in the head differential and11DCLE was not detected when there was an upward gradient. The 11DCLE concentration in the adjacent UFS well 02058 has been stable, with an average of about 7 µg/L. The presence of contamination in well 02057 and the questionable aquitard were known when the well was selected for the CFS network. Overall, the well has shown decreasing concentration trends, which are consistent with expectations. Thus, replacing well 02057 or any other action besides continued monitoring is considered unnecessary by Army and Shell.

Dieldrin was detected in Basin F CFS well 26153, and the concentration increased from near the MRL in FY12 to 0.0526 µg/L in FY14. Dieldrin has been detected previously in well 26153 (in 1992 and 1997) and the FY14 concentration is within the historical range. Dieldrin has been detected historically in nearby UFS well 26015, and the concentration decreased to LT 0.0132 µg/L in FY14. The concentrations of indicator analyte chloride have been variable in well 26153. There were no comments about the CFS classification of well 26153 in HLA 1994. The vertical gradient was similar during the FYR period to the pre-2002 gradient. Therefore, the water quality results for well 26153 are consistent with previous results and no significant change in the conditions is apparent.

Chloride is naturally occurring and generally occurs at higher concentrations in the UFS compared to the underlying CFS. The chloride concentrations in the CFS wells were compared to corresponding data for adjacent UFS wells to evaluate water quality trends. Chloride trends noted during this FYR reporting period are shown in Figures 5.1.3.2-2 through 5.1.3.2-4 and include the following:

- Chloride concentrations showed stable or decreasing trends in CFS wells in the South Plants area (wells 01102, 01109), the vicinity of former Basin F (23187, 26147, 26150, 26152, and 26153), and in the vicinity of Basin A (35063, 35068, 36113, 36159, 36114 and 36171) (Figures 5.1.3.2-2 through 5.1.3.2-4). In the Basin A area, CFS well 36159 historically has had a higher chloride concentration than was detected in its companion UFS well 36158. In the Basin F area, CFS well 26147 historically has had a higher chloride concentration than was detected in its companion UFS well 26146.
- During the reporting period, chloride concentrations also increased in wells 01067, 01300 and 02057 within the South Plants area, and in well 26150 upgradient of the former Basin F. Although concentrations were higher, the concentrations were within historical ranges in each well.

- Chloride concentrations in well 35067 have had an increasing trend for approximately 25 years. Concentrations appear to have remained stable from FY09 to FY14 (Figure 5.1.3.2-2). Adjacent UFS well 35065 has had a similar increasing trend and the concentrations are an order-of-magnitude higher. The increasing concentration trend in well 35067 indicates potential downward migration of groundwater from the UFS to the CFS, and the downward vertical hydraulic gradient corroborates this trend. However, the aquitard in well 35067 is questionable (HLA 1994), and the well may be semi-confined.

The chloride concentrations in CFS well 35083 have shown an increasing trend since 1993, which stabilized during the current reporting period. These concentrations are higher than in nearby UFS wells by one to two orders of magnitude. The FY14 chloride concentration in well 35083 was 1,130,000 µg/L. Well 35013 is the paired UFS well for 35083 and was sampled in FY14 when chloride was measured at 89,500 µg/L. The vertical gradient between the UFS and CFS in this area is downward. UFS well 35013 has been contaminated by a variety of VOCs (e.g., carbon tetrachloride, 21.9 µg/L in FY14) that have not been detected in CFS well 35083. Because organic analytes detected in UFS well 35013 have not been detected in CFS well 35083, and the UFS chloride concentrations are much lower, the source of higher chloride concentrations in the CFS is not directly apparent.

Table 5.1.3.2-3. Confined Flow System Water Quality Evaluation, 2009–2014

Well	Comments
South Plants	
01067	Chloride concentration trend is slightly upward, but within typical historical range. 1,1-dichloroethane was detected in FY14 (0.509 µg/L).
01102	Chloride concentration is stable within typical historical range. No other indicator analytes were detected.
01109	Chloride concentrations showed small decrease since FY09, but similar to historical range. No other indicator analytes were detected.
01300	Chloride concentrations decreased from 41,600 µg/L in FY09 to 37,100 µg/L in FY14. No other indicator analytes were detected.
02057	Chloride concentration trend slightly upward since FY09. Chlorobenzene is still present at low concentrations. 1,1-dichloroethane decreased to below the detection limit in 2009. No other indicator analytes detected. Upward gradient between this well and unconfined well 02058 existed from FY09 to FY14. Small downward gradient between the well pair was observed in FY14.
35083	Chloride concentrations show steady increasing trend with historical high of 1,620,000 µg/L in FY12, but decreased to 1,130,000 µg/L in FY14. No other indicator analytes than chloride were detected. This well does not have a bentonite seal, which may affect its integrity.

Table 5.1.3.2-3. Confined Flow System Water Quality Evaluation, 2009–2014 (Concluded)

Well	Comments
36183	Small decreasing chloride trend from 84,700 µg/L in FY09 to 72,900 µg/L in FY14, but within historical range for this well. No other indicator analytes were detected.
Basin F	
23187	Chloride concentrations show small (about 16%) decreasing trend. High concentrations are present. The other indicator analyte, dieldrin, was not detected.
23193	Well 23193 is damaged and cannot be sampled, but water level measurements are still possible.
26147	Chloride stable at elevated concentrations. The other indicator analyte, dieldrin, was not detected.
26150	Chloride decreased to lowest historical level of 81,400 µg/L in FY09, then increased to 137,000 µg/L in FY12, which is within typical historical ranges. The other indicator analyte, dieldrin, was not detected.
26152	Chloride showed a small decrease from FY09 to FY14; consistent with historical levels. The other indicator analyte, dieldrin, was not detected.
26153	Chloride concentrations are variable and generally below 1980s and 1990s levels. Increased from 113,000 µg/L in FY07 to 193,000 µg/L in FY12, and then decreased to lowest historical level of 3,320 µg/L in FY14. The FY14 value is questionable. The other indicator analyte, dieldrin, increased from FY12 to FY14.
Basin A	
35063	Chloride concentrations slightly decreased (about 15%) since FY09.
35067	Chloride concentrations on upward trend since 1989 with a 48% increase between FY04 and FY09. Chloride concentrations have remained stable near 490,000 µg/L from FY09 to FY14. Aquitard is questionable and well may be semi-confined.
35068	Chloride concentrations decreased from 80,800 µg/L in FY09 to 48,900 µg/L in FY14**.**
36113	Chloride concentrations are stable to slightly decreasing (about 5%) since FY09.
36114	Chloride concentrations indicate a small decreasing trend (about 11%) from FY09 to FY14 and close to historical high concentrations.
36159	Chloride concentrations decreased since FY09 (about 22%), but remain at high concentrations.
36171	Chloride concentrations increased from FY07 to FY09 about 69%, but then decreased approximately 41 % by FY14 and are still very low (21,400 µg/L).

Figure 5.1.3.2-2. Time Concentration Plot for Chloride in Basin A CFS Wells

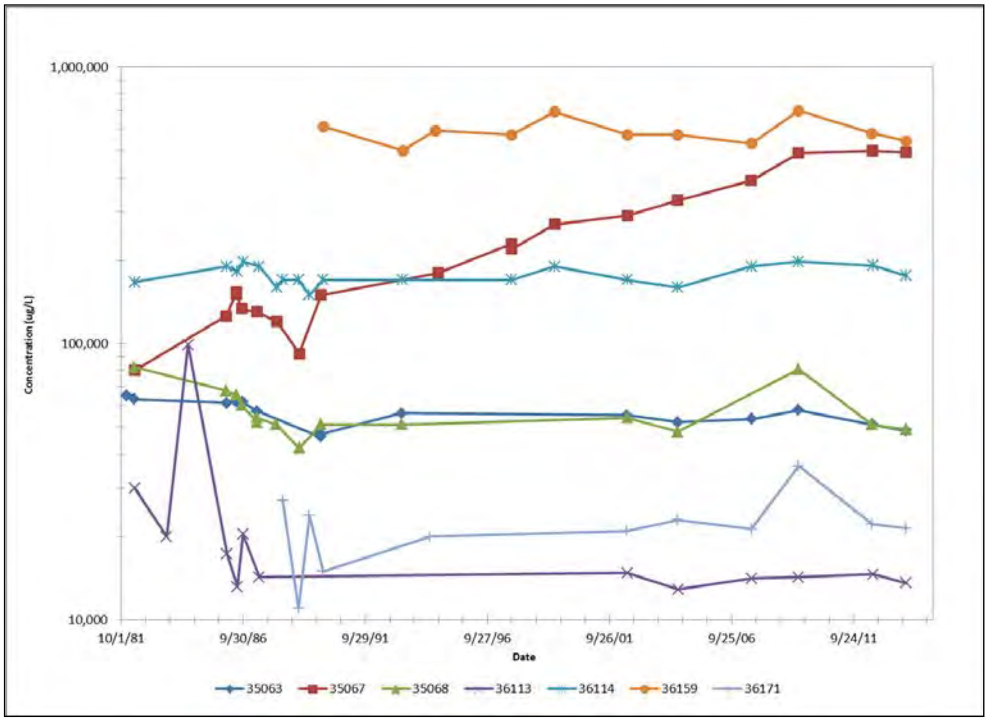


Figure 5.1.3.2-3. Time Concentration Plot for Chloride in Former Basin F CFS Wells

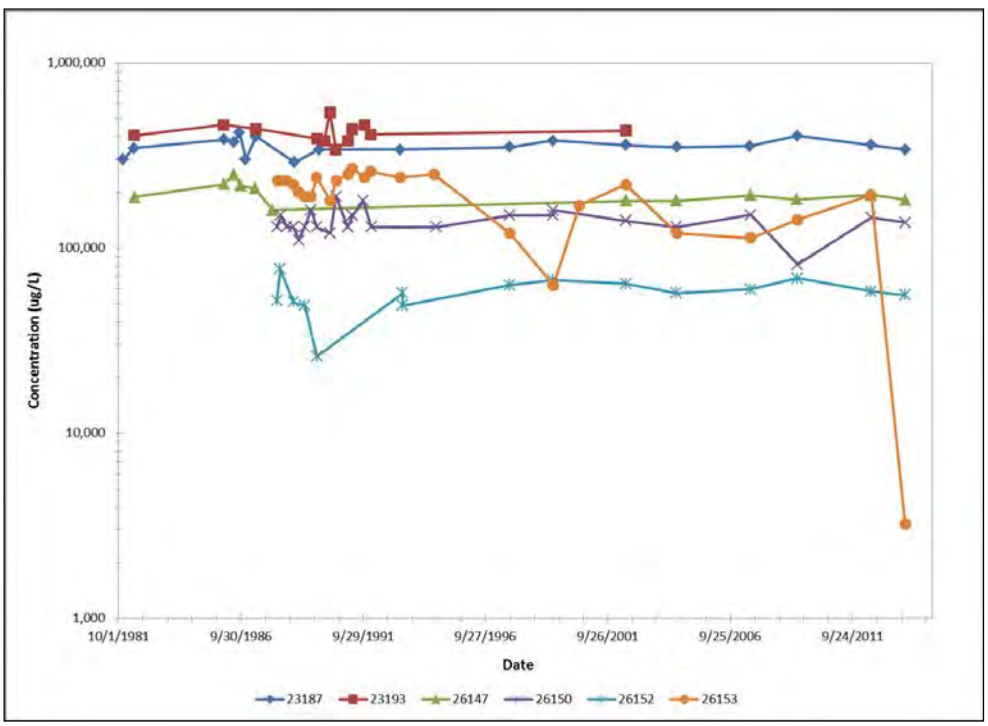
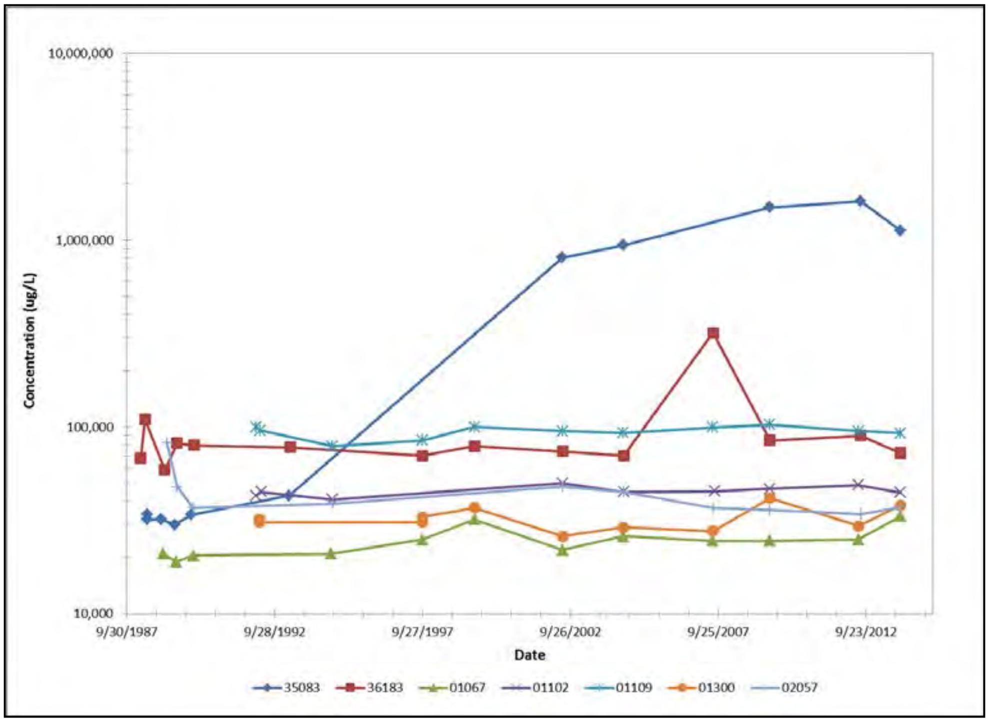


Figure 5.1.3.2-4. Time Concentration Plot for Chloride in South Plants CFS Wells



Well 35083 is screened in the Denver Formation 1U Sand/Lignite A, which underlies the A Sand. Well completion information for well 35083 indicates there is no bentonite well seal installed on top of the filter pack, and that fine sand was used to prevent grout from entering the filter pack and well screen. Groundwater with elevated concentrations of chloride may be migrating laterally from South Plants through Lignite A or the A Sand, and then "leaking" into well 35083 from above if the grout does not provide a seal of the annulus. On the other hand, the grout seal may be adequate since vertical migration from adjacent UFS well 35013 is not indicated. Since normal groundwater pH has been measured in well 35083 (7.57 in FY09 and 7.46 in FY12) deteriorating grout is unlikely as would be indicated by elevated pH measurements. Chloride concentrations lower than those measured in well 35083 were observed in FY14 in upgradient wells installed within the A Sand including 01067 and 01300 (33,400 and 38,100 µg/L, respectively).

Based on apparent vertical gradients and the distribution of chloride in corresponding UFS and CFS wells, downward migration of chloride is likely occurring in this area. Lateral migration may account for elevated chloride within the CFS in situations where the concentration of chloride in the overlying UFS is lower. Since mobile organic contaminants that are present in the overlying UFS were not detected in well 35083, downward migration must not be significant in the vicinity of the well. A combination of lateral and vertical migration may explain the observed historical increasing chloride trend in well 35083, which stabilized during the FYR reporting period. To help determine if there is lateral or vertical migration of chloride in the A Sand and

1U Sand, Army and Shell propose to add CFS wells 02047 and 02048 to the CFS network. They are located upgradient of well 35083 and are screened in the A Sand and 1U Sand, respectively.

Summary

During this FYR period, the vertical hydraulic gradients were downward in most UFS/CFS well pairs, with an upward gradient in one well pair in South Plants. The head differentials in the South Plants well pairs have decreased in response to soil cover completion. Organic indicator analytes were detected in three wells within the CFS (Table 5.1.3.2-2). As summarized below, increases in chloride concentrations within the CFS and the discrepancies between chloride concentrations detected in the CFS and UFS can be attributed to several conditions.

Low concentrations of 1,1-dichloroethane, chlorobenzene, and dieldrin were detected in CFS wells 01067, 02057, and 26153, respectively. These analytes are present in the overlying UFS. Two of the wells (01067 and 02057) have questionable aquitards and may be semi-confined. Dieldrin has been detected previously in well 26153 and the concentrations were within the historical range. Continued monitoring of these wells is planned.

Changes in chloride concentrations for wells 01067, 01300, 02057, and 26150 were within historical ranges for the wells.

Increases in chloride concentrations in well 35067 were evaluated along with the hydraulic properties of the UFS and CFS in that area. The results indicate that vertical migration of groundwater has been taking place in the vicinity of well 35067 for over 25 years and that communication between the two flow systems demonstrates that confined conditions do not locally exist within this zone in this area. The data indicate that confined conditions are present in adjacent CFS well 35068. Since the zone below the screened zone in well 35067 is monitored, and the chloride concentration in well 35067 may have stabilized, replacing well 35067 is not considered necessary.

Substantial levels of chloride concentrations in well 35083 were evaluated along with the hydraulic properties of the UFS and CFS in that area. It is likely that a combination of vertical and lateral migration of groundwater is taking place in the vicinity of well 35083. Adding CFS wells 02047 and 02048 to the CFS well network is proposed to evaluate chloride migration near well 35083.

If CFS well 23193 cannot be sampled because it is obstructed and cannot be repaired, adding CFS alternate well 23230 to the CFS network is proposed to replace well 23193.

5.1.3.3 On-Post Surface Water Monitoring

Surface water quality has been monitored by collecting and analyzing data from streams, ditches, lakes, and ponds at RMA since the late 1980s. This section summarizes the surface water data collected during the FYR period (FY09–FY14).

In 2001, the Surface Water Monitoring Program identified in the Surface Water SAP (FWENC 2001) was issued to ensure that the surface water monitoring requirements defined in the On-and Off-Post RODs were addressed. On-post COCs and monitoring objectives, sites, and frequencies were identified in the Surface Water SAP. Data quality objectives for evaluating the on-post and off-post data were also developed in the SAP.

The objective for the on-post Surface Water Monitoring Program identified in the Surface Water SAP is to ensure that there are no unacceptable effects on biota from surface water contamination. The decision rules in the Surface Water SAP are based on comparing the sampling results with concentrations that might cause acute or chronic effects. Accordingly, the water quality data are compared to the aquatic life-based acute and chronic standards in CWQCC Regulations No. 31 (5 Code of Colorado Regulations 1002-31) and No. 38 (5 Code of Colorado Regulations 1002-38).

Requirements for surface water monitoring in the On-Post ROD are discussed in Sections 1.3.2.2 and 2.4. In accordance with the On-Post ROD, monitoring of surface water occurred while remedial actions were being conducted. The effects of the remedy on human health and environment as assessed through monitoring of surface water during remedy implementation were evaluated in a previous report (URS 2013). This 2013 surface water monitoring report evaluated post-ROD on-post and off-post data and evaluated future data needs.

As reported in the 2013 Surface Water Quality Monitoring Report (FY1996 through 2011) for the Rocky Mountain Arsenal, the on-post surface water sampling program shows that very little contamination is present in the surface water bodies. There was only one detection of an organic analyte (dieldrin) in on-post surface water samples during the previous FYR period, which occurred in Upper Derby Lake (SW01004) in 2008. The concentration was below the aquatic life standards. Higher dissolved organic carbon (DOC)/total organic carbon (TOC) concentrations were observed in Havana Pond than in the lakes and First Creek, which is consistent with urban runoff. Arsenic was detected at low concentrations consistent with background levels. Selenium was the only inorganic analyte detected at concentrations above an aquatic life standard. The detections were intermittent, occurring in the two north boundary First Creek sites. Most of the detected concentrations above aquatic standards have been intermittent and occur in water flowing onto RMA at sites located at the south boundary. The U.S. Geological Survey (USGS) (2005) and URS (2013) reported that application of road deicers south of RMA appears to have short-term effects on the interceptors, Havana Pond and Upper Derby Lake. Increasing trends in chloride, sodium, and sulfate concentrations have been observed in the South Lakes and First Creek. Increasing concentrations of sulfate in First Creek likely are a result of three factors: urban runoff south of RMA, upstream development, and groundwater discharge into the creek

Long-term on-post surface water monitoring was conducted through the end of FY09. At the end of FY09, the soil contaminant remedy areas had clean backfill, sub-grade, and intermediate or final cover on the surface, thereby eliminating movement of contaminated soil to surface water. The 2010 LTMP addressed the off-post surface water monitoring program, which was revised in 2013 to incorporate the findings from the 2013 URS report. The off-post surface water monitoring for this FYR period is discussed in Section 5.2.4.

An on-post short-term surface water monitoring program was implemented in FY12 and continued in FY13 to confirm that surface water quality is not adversely impacted by cover soils during the establishment of cover vegetation and that groundwater plumes are not migrating into the lakes.

The on-post surface water sampling locations are shown on Figure 5.1.3.3-1 and include:

- Borrow Area 5 Pond Outlet (SW24005)
- Former Basin E Pond Outlet (SW26002)
- North Plants (SW25101)
- Lake Ladora (SW02020, SW02021, SW02009)
- Lower Derby Lake (SW01006)

One dry season (summer/fall 2012) and one wet season (spring 2013) sample were to be collected from each site. The analyte list for the sites includes the on-post surface water COCs (Foster Wheeler 2001), VOCs (for SW01006, SW02021, SW020009, and SW24005 only) and DIMP (for SW24005 only). Table 5.1.3.3-1 includes the analyte list and standards for the on-post surface water COCs. The data are reported in the ASRs for FY12 and FY13.

Summary of On-Post Surface Water Quality Monitoring Results

The lake sample concentrations were below the aquatic life standards and below the CBSGs/PQLs. Thus, these data indicate that runoff from exposed surface soil from the South Plants cover does not have the potential to impact surface water above acute or chronic aquatic life standards, and that South Plants groundwater plumes are not migrating into the lakes above CBSGs.

In FY12, the copper concentrations at lake sites SW01006, SW02020, and SW02021 exceeded both the calculated acute and chronic aquatic life standards, but these concentrations were suspect based on historical data (Army and Shell, 2013). When the lakes were sampled again in FY13, the copper concentrations at these sites were below the MRL of 10 µg/L, which is consistent with the historical data for the lakes. Thus, the FY12 detections were not confirmed and likely were erroneous.

The concentrations of a few inorganic analytes were above the aquatic life standards at two of the three cover locations (i.e., SW25101 and SW26002). The concentrations were below the aquatic life standards and off-post CSRGs/PQLs at the third soil cover site (SW24005).

Site SW25101 (North Plants) was sampled in 2013 during the September storm event, which was the only time it had sufficient water to sample. Only the copper concentration (17.3 µg/L) was above the calculated chronic standard of 12.4 µg/L. Aldrin and arsenic concentrations were slightly above the CSRG/PQL. Based on the topography and lack of surface water at this location (except during the September 2013 storm event) contaminants at this location do not have the potential to migrate to downstream receptors at concentrations above the aquatic life standards; or have the potential to migrate off-post and exceed the off-post remediation goals in off-post surface water.

Site SW26002 (Former Basin E Pond) was sampled in 2012 and 2013 (Table 5.1.3.3.-2) The copper, manganese, nickel, and zinc concentrations were above one or both calculated aquatic life standards in 2013, and were higher than in 2012. The 2013 arsenic concentration also was higher in 2013 than in 2012, and was 74.6 µg/L, which is below the aquatic life standards, but above the CSRG.

Table 5.1.3.3-2. SW26002 Concentrations above Aquatic Life Standards

SW26002	Concentrations, µg/L		FY13 Calculated Aquatic Life Standards	
Analyte	**FY12**	**FY13**	**Acute, µg/L**	**Chronic, µg/L**
Copper	LT 10	257	50	29
Manganese	57.1	6420	4738	2618
Nickel	LT 20	422	1513	168
Zinc	10	2170	565	428

Based on the topography, contaminants at this location do not have the potential to migrate to downstream receptors at concentrations above the aquatic life standards; or have the potential to migrate off-post and exceed the off-post remediation goals in off-post surface water.

The former Basin E RI/FS soil concentration data (for copper and zinc) and regional background soil concentration data (for manganese and nickel) indicate that the shallow surface soil concentrations are within background ranges and the surface water concentrations may be consistent with the background soil levels. Additional investigation is needed to determine whether the surface water concentrations are consistent with background soil levels.

Due to the lack of surface water at some of the sites during the FYR period, additional sampling will be conducted in 2015. As a follow-up action for the metals detections above aquatic life standards, metals will be added to the analyte list for the First Creek sites, which are part of the off-post surface water monitoring program. At the on-post sites, spring 2015 samples will be collected at site SW24005 and SW25101, if possible. A summer/fall 2015 sample will be collected at SW020009. For site SW26002, spring 2015 and summer/fall 2015 samples will be collected, if possible, to obtain more metals data for additional assessment of the site.

5.1.4 Post-Closure Groundwater Monitoring

Post-closure groundwater monitoring of the HWL, ELF, and Basin F were performed in accordance with the PCGMPs prepared for each of the sites (TtEC 2011c, TtEC 2010a, and TtEC 2011d, respectively). The results of these monitoring programs were documented in annual post-closure groundwater monitoring reports, which were distributed to the Regulatory Agencies as part of their respective Annual Covers Reports.

5.1.4.1 HWL Post-Closure Groundwater Monitoring Results

Closure groundwater monitoring of the HWL was initiated in October 2006, following the last waste load into the HWL and continued until May 2009. This section presents the results of the HWL post-closure groundwater monitoring program beginning in July 2009. The July 2009 sampling event is considered the first HWL post-closure monitoring event, based on final inspection of the HWL cap by the Regulatory Agencies.

HWL Water Level Monitoring

Water levels were measured in 64 wells quarterly to evaluate the UFS and confined flow system (CFS) flow conditions in the area of the CAMU and to identify any significant changes in flow direction in the area of the CAMU. Wells used in HWL post-closure groundwater monitoring are shown on Figure 5.1.4.1-1. Across the entire CAMU, groundwater flow is generally to the north and northwest. No significant variations in groundwater flow directions have been identified during post-closure monitoring. However, local variations in this trend occur, such as beneath the HWL area where groundwater flows to the north and northeast. With the exception for well 25194 discussed below, the overall groundwater flow direction is consistent with previous post-closure monitoring in the CAMU area.

The post-closure groundwater monitoring reports from 2011 and 2012 indicated that the water level data from well 25194 were considered unacceptable for use in contouring the UFS. Based on surrounding wells, water levels from well 25194 did not appear indicative of the actual water table elevation in the UFS because it appeared to be a perched zone. These reports stated that well 25194 would continue to be monitored as part of the downgradient HWL water-quality well network in accordance with the HWL Post-Closure Groundwater Monitoring Plan (TtEC 2011c).

However, while preparing the 2013 annual post-closure groundwater monitoring report, the site hydrogeology, water level, and water quality data for well 25194 (and its predecessor well 25094) were re-evaluated. Monitoring well 25094 was closed in 2008. Since 2008, water levels have risen in well 25194. The rise in water levels likely is in response to recharge from the grass-lined perimeter channel that runs along the west side of the HWL, and was constructed in 2008. The 2013 water elevation in well 25194 is similar to those in the upgradient wells located south of the HWL. Thus the water level data from well 25194 appeared to be representative of the UFS, but upgradient of the HWL rather than downgradient as previously assumed.

With inclusion of well 25194 in the UFS, a more pronounced groundwater high became evident along the west side of the HWL. This configuration of the water table is consistent with recharge from the perimeter ditch located along the west side of the HWL. This interpretation is further supported by the increasing trend in water elevations in monitoring wells 25027, 25194, and 25203 located along the west side of the HWL since 2008.

The Army prepared a Non-Routine Action Plan and an OCN that explain the revised interpretation of the data.

HWL Post-Closure Groundwater Quality

The HWL water quality network wells and SOM wells are shown on Figure 5.1.4.1-1. As noted in the HWL Post-Closure Groundwater Monitoring Plan (TtEC 2011c), wells 25086 and 25088 were installed dry. These two wells are sampled only if groundwater levels are within the well screen and adequate groundwater is available. Both wells were dry for all sampling events between 2009 and 2014. Groundwater samples collected from the HWL were submitted to Applied Research and Development Laboratory (ARDL) in Mount Vernon, Illinois for analysis. The samples were analyzed for 16 indicator compounds (ICs) each quarter, and for the full suite of analytes during the annual sampling event. The lists of ICs and full analyte suites are available in the HWL Post-Closure Groundwater Monitoring Plan.

Statistical Evaluation of 2009 Analytical Data

Prediction limits are statistical values used to compare the baseline or background concentrations to concentrations in the downgradient wells, and are used to evaluate potential impacts on the groundwater and effectiveness of the HWL remedy. Prediction limits were calculated from data collected during the HWL's preoperational, operational, and closure groundwater monitoring period for upgradient wells.

Post-closure HWL groundwater monitoring began in July 2009. The results from the water quality sampling completed during July and October 2009 were compared to the prediction limits calculated from the April 2009 sampling results. None of the downgradient HWL wells had reported values above the calculated prediction limits in the last two quarters of 2009. Consequently, there were no statistically significant increases in the indicator compounds (ICs) in the downgradient HWL monitoring wells.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure and post-closure O&M of the HWL.

Statistical Evaluation of 2010 Analytical Data

Prediction limits were calculated from data collected during the HWL's preoperational, operational, closure, and post-closure groundwater monitoring periods for upgradient wells.

The results from the water quality sampling completed during 2010 post-closure groundwater monitoring period were compared to the prediction limits calculated from the July and October 2009 sampling results. The ICs detected in downgradient HWL wells include lead, arsenic, and chromium. Lead was detected in wells 25085, 25087, 25183, and 25195 at concentrations ranging from 3.2 µg/L (July) in well 25183 to 11.2 µg/L (April) in well 25195, which were all below the prediction limit of 15 µg/L. Arsenic was detected in January at the MRL (1 µg/L) in well 25195, while the prediction limit was 3.4 µg/L. Chromium was detected in well 25195 at a concentration of 19.1 µg/L (January), which was also below the prediction limit of 21.2 µg/L. None of the downgradient HWL wells had reported values above the calculated prediction limits in 2010. Consequently, there were no statistically significant increases in the ICs in the downgradient HWL monitoring wells.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure and post-closure O&M of the HWL.

Statistical Evaluation of 2011 Analytical Data
Prediction limits were calculated from data collected during the HWL's preoperational, operational, closure, and post-closure groundwater monitoring periods for upgradient wells.

The results from the water quality sampling completed during 2011 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2010 sampling results. Based on the analytical results none of the downgradient HWL wells that were used in the statistical evaluation had reported values above the calculated prediction limits. The ICs detected in downgradient HWL wells include lead and dieldrin. Lead was detected in wells 25085, 25087, 25183, 25194, and 25195 at concentrations ranging from 3.5 μg/L (July) in well 25087 to 9.8 μg/L (July) in well 25194, which were below the prediction limit of 15 μg/L. Dieldrin was detected at 0.0269 μg/L (October) and 0.0368 μg/L (July) in well 25194, which was slightly above the prediction limit of 0.03 μg/L. However, due to the lack of baseline data, well 25194 data was used as an indicator of potential perched water contamination and not included in the prediction limit evaluation. As specified in the HWL Post-Closure Groundwater Monitoring Plan (TtEC 2011c, an intrawell comparison using combined Shewhart-CUSUM control charts may be used if any of the dry downgradient wells become saturated and are sampled. This approach was applicable to well 25194 because the previously dry well had become saturated and had been sampled. The EPA guidance documents (EPA 1989, EPA 1992) recommend collecting a minimum of eight baseline samples before constructing the control charts. The Army committed to creating the control charts once eight samples were collected and using them to identify immediate and gradual changes in IC concentrations.

Consequently, there were no statistically significant increases in concentrations of ICs in downgradient monitoring wells. Based on the statistical evaluation, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure, and post-closure of the landfill.

Statistical Evaluation of 2012 Analytical Data
Prediction limits were calculated from data collected during the HWL's preoperational, operational, closure, and post-closure groundwater monitoring periods for upgradient wells.

The ICs detected in downgradient HWL wells included lead, chloroform, and dieldrin. Lead was detected in wells 25085, 25087, 25183, 25194, and 25195 at concentrations ranging from 3.3 μg/L (October) in well 25195 to 7.1 μg/L (January) in well 25194, which were below the upper reporting limit of 15 μg/L. Chloroform was detected in well 25087 during the October 2012 sampling event at a concentration of 0.206 μg/L, which was below the upper reporting limit of 0.4 μg/L. Dieldrin was detected in well 25194 during all four sampling events at concentrations ranging from of 0.0128 μg/L (October) to 0.0231 μg/L (April), which were below the upper reporting limit of 0.03 μg/L. No ICs exceeded prediction limits in downgradient monitoring wells in 2012.

Based on the statistical evaluation, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure, and post-closure of the landfill.

In 2011 some reporting limits were changed as a result of a MRL study required by the CQAP (RVO 2009) for method recertification every three years. The MRLs that changed in 2011 affected all the OCPs and NDMA, but dieldrin was the only IC. The MRL for dieldrin changed from 0.03 µg/L in 2011 to 0.0066 µg/L in 2012. Samples collected in 2012 were analyzed using the new laboratory method and lower MRL, but were compared to prediction limits calculated with data from the older method and higher MRL. The Army committed to calculating new prediction limits when sufficient data were available in accordance with EPA guidance (EPA 1989, EPA 1992), which recommends using a minimum of eight data points.

Statistical Evaluation of 2013 Analytical Data
Prediction limits were calculated from data collected during the HWL's preoperational, operational, closure, and post-closure groundwater monitoring periods for upgradient wells.

The results from the water quality sampling completed during 2013 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2012 sampling results. Lead and dieldrin were the only ICs detected in downgradient wells. Lead was detected in wells 25085, 25087, 25183, 25194, and 25195 at concentrations ranging from 4.6 µg/L in well 25183 to 6.2 µg/L in well 25087. This range of values is below the upper prediction limit value of 15 µg/L. Dieldrin was detected in well 25194 at concentrations ranging from 0.0107µg/L to 0.0515 µg/L. The dieldrin values, with the exception of the value from well 25194 collected during the February 2013 sampling event (0.0515 µg/L), were below the 2013 upper prediction limit value of 0.03 µg/L. The Regulatory Agencies were notified of the dieldrin prediction limit exceedance in Non-Routine Action Plan (NRAP)-2014-006.

Based on this statistical evaluation, with the exception of the dieldrin concentration in 25194, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure and post-closure O&M of the HWL. The Army and Regulatory Agencies are using the consultative process to establish a process for determining the source of the dieldrin in well 25194. During a consultative meeting in August 2015 the Army committed to perform subsurface sampling near 25194 and to install another well downgradient of the HWL to supplement the downgradient well network. The goal is to identify the dieldrin source and to address the change in hydrology near well 25194. The sampling and well installation are planned for 2016.

Statistical Evaluation of 2014 Analytical Data
Prediction limits were calculated from data collected during the HWL's preoperational, operational, closure, and post-closure groundwater monitoring periods for upgradient wells.

The results from the water quality sampling completed during 2014 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2013 sampling results. Dieldrin and lead were the only ICs detected in the downgradient wells. Dieldrin was detected at a concentration of 0.0443 µg/L in well 25194. The dieldrin value exceeds the 2013 upper prediction limit value of 0.03 μg/L. Lead was detected in wells 25085, 25087, 25183, 25194, and 25195 at concentrations ranging from 4.5 μg/L in well 25183 to 6.5 μg/L in well 25194. The range of values in the downgradient wells was below the upper prediction limit value of 15 μg/L.

Based on this statistical evaluation, with the exception of the dieldrin concentration in 25194, the Army concluded that the groundwater quality around the HWL had not been affected by operations, closure and post-closure O&M of the HWL. The dieldrin detected in well 25194 may be pre-existing contamination related to Sand Creek Lateral and migration from the Basins C/F area. An investigation is planned to assess these potential sources, and a new downgradient well will be installed to address the change in hydrology near well 25194.

HWL Long-Term Lead Concentration Trends (Appendix E)

The historical concentration trend data are plotted for lead on page E-1 in Appendix E and show the upgradient and downgradient wells for the HWL. The upgradient and downgradient well concentrations are highly variable with intermittent detections, are generally similar, and below the upper prediction limit (UPL).

5.1.4.2 ELF Post-Closure Groundwater Monitoring Results

Preoperational groundwater monitoring for the ELF was completed in April 2006, followed by operational monitoring from April 2006 through July 2008. Closure monitoring was completed in the spring of 2010 and post-closure monitoring began in the summer of 2010. The July 2010 sampling event is considered the first ELF post-closure monitoring event, based on final inspection of the ELF cap by the Regulatory Agencies.

ELF Water Level Monitoring

Water levels were measured in 66 wells quarterly to evaluate the UFS and CFS flow conditions in the area of the CAMU and to identify any significant changes in flow direction in the area of the CAMU. Wells used in ELF post-closure groundwater monitoring are shown on Figure 5.1.4.2-1. Across the entire CAMU, groundwater flow is generally to the north and northwest. No significant variations in groundwater flow directions have been identified during post-closure monitoring.

ELF Post-Closure Groundwater Quality

The ELF water quality network wells are shown on Figure 5.4.1.2-1. Groundwater samples collected from the ELF were submitted to ARDL in Mount Vernon, Illinois for analysis. The samples were analyzed for 13 ICs each quarter, and the expanded analyte suite of 70 compounds annually. The lists of ICs and full analyte suites are available in the ELF Post-Closure Groundwater Monitoring Plan (TtEC 2010a).

Statistical Evaluation of 2010 Analytical Data

Prediction limits were calculated from data collected during the ELF's preoperational, operational, and closure groundwater monitoring period for upgradient wells.

Post-closure ELF groundwater monitoring began in July 2010. The results from the water quality sampling completed during the July and October 2010 post-closure monitoring were compared to the prediction limits calculated for the ELF from the 2009-2010 sampling results. Lead was the only IC detected in a downgradient well (25093) at a concentration of 3.3 µg/L (July), which was below the upper prediction limit value of 26.3 µg/L. Historically, lead was detected in downgradient wells prior to waste being placed in the ELF (April 2006). There were no statistically significant increases in the ICs in the downgradient ELF monitoring wells.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the ELF had not been affected by operations, closure and post-closure O&M of the ELF.

Statistical Evaluation of 2011 Analytical Data

Prediction limits were calculated from data collected during the ELF's preoperational, operational, closure, and post-closure groundwater monitoring period for upgradient wells.

The results from the water quality sampling completed during 2011 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2010 sampling results. Lead was detected in wells 25092, 25093, 25102, 25120, and 26099 at concentrations ranging from 3.1 µg/L in well 25093 (July) to 8.2 µg/L in well 26099 (October), which were below the upper prediction limit value of 26.3 µg/L. DIMP was detected in well 25093 at concentration of 6.28 µg/L (July), with the corresponding duplicate concentration LT 0.5 µg/L. Detection of DIMP was above the calculated prediction limit of 0.5 µg/L. Statistically, the concentration for DIMP at 6.28 µg/L was considered an outlier and not representative of the data set.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the ELF had not been affected by operations, closure and post-closure O&M of the ELF.

Statistical Evaluation of 2012 Analytical Data

Prediction limits were calculated from data collected during the ELF's preoperational, operational, closure, and post-closure groundwater monitoring period for upgradient wells.

The results from the water quality sampling completed during 2012 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2011 sampling results. Lead was the only IC detected in downgradient wells. Lead was detected in wells 25092, 25093, 25102, 25120, and 26099 at concentrations ranging from 6 µg/L in well 25092 (January) to 8.8 µg/L in well 26099 (January), which were below the upper prediction limit value of 26.3 µg/L. Historically, lead was detected in downgradient wells prior to waste being placed in the ELF (April 2006). No ICs exceeded prediction limits in downgradient monitoring wells in 2012.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the ELF had not been affected by operations, closure and post-closure O&M of the ELF.

In 2011 some reporting limits were changed as a result of a MRL study required by the CQAP (RVO 2009) for method recertification every three years. The MRLs that changed in 2011 affected all the OCPs and NDMA, but dieldrin was the only IC. The MRL for dieldrin changed from 0.03 µg/L in 2011 to 0.0066 µg/L in 2012. Samples collected in 2012 were analyzed using the new laboratory method and lower MRL, but were compared to prediction limits calculated with data from the older method and higher MRL. The Army committed to calculating new prediction limits when sufficient data were available in accordance with EPA guidance (EPA 1989, EPA 1992), which recommends using a minimum of eight data points.

Statistical Evaluation of 2013 Analytical Data

Prediction limits were calculated from data collected during the ELF's preoperational, operational, closure, and post-closure groundwater monitoring period for upgradient wells.

The results from the water quality sampling completed during 2013 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2012 sampling results. Lead was the only IC detected (October 2013 event only) in downgradient wells. Lead was detected in wells 25092, 25093, 25102, 25120, and 26099 at concentrations ranging from 3.0 µg/L in well 25102 to 7.5 µg/L in well 25120. This range of values was below the upper prediction limit value of 26.3 µg/L. Historically, lead was detected in downgradient wells prior to waste being placed in the ELF (April 2006). No ICs exceeded prediction limits in downgradient monitoring wells in 2013.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the ELF had not been affected by operations, closure and post-closure O&M of the ELF.

Statistical Evaluation of 2014 Analytical Data

Prediction limits were calculated from data collected during the ELF's preoperational, operational, closure, and post-closure groundwater monitoring period for upgradient wells.

The results from the water quality sampling completed during 2014 post-closure groundwater monitoring period were compared to the prediction limits calculated from the 2013 sampling results. Lead was the only IC detected (January and April 2014 events) in the downgradient wells. Lead was detected in wells 25092, 25093, 25102, 25120, and 26099 at concentrations ranging from 3.3 µg/L in well 25093 to 6.8 µg/L in well 25120. The range of values is below the upper prediction limit value of 26.3 µg/L. Historically, lead was detected in downgradient wells prior to waste being placed in the ELF (April 2006). No ICs exceeded prediction limits in downgradient monitoring wells in 2014.

Based on this statistical evaluation, the Army concluded that the groundwater quality around the ELF had not been affected by operations, closure and post-closure O&M of the ELF.

ELF Long-Term Lead Concentration Trends (Appendix E)

The historical concentration trend data are plotted for lead on page E-1 in Appendix E and show the upgradient and downgradient wells for the ELF. The upgradient and downgradient well concentrations are highly variable with intermittent detections, are generally similar, and below the UPL.

5.1.4.3 Basin F Post-Closure Groundwater Monitoring Results

The Basin F Post-Closure Groundwater Monitoring program is intended to demonstrate that post-closure care of the Basin F Surface Impoundment and the Basin F Wastepile satisfy RCRA closure performance standards, which includes the requirement to control, minimize or eliminate post-closure escape of hazardous contaminants to groundwater (6 Code of Colorado Regulations 1007-3, Section 265, Subpart G).

The annual post-closure groundwater sampling for Basin F began in October 2010 and was moved to April of each year beginning in 2011. Water levels were collected from a network of 27 groundwater monitoring wells, while groundwater samples were collected from nine wells in the Basin F Wastepile (WP) and Principal Threat (PT) well networks as shown on Figure 5.1.4.3-1.

Basin F Water Level Monitoring

Water levels were measured annually in 27 Basin F network wells to evaluate UFS conditions in the area of Basin F. This information is used to evaluate groundwater flow for significant changes in flow direction over time. Wells used in Basin F post-closure groundwater monitoring are shown on Figure 5.1.4.3-1. The flow direction and groundwater elevations in the UFS are consistent with historical flow and elevations. Groundwater flow in the vicinity of Basin F continues to be to the north and northeast. Local variations occur beneath the east and west sides of Basin F where groundwater flows to the northeast and west, respectively. Between 2006 and 2014, water levels in downgradient wells 26015, 26017, 26157, and 26163 and upgradient wells 26028, and 26073 have shown only minor fluctuations due to seasonal or storm events. Since 2006, water levels have increased slightly in upgradient wells 26028 and 26128, and downgradient wells 26133 and 26173. The CFS in the Basin F area is addressed as part of the Long-Term Monitoring Plan (TtEC and URS 2010).

Basin F Post-Closure Groundwater Quality

In 2006, the Basin F water quality well network was divided into a Basin F WP component (wells 26015, 26017, 26028) and Basin F PT component (wells 26015, 26073, 26128, 26133, 26157, 26163, and 26173) based on a well's location relative to a contaminant source and its corresponding groundwater flow path. Downgradient well 26015 is included in both groups due to overlapping groundwater flow paths.

Since pre-existing groundwater contamination is present under Basin F, baseline sample results from both upgradient and downgradient wells adjacent to Basin F were used to calculate prediction limits. Prediction limits are statistical values used to compare the baseline or background concentrations to concentrations in the downgradient wells, and are used to evaluate potential impacts on the groundwater and effectiveness of the Basin F remedy. Eleven indicator analytes were selected for Basin F to establish baseline contaminant trends and calculate prediction limits.

The analytical results for the indicator analytes were evaluated from samples collected from the start of post-closure monitoring in October 2010 and continued with each annual sampling event through April 2014.

Statistical Evaluation of 2010 Analytical Data
Prediction limits for the eleven indicator analytes were calculated using the baseline groundwater monitoring data (2006) and groundwater data from 2007-2009 for upgradient wells (26028, 26073, and 26128). The sample results for downgradient wells in 2010 were compared to prediction limits calculated from the 2009 sampling event. Prediction limits were calculated based on the certified MRL applicable at the time. The October 2010 Basin F prediction limit exceedances are presented in Table 5.1.4.3-1.

Table 5.1.4.3-1. 2010 Basin F Prediction Limit Exceedances

Well	Well Network	Analyte	2010 Concentration (µg/L)	Upper Prediction Limit Value (µg/L)
26015	WP/PT	Sulfate	675,000	651,521
26017	WP	Chloroform	0.375	0.2
26017	WP	Tetrachloroethylene	0.549	0.283
26163	PT	NDMA	1.54	1.24
26163	PT	Sulfate	4,040,000	2,610,000
26173	PT	Tetrachloroethylene	408	321

The concentrations above the prediction limits were within the historical ranges for the respective wells. The increase in contaminant concentrations in downgradient wells was attributed to rising water levels, ponding of water in below grade excavations in the vicinity of wells 26015 and 26163 during key-cut excavation around the perimeter of Basin F, or the slow vertical migration of contaminants through the vadose zone when PT soil was excavated and the soil exposed to surface water infiltration. No other downgradient Basin F wells reported values above the calculated prediction limits. Based on the statistical evaluation the Army concluded that groundwater quality downgradient of Basin F was not significantly affected. Additional information regarding the post-closure groundwater monitoring of Basin F is available in the Basin F Post-Closure Groundwater Monitoring Report 2010-2011 (TtEC 2011j).

Statistical Evaluation of 2011 Analytical Data
The 2011 sampling event occurred in April and May of 2011, only six months after the 2010 event. Thus the prediction limits were not updated for 2011 and the 2009 prediction limits were used during the 2011 statistical evaluation. The April/May 2011 Basin F prediction limit exceedances are presented in Table 5.1.4.3-2.

Table 5.1.4.3-2. 2011 Basin F Prediction Limit Exceedances

Well	Well Network	Analyte	2011 Concentration (µg/L)	Upper Prediction Limit Value (µg/L)
26015	WP/PT	Chloroform	0.343	0.2
26015	WP/PT	Copper	12.3	10
26017	WP	Chloroform	0.294	0.2
26163	PT	NDMA	1.25	1.24
26163	PT	DIMP	999	762.8
26163	PT	Copper	16.1	10
26173	PT	Tetrachloroethylene	482	321

These concentrations above the prediction limits were within the historical ranges for the respective wells. The increase in contaminant concentrations in downgradient wells was attributed to rising water levels, ponding of water in below grade excavations in the vicinity of wells 26015 and 26163 during key-cut excavation around the perimeter of Basin F, or the slow vertical migration of contaminants through the vadose zone when PT soil was excavated and the soil exposed to surface water infiltration. No other downgradient Basin F wells reported values above the calculated prediction limits. Based on the statistical evaluation the Army concluded that groundwater quality downgradient of Basin F was not significantly affected. Additional information regarding the post-closure groundwater monitoring of Basin F is available in the Basin F Post-Closure Groundwater Monitoring Report 2010-2011 (TtEC 2011j).

Statistical Evaluation of 2012 Analytical Data
The prediction limits for the eleven indicator analytes were calculated using the baseline groundwater monitoring data (2006) and groundwater data from 2007-2011 for the upgradient wells. The water quality sample results for downgradient wells in 2012 were compared to prediction limits calculated from the 2010/2011 Basin F sampling events. Prediction limits were recalculated based on the most current certified MRL. The 2012 Basin F prediction limit exceedances are presented in Table 5.4.1.3-3.

Table 5.1.4.3-3 2012 Basin F Prediction Limit Exceedances

Well	Well Network	Analyte	2012 Concentration (µg/L)	Upper Prediction Limit Value (µg/L)
26017	WP	Chloroform	0.265	0.2
26173	PT	Tetrachloroethylene	556	321

Concentrations for most indicator analytes during post-closure monitoring have decreased compared to baseline closure monitoring. Increase in contaminant concentrations or high concentrations in downgradient wells, may have been the result of residual contamination that is present in the saturated zone and also may be continuing to migrate from the vadose zone to the saturated zone. Ponding of water in below grade excavations during key-cut excavation around the perimeter of Basin F may have mobilized additional contamination to the groundwater. Consequently, the post-closure concentrations were compared to the historical concentration ranges for the wells. Contaminants occurring in the Basin F pathway occur primarily in alluvial-filled paleochannels and in weathered bedrock, affecting migration pathways and travel times from WP and PT sites to downgradient wells. These likely would be short-term increases.

Based on the concentration of analytes for chloroform and tetrachloroethylene above their prediction limits, the PCP statistical protocol indicates that contaminants associated with Basin F WP and PT potentially have impacted groundwater quality. However, since the 2012 chloroform and tetrachloroethylene concentrations are within the historical ranges for the affected wells, the exceedances likely are caused by residual contamination and are consistent with pre-existing contamination that was present before the Basin F post-closure period. Based on the statistical evaluation and historical data the Army concluded that groundwater quality downgradient of Basin F was not significantly affected. Additional information regarding the post-closure groundwater monitoring of Basin F is available in the Basin F Post-Closure Groundwater Monitoring Report 2012 (TtEC 2012b).

Statistical Evaluation of 2013 Analytical Data
The prediction limits for the eleven indicator analytes were calculated using the baseline groundwater monitoring data (2006) and groundwater data from 2007-2012 for upgradient well 26028. The water quality sample results for downgradient wells in 2013 were compared to prediction limits calculated from the 2010 through 2012 Basin F sampling events.

No downgradient Basin F WP or PT wells reported values above the calculated prediction limits. The Army concluded, based on the statistical evaluation, that groundwater quality downgradient of the Basin F had not been significantly affected.

Statistical Evaluation of 2014 Analytical Data
The prediction limits for the eleven indicator analytes were calculated for the WP wells using the baseline groundwater monitoring data (2006) from upgradient well 26028 and downgradient wells 26015 and 26017 and groundwater data from 2007-2013 for upgradient well 26028. The water quality sample results for downgradient wells in 2014 were compared to prediction limits calculated from the 2010 through 2013 Basin F WP sampling events. The Basin F WP prediction limits were applied to downgradient wells 26015 and 26017.

Likewise the prediction limits for PT wells were calculated using baseline groundwater monitoring data from 2007-2013 for the upgradient Basin F PT wells 26073 and 26128 and 2007 baseline data from the downgradient wells 26015, 26163, and 26173. The 2014 prediction limits calculated for the eleven indicator analytes provide a baseline upper concentration limit that have been compared to indicator analyte concentrations in groundwater collected during the 2010 through 2013 Basin F PT sampling events from downgradient monitoring wells 26015, 26163, and 26173. The 2014 Basin F prediction limit exceedances are presented in Table 5.1.4.3-4.

Table 5.1.4.3-4 2014 Basin F Prediction Limit Exceedances

Well	Well Network	Analyte	2014 Concentration (µg/L)	Upper Prediction Limit Value (µg/L)
26015	WP/PT	Chloroform	0.277	0.2
26163	PT	Copper	28.5	21
26163	PT	DCPD	51.7	51.2
26163	PT	DIMP	769	762.8
26173	PT	Tetrachloroethylene	496	321

The remaining reported values from the downgradient Basin F WP and PT wells were below the respective prediction limits. The 2014 chloroform concentration in well 26015 was within the historical range of chloroform values for the well. The 2014 DCPD and DIMP concentrations in well 26163 and the tetrachloroethylene concentration in well 26173 were also within the respective historical range of values for each well. The copper concentration is slightly above the historic range of values for well 26163, but lower than the historical ranges for upgradient well 26128 (50.1 µg/ /L in 1986) and downgradient wells 26015 (34 µg//L in 1998) and 26157 (127 µg/ /L in 1999). A conclusion could be made based on the statistical evaluation that groundwater quality downgradient of the Basin F PT area was potentially affected in the vicinity of well 26163. However, since the 2014 copper concentration is within the historical range of the pre-existing Basin F contamination, it likely represents residual contamination that does not reflect on the effectiveness of the remedy. A conclusion can be made from the statistical evaluation that groundwater quality downgradient of the Basin F WP has not been significantly affected.

<u>Basin F Long-Term Concentration Trends (Appendix E)</u>

Groundwater quality downgradient of the former Basin F is evaluated by comparing indicator compound concentrations in samples collected from upgradient monitoring wells with concentrations in samples collected from downgradient monitoring wells. The statistical comparison and trend analyses results provide quantitative evidence regarding the potential impact of the former Basin F on groundwater. Comparisons with historical data are sometimes used to qualitatively evaluate potential short-term increases in concentrations caused by mobilization of contaminants during intrusive activities associated with remedy implementation and pre-existing residual contamination that may have been mobilized by fluctuating water levels. The historical concentration trend data are plotted for selected analytes in Appendix E and show the upgradient and downgradient wells for the Basin F Wastepile wells and the Principal Threat (PT) wells. The analytes evaluated include chloroform, dieldrin, DIMP, and tetrachloroethylene.

- Wastepile

  Chloroform (page E-2) was not detected in upgradient well 26028 and shows decreasing concentrations overall in the downgradient wells, with current concentrations well below the CBSG of 6 µg/L. The dieldrin concentrations (page E-2) have been similar in the upgradient and downgradient wells and been more stable overall, which is expected because of its less soluble and more sorptive nature. The more recent dieldrin concentrations have decreased in the upgradient and downgradient wells, however, and been below the UPL. DIMP concentrations (page E-3) have increased in upgradient well 26028 and decreased dramatically in the downgradient wells and are below the UPL and below the CBSG of 8 µg/L. Tetrachloroethylene (page E-3) was not detected in the upgradient well and shows decreasing concentrations overall in the downgradient wells, with current concentrations well below the UPL and CBSG of 5 µg/L.

- Principal Threat

The chloroform concentrations (page E-4) have been relatively stable in upgradient well 26073 and decreased overall in the downgradient wells, with current concentrations below the UPL. The recent upgradient and downgradient well concentrations of chloroform are relatively similar. Downgradient wells 26133 and 26157, which are unconfined Denver wells located farther downgradient form Basin F, have shown dramatic chloroform concentration decreases. The dieldrin concentrations (page E-4) have been similar in the upgradient and downgradient wells and been more stable overall, which is expected because of its less soluble and more sorptive nature. DIMP concentrations (page E-5) have decreased overall in the upgradient and downgradient wells and are near or below the UPL. Tetrachloroethylene concentrations (page E-5) have decreased overall in the upgradient and most of the downgradient wells. Downgradient well 26173 has shown a recent increasing trend above the UPL, possibly because of rising water levels.

5.1.5 Other On-Post Groundwater Monitoring

5.1.5.1 2014 On-Post Plume Mapping

On-post plume-extent sampling was conducted in 2014 for nine indicator analytes, which included DIMP, dieldrin, chloroform, benzene, NDMA, carbon tetrachloride, dithiane, arsenic, and DBCP. After the 2014 water quality results were obtained and evaluated, fourteen wells were selected to provide additional data, and were sampled in 2015. These additional data were included in the maps. The last on-post plume mapping at RMA was conducted in 1994, and was intended to show the pre-ROD groundwater contaminant distributions. The 2014 maps are compared to the 1994 maps both qualitatively and quantitatively to show whether there have been changes in the plumes since the On-post ROD was issued in 1996.

Interpretation

The 2014 on-post plume maps are discussed for each indicator analyte. The contour intervals were selected to be similar to the 1994 plume maps. The 1994 plume extent for each analyte, based on the 1994 MRL, is shown on the 2014 maps for comparison. Fewer wells were sampled in 2014/2015 than in 1993/1994. Consequently, available data, both historical and current, were considered in constructing the 2014 plumes. For example, to better relate the downgradient plumes to sources, the 1994 concentration data were re-examined in many areas. Recent and historical project-specific monitoring data were also considered in mapping the 2014 plumes (e.g., CADT IRA, Shell Disposal Trenches IRA, STF IRA, GWMR Project in STF and Lime Basins, LWTS, Basin F, HWL, and ELF). Additionally, the historical concentration trends in individual wells between 1994 and 2014 were considered in the plume interpretations. In the CADT and Shell Disposal Trenches source areas, limited or no new data are available. Consequently, the historical data were used in an attempt to depict the current groundwater contamination in a realistic manner. Since these sites are contained by slurry walls, little change in the contaminant concentrations was assumed unless indicated otherwise by new data.

Comparison of the 1994 and 2014 plumes is complicated in some areas because of a variety of factors which include: 1) lower 2014 MRLs than in 1994; 2) new well networks in some project areas that did not exist in 1994; and 3) the downgradient plumes were related to known sources in more detail for the 2014 plumes than in 1994. For example, isolated contaminant detections were shown for many wells in the 1994 maps that are in known migration pathways. Where appropriate, plumes are shown in these areas in the 2014 maps instead of isolated well detections.

To aid the 1994/2014 comparison, the 1994 and 2014 concentrations in key wells for each analyte are tabulated to show temporal changes. The key wells chosen include wells in or near source areas and downgradient of sources. To quantify the overall changes in concentrations for each analyte between 1994 and 2014, the average concentration for the wells sampled in 1993/1994 and 2014/2015 was calculated; both for all the wells sampled for each analyte, and for the subset of wells that had detections in 1994. Additionally, the on-post plume areas above CSRGs/PQLs in 1994 and 2014 were calculated for each analyte. The plume area calculations are not strictly comparable because more wells were used in the 1994 plume mapping than were used in the 2014 plume mapping. To attempt to compensate for this difference, considerable effort was placed in re-examining the 1994 data and using historical and current data to augment the 2014 plume interpretations. In 1994, numerous isolated detections were plotted instead of drawing plumes in known migration pathways. Thus, although the 2014 plume interpretations were based on fewer wells than in 1994, the 2014 plumes reflect a more realistic depiction and likely is more conservative than the 1994 depiction. Thus, the decreases in the plume extents in 2014 likely are greater than indicated. The changes in the mapped areas are discussed for each analyte and included in Table 5.1.5.1-10 at the end of this section.

It should be noted that comparing site-wide average concentrations may be less useful than individual well concentration comparisons because the project was not designed to provide the density of data necessary to estimate site-wide concentration changes. However, selecting wells sampled in 1994 was one of the criteria for selecting wells for the 2014 network. Since the averages only pertain to the subset of wells sampled in both monitoring events, the average concentration data are useful for comparison.

Diisopropylmethyl phosphonate (DIMP)

The DIMP MRLs were similar (i.e., 0.218 - 2 µg/L in 1994 and 0.5 µg/L in 2014). Figure 5.1.5.1-1 is the 2014 DIMP plume map. The major DIMP sources include former Basins A, C, and F, CADT, and North Plants. DIMP is a mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. Areas where changes in the DIMP plume interpretation are affected by changes in the well network after 1994 include the area between the CADT and HWL, with post-1994 project wells installed in the Bedrock Ridge, HWL, and ELF areas.

Decreases in the DIMP plume extent and concentrations between 1994 and 2014 occurred in South Plants, South Lakes area, former Basins A and F, north of former Basin F, downgradient of BANS, downgradient of BRES, downgradient of North Plants, upgradient of the NWBCS, and upgradient of NBCS. DIMP concentrations in the former Basin A and CADT areas are lower due to mass extraction and mass removal by the CADT and BANS dewatering systems and treatment at BANS. Significant DIMP mass is contained by the CADT slurry wall/dewatering system. The areas where DIMP concentrations are still above the CSRG of 8 µg/L have decreased dramatically in the former Basins C and F areas, and north of former Basin F.

The additional project-specific and site-wide monitoring data created a better understanding of DIMP plume migration in the Bedrock Ridge/North Plants/HWL areas. It appears that the Bedrock Ridge plume migrates to the west of the North Plants plume and migrates under the northeast corner of the HWL. Figure 5.1.5.1-1 shows that operation of the BRES has cut off the DIMP plume concentrations above the CBSG/CSRG of 8 µg/L between the BRES and North Plants. For the first time, the DIMP concentrations in all the BRES downgradient performance wells were below 8 µg/L in 2014.

Site wide, the average of the DIMP concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 1,116 µg/L to 387 µg/L, which is a 65 percent decrease. For the subset of wells with detections in 1993/1994, the average DIMP concentration decreased from 1,640 µg/L to 569 µg/L, also a 65 percent decrease. The DIMP plume area above the CSRG of 8 µg/L decreased from 1,179 acres in 1994 to 560 acres in 2014, which is a 53 percent decrease.

With decreases in the DIMP concentrations upgradient of the treatment systems, the treatment plant influent concentrations have decreased at BANS, NWBCS, and NBCS. BANS treats flows from different extraction/dewatering systems, but for the plume mapping evaluation, concentrations in the BANS-specific influent or BANS dewatering-well flows are compared. The average DIMP concentrations in the BANS influent decreased from 980 µg/L in 1994 to in 25.6 µg/L in 2014. DIMP was not detected in the NWBCS influent in either time period. The average DIMP concentrations in the NBCS influent decreased from 95 µg/L in 1994 to 3.1 µg/L in 2014.

Table 5.1.5.1-1 shows the DIMP concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the covers were constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-1. DIMP Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
Basin A		
35065	820	13
36108/36630	25,000	8,760
36177/36632	11,000	7,790
36538	46,000	18,300
36599/36633	1,300	156
BANS Downgradient		
26006	830	13.2
27025	6.67	1.51
CADT/Downgradient		
36189	5,000	468
36594	770	24
Basin F/Downgradient		
23096	170	11
23142	410	4.4
23231/23160	1,300	2.1
24201	760	2.8
26157	2,500	49.9
26163	1,800	769
North Plants		
25054	110	12

Dieldrin

The dieldrin MRLs were lower by an order of magnitude in 2014 (i.e., 0.05 µg/L in 1994 and 0.00361 to 0.0066 µg/L in 2014). Figure 5.1.5.1-2 is the 2014 dieldrin plume map. The major dieldrin sources include South Plants, former Basins A, C, and F, Shell Disposal Trenches, and Sand Creek Lateral. Dieldrin has low solubility and high partition coefficients such that it is more persistent in groundwater than other RMA analytes. Thus, decreases in the plume extent and concentrations due to remedy implementation are expected to be less significant than for other analytes. Areas where changes in the dieldrin plume interpretation are affected by changes in the well network after 1994 include the area south and west of the HWL and ELF, with post-1994 project wells installed in the LWTS, HWL, and ELF areas.

With the lower MRL in 2014 and interpretation differences, the dieldrin plume extent appears larger than in 1994 in several areas. These areas include South Plants, South Lakes, CADT, between former Basin A and Basin F, downgradient of Sand Creek Lateral in Sections 2, 35, 26, and 25, and upgradient of the east portion of the NBCS. In the South Lakes area, the dieldrin plume migrates under Lake Ladora in two areas that appear to have Sand Creek Lateral sources on the north and east side of the lake. This plume migrates to the NWBCS Southwest Extension, where it is captured and treated. Sand Creek Lateral is the likely source of the some of the dieldrin plumes in Sections 2, 35, 26, and 25.

The additional site-wide monitoring data created a better understanding of dieldrin plume migration between former Basins A and F. Although the alluvium is unsaturated, the dieldrin plume appears to have migrated through the subcropping A Sandstone in the Denver Formation bedrock at the north end of Basin A. This migration pathway explains the dieldrin detections in wells located south of the ELF and east of former Basins C and F. At the request of the Regulatory Agencies, additional evaluation of this migration pathway is provided in Appendix F. The resulting conclusions and recommendations are provided below.

In developing the remedy for RMA, Basin A was determined to be a natural groundwater containment feature, with the only known outlets for contaminated groundwater flow assumed to be toward BANS and BRES. A third outlet for contaminated groundwater north of former Basin A is interpreted to exist that is not intercepted by BANS or BRES.

Dieldrin has been detected historically upgradient of former Basins C and F and can now be attributed to the north Basin A pathway. The north Basin A dieldrin plume intersects the Basins C /F plume and is intercepted and treated to meet remediation goals at the NBCS.

Dieldrin has been detected historically in wells 25022 and 25106, which are located north of former Basin A and upgradient of the ELF. The presence of dieldrin in wells upgradient of the ELF affects the ELF groundwater monitoring program, but is addressed by the upper prediction limit statistical evaluation of the ELF groundwater data, and does not significantly hinder the landfill performance evaluations.

The dieldrin mass flux in the north Basin A pathway is estimated to be extremely low (0.000059 lb/year) and the contaminant migration does not affect remedy protectiveness. Therefore, in Army and Shell's opinion, additional remedial action for the north Basin A pathway is not warranted.

Future monitoring of this migration pathway is appropriate, however. Wells 25022 and 25106, which are located upgradient of the ELF, are sampled under the ELF Post-Closure Plan (PCP). Monitoring of wells 25004 and 36112, which are screened in the A Sandstone and located upgradient of wells 25022 and 25106, is proposed and would be conducted under the LTMP Water Quality Tracking category (twice in five-year frequency) to obtain additional groundwater quality data for this recently identified migration pathway. Water levels are already monitored for these wells under the LTMP and ELF PCP. If this proposal is acceptable to the Regulatory Agencies, an OCN will be issued to amend the LTMP.

Areas where dieldrin concentrations are lower in 2014 than in 1994 include portions of former Basins A, former Basin F, north of former Basin F, downgradient of BANS, and some of the NWBCS plume wells.

Site wide, the average of the dieldrin concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 0.625 µg/L to 0.323 µg/L, which is a 48 percent decrease. For the subset of wells with detections in 1993/1994, the average DIMP concentration decreased from 1.08 µg/L to 0.51 µg/L, which is a 53 percent decrease. The dieldrin plume area above the PQLs of 0.05 µg/L and 0.013 µg/L increased from 1,902 acres in 1994 to 2,804 acres in 2014, which is a 47 percent increase. The lower PQL in 2014 caused the mapped plume area to be larger in areas where the concentrations were below the former PQL. Well network and interpretational differences between 1994 and 2014 also caused the mapped plume area to be larger in 2014. Comparing the plume areas based on the former PQL probably is more meaningful, and the dieldrin plume area above the PQL of 0.05 µg/L decreased from 1,902 acres in 1994 to 1,606 acres in 2014, which is a 16 percent decrease.

With decreases in the dieldrin concentrations upgradient of the NBCS, the NBCS treatment plant influent concentration decreased from 0.513 µg/L in 1994 to in 0.328 µg/L in 2014. The BANS treatment plant configuration has changed, so the comparison may be less meaningful than for the other system, but the average dieldrin concentration in the BANS influent increased from 0.318 µg/L in 1994 to 0.385 µg/L in 2014. The average dieldrin concentration in the NWBCS influent has been relatively stable at 0.243 µg/L in 1994 and 0.23 µg/L in 2014.

Table 5.1.5.1-2 shows the dieldrin concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated.

Table 5.1.5.1-2. Dieldrin Concentrations in Selected Wells in 1993/1994 and 2014/2015

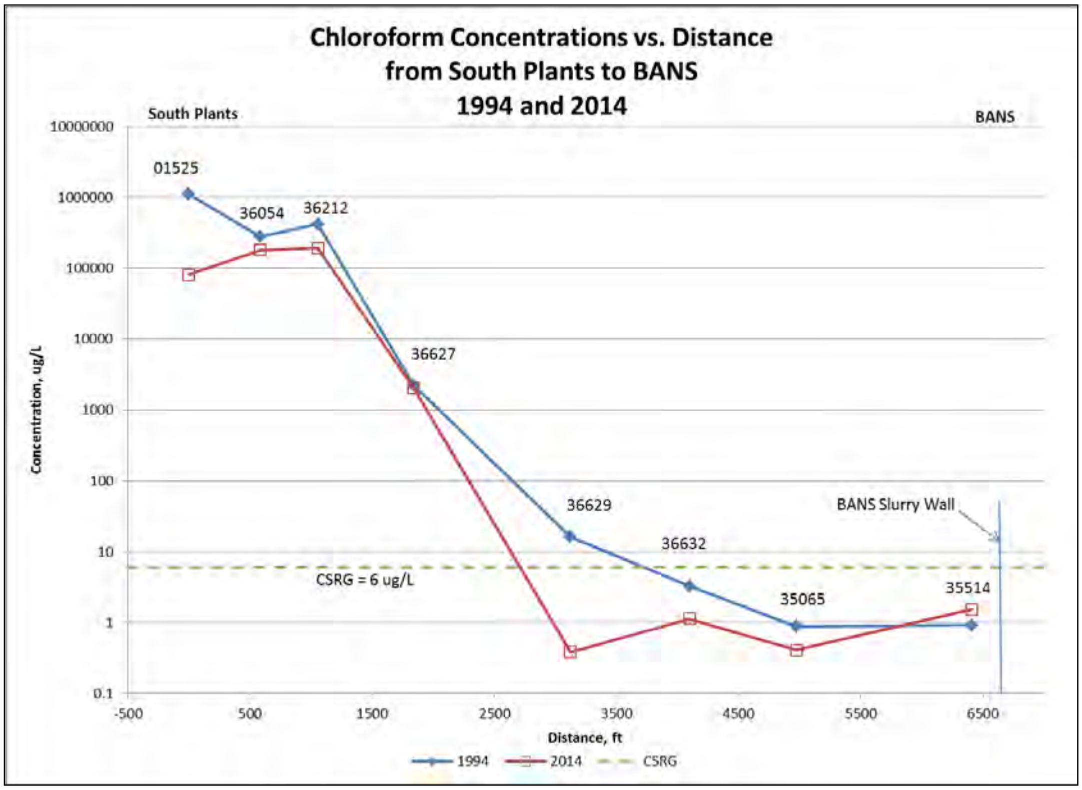
Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01078	1.6	0.173
01525	0.319	0.775
Basin F/Downgradient		
26015	0.529	LT 0.0132
26163	6.05	0.948
23142	0.694	0.329
BANS Downgradient		
26006	4.5	0.371
27025	0.579	0.443
27082	0.297	0.422
NWBCS Plume		
03005	3.6	0.181
03016	0.0648	0.0511
34005	4.7	2.63
34508	2.1	1.41
Sand Creek Lateral Plumes		
35037	5.7	1.58
27083	4.4	2.64
02524	0.519	0.61

Chloroform

The chloroform MRL was slightly lower in 2014 (i.e., 0.5 µg/L in 1994 and 0.2 µg/L in 2014). Figure 5.1.5.1-3 is the 2014 chloroform plume map. The major chloroform sources include South Plants, former Basin F, CADT, Shell Disposal Trenches, and North Plants. The Hydrazine Blending and Storage Facility, which was located in the east end of South Plants, and Sand Creek Lateral may be minor sources. Chloroform is a mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. Areas where changes in the chloroform plume interpretation are affected by changes in the well network after 1994 include the area between the CADT and HWL, with post-1994 project wells installed in the Bedrock Ridge, HWL, and ELF areas.

Decreases in the chloroform plume extent and concentrations between 1994 and 2014 occurred in South Plants, South Lakes area, former Basin F, north of former Basin F, downgradient of BRES, downgradient of North Plants, upgradient of the NWBCS, and upgradient of NBCS. Chloroform concentrations in the CADT area are lower due to mass extraction and mass removal by the CADT dewatering system and treatment at BANS. The areas where chloroform concentrations are still above the CSRG of 6 µg/L have decreased dramatically in the former Basin F area, and north of former Basin F.The extremely high chloroform concentrations in South Plants (over 100,000 µg/L) continue to migrate to the north, consistent with historical migration. The historical attenuation of chloroform continues to occur north of South Plants with the concentrations decreasing to less than the CSRG of 6 µg/L far upgradient of the BANS. In fact, it appears that the area exceeding 6 µg/L north of South Plants has receded since 1994. Figure 5.1.5.1-4 shows the chloroform concentrations with distance from South Plants to BANS in 1994 and 2014 in or near the centroid (or centerline) of the plume. The concentration decrease with distance from the source has been very consistent during the two time periods. The centroid of the plume may be east of well 36629 in 2014, and a different well was sampled in 1994 (36123) which may explain the difference in the concentrations at well 36629.

Figure 5.1.5.1-4. Chloroform Concentrations from South Plants to BANS



The source of the high chloroform concentrations likely is in South Plants, but a significant amount of chloroform mass is contained within the Lime Basins slurry wall and will be extracted and treated at BANS. The Lime Basins portion of the GWMR Project, which was completed in 2010, also removed significant chloroform mass prior to installation of the Lime Basins slurry wall. Approximately 848 kg (1,870 pounds) of chloroform were removed during the GWMR Project. Significant chloroform mass is contained within the Shell Disposal Trenches and CADT slurry walls and extracted by the CADT dewatering system.

The additional project-specific and site-wide monitoring data created a better understanding of chloroform plume migration in the Bedrock Ridge/North Plants/HWL areas. It appears that the Bedrock Ridge plume migrates to the west of the North Plants plume and migrates under the northeast corner of the HWL. The chloroform concentrations in the BRES downgradient performance wells have decreased since baseline sampling was conducted in 1998 with only one well above the CSRG of 6 µg/L in 2014 (from 790 µg/L in 1998 to 19.3 µg/L in 2014 in well 36566).

Site wide, the average of the chloroform concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 26,434 µg/L to 11,911 µg/L, which is a 55 percent decrease. For the subset of wells with detections in 1993/1994, the average chloroform concentrations decreased from 46,046 µg/L to 20,749 µg/L, also a 55 percent decrease. The chloroform plume area above the CSRG of 6 µg/L decreased from 1,222 acres in 1994 to 690 acres in 2014, which is a 44 percent decrease.

With decreases in the chloroform concentrations upgradient of the treatment systems, the treatment plant influent concentrations have decreased at NWBCS and NBCS. The average chloroform concentrations in the NWBCS influent decreased from 3.8 µg/L in 1994 to 1.6 µg/L in 2014. The average chloroform concentrations in the NBCS influent decreased from 7.9 µg/L in 1994 to 0.68 µg/L in 2014. The average chloroform concentrations in the BANS influent were less than the CSRG in 1994 and 2014 (LT 5 µg/L in 1994 and 0.6 µg/L in 2014).

Table 5.1.5.1-3 shows the chloroform concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the Integrated Cover System was constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-3. Chloroform Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01078	21,000	31,700
01525	1,100,000	81,400
36109/36631	930,000	799,000
Basin A		
36056/36627	2,200	2,010
36123/36629	16.3	0.384
Basin F/Downgradient		
26133	18,000	LT 5
26157	36,000	LT 5
26173	47.3	3.3
23095	11,300	LT 4
23096	5,600	108
CADT/Downgradient		
36189	47.2	13.5
36594	5000	144
NWBCS Plume		
22043	21.7	11.5
34005	20	6.21
34508	13.5	11.6
Sand Creek Lateral Plumes		
35037	3.66	2.73
27083	18.6	13.5

Benzene

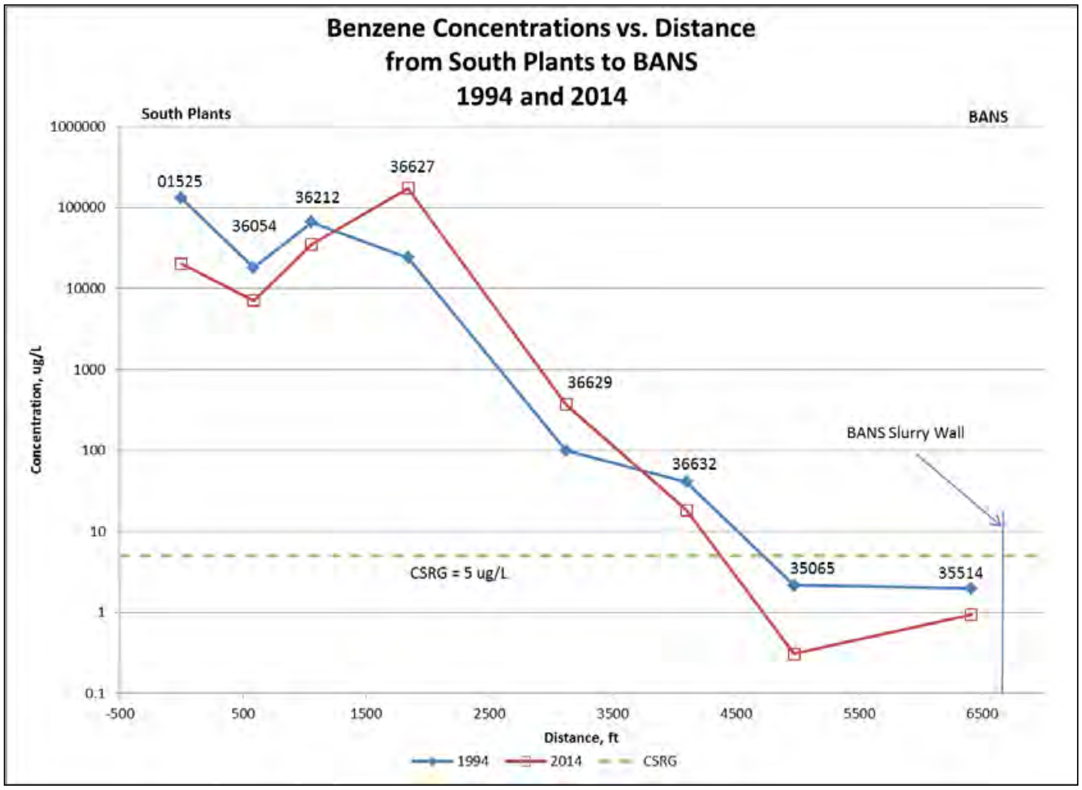
The benzene MRL was lower in 2014 (i.e., 1 to 4 µg/L in 1994 and 0.2 µg/L in 2014). Figure 5.1.5.1-5 is the 2014 benzene plume map. The major benzene sources include STF, South Plants, and Shell Disposal Trenches. Minor sources included former Basin F and CADT. Benzene is a mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. The details of the high-concentration benzene plume in the STF area north of Lower Derby Lake was based on the mapping of the plume in 2009/2010 for the GWMR Project. Monitoring of the benzene plume during the GWMR Project from 2006 to 2010 showed that the plume was very stable. Areas where changes in the benzene plume interpretation are affected by changes in the well network after 1994 include the STF and the area between the CADT and BRES, with post-1994 project wells installed in the STF and Bedrock Ridge areas.

Decreases in the benzene plume extent and concentrations between 1994 and 2014 occurred in STF, South Plants, South Lakes area, former Basin F, north of former Basin F, and upgradient of NBCS. Benzene concentrations in the CADT area are lower due to mass extraction and mass removal by the CADT dewatering system and treatment at BANS. The areas where benzene concentrations are still above the CSRG of 3 µg/L have decreased dramatically in the former Basin F area, and north of former Basin F. Benzene is not detected upgradient of the NBCS.

The high-concentration benzene plume in the STF (10,000 to over 1,000,000 µg/L) continues to be stable, and likely has receded, which is consistent with historical observations. Attenuation of benzene continues to occur at the fringes of the plume, with the concentrations decreasing to less than the CBSG of 5 µg/L (and less than the MRL of 0.2 µg/L) well upgradient of the South Lakes. Interaction of the oxygenated water in the lakes with the groundwater near the lakes enhances the attenuation of benzene in the groundwater by aerobic biodegradation. The STF portion of the GWMR Project, which was completed in 2010, removed significant benzene mass. Benzene LNAPL was discovered and removed during operation of the STF dewatering wells. An estimated total of 2863.5 kg (6,313 pounds) of benzene was removed from the STF plume during the GWMR Project.

The extremely high benzene concentrations in South Plants (over 100,000 µg/L) continue to migrate to the north, consistent with historical migration. Attenuation of benzene continues to occur north of South Plants with the concentrations decreasing to less than the CSRG of 5 µg/L upgradient of BANS. Benzene concentrations in Basin A wells 36056/36627 increased from 24,000 µg/L in 1994 to 172,000 µg/L in 2014, likely due to a change in the groundwater flow direction around the Lime Basins slurry wall. Figure 5.1.5.1-6 shows the benzene concentrations with distance from South Plants to BANS in 1994 and 2014 in or near the centroid of the plume. The concentration decrease with distance from the source has been consistent during the two time periods.

Figure 5.1.5.1-6. Benzene Concentrations from South Plants to BANS



As discussed above, the higher concentration at well 36627 in 2014 (over 100,000 µg/L) shown in Figure 5.1.5.1-6 likely is due to a change in the flow direction around the Lime Basins slurry wall, and is not interpreted to be caused by migration of the high concentration portion of the plume farther north.

A significant amount of benzene mass is contained within the Lime Basins slurry wall and will be extracted and treated at BANS. Significant benzene mass also is contained within the Shell Disposal Trenches slurry wall and by the CADT slurry wall/dewatering system.

The additional project-specific and site-wide monitoring data created a better understanding of benzene plume migration in the Bedrock Ridge area. The benzene plume extends from the CADT to the BRES, where it is captured.

Site wide, the average of the benzene concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 2,979 µg/L to 2,462 µg/L, which is a 17 percent decrease. For the subset of wells with detections in 1993/1994, the average benzene concentration decreased from 17,689 µg/L to 14,634 µg/L, also a 17 percent decrease. The benzene CSRG is 5 µg/L at BANS and 3 µg/L at the boundary systems. The benzene plume area above the CSRG of 3 µg/L decreased from 424 acres in 1994 to 285 acres in 2014, which is a 33 percent decrease.

With decreases in the benzene concentrations upgradient of the treatment systems, the treatment plant influent concentrations have decreased. The average benzene concentrations in the BANS-specific influent were 1.31 µg/L in 1991 (LT 5 µg/L in 1994) and LT 0.2 µg/L in 2014. The average benzene concentrations in the NBCS influent were LT 5 µg/L in 1994 and LT 0.2 µg/L in 2014. Benzene no longer is detected at NBCS and was not detected at NWBCS in 1994 or 2014.

Table 5.1.5.1-4 shows the benzene concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the covers were constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-4. Benzene Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Tank Farm		
01605	11,000	LT 0.2 (2010)
02522	94,000	LT 0.2 (2010)
South Plants		
01525	130,000	20,000
36181	49,000	2,750
26173	6.89	LT 2
Basin A/Lime Basins		
36056/36627	24,000	172,000
36212	66,000	34,800
36538	210	8.16
Basin F/Downgradient		
26133	77	LT 5
26163	53	LT 2
26173	6.89	LT 2

N-nitrosodimethylamine (NDMA)

The NDMA MRL was an order-of-magnitude lower in 2014 (i.e., 0.033 µg/L in 1994 and 0.00115 µg/L in 2014). A PQL study in 2012 resulted in the PQL being reduced from 0.033 µg/L to 0.018 µg/L. Figure 5.1.5.1-7 is the 2014 NDMA plume map. The major NDMA sources include the chemical sewer in two areas in South Plants, the Hydrazine Blending and Storage Facility (HBSF), and former Basin F. NDMA is a mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected.

Decreases in the NDMA plume extent and concentrations between 1994 and 2014 occurred in South Plants, former Basin F, north of former Basin F, and upgradient of NBCS. The areas where NDMA concentrations are still above the former PQL of 0.033 µg/L have decreased in South Plants, former Basin F, and north of former Basin F.

Between 1994 and 2014, an increase in the NDMA plume extent occurred downgradient of the HBSF in Section 1, and the plume extends to well 36069, which is east of the CADT, and then to the First Creek alluvium in Section 36, where it attenuates to below detectable levels. Other areas where the plume appears larger than in 1994 include South Plants southwest, north of South Plants, former Basin A, downgradient of BANS, northwest from former Basin F, and a small area below the former and current PQL near the NWBCS.

The North of Basin F IRA extraction well in Section 23 pumped NDMA-contaminated groundwater to BANS from 1993 to 2002. Since BANS has no NDMA treatment process, a plume extends downgradient of BANS and migrated to the NWBCS, where the concentrations were below the former and current PQLs.

Site wide, the average of the NDMA concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 0.663 µg/L in 1994/1994 to 0.178 µg/L in 2014/2015, which is a 73 percent decrease. For the subset of wells with NDMA detections in 1993/1994, the average NDMA concentration decreased from 1.52 µg/L in 1994/1994 to 0.41 µg/L in 2014/2015, which also is a 73 percent decrease. The NDMA plume area above the PQLs of 0.033 and 0.018 µg/L decreased from 732 acres in 1994 to 530 acres in 2014, which is a 28 percent decrease. Comparing the areas above the former PQL is probably more meaningful, and the NDMA plume area decreased from 732 acres in 1994 to 349 acres in 2014, which is a 52 percent decrease.

With decreases in the NDMA concentrations upgradient of the treatment systems, the treatment plant influent concentrations have decreased at BANS and NBCS. The average NDMA concentrations in the BANS influent were 0.12 µg/L in 1996 (no data in 1994) and 0.015 µg/L in 2014. The average NDMA concentrations in the NBCS influent decreased from 0.263 µg/L in 1994 to 0.0124 µg/L in 2014. The average NDMA concentrations in the NWBCS influent were LT 0.0157 µg/L in 1996 (no data in 1994) and LT 0.00115 µg/L in 2014.

Table 5.1.5.1-5 shows the NDMA concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-5. N-nitrosodimethylamine (NDMA) Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01525	1.3	2.57
BANS Downgradient		
26006	0.052	0.0414
27025	LT 0.0157 (1995)	LT 0.0016
Basin F/Downgradient		
26133	0.6	0.199
26157	3.3	0.633
26163	2.0	0.883
26173	1.2	0.0397
23231/23160	7.2	0.115
24101	3.7 (1995)	0.112
24201	0.69	0.0128

Carbon Tetrachloride

The carbon tetrachloride (CCL4) MRL was lower in 2014 than in 1994 (i.e., 0.99 µg/L in 1994 and 0.263 µg/L in 2014). The 1994 CCL4 data were not mapped previously, but a 1994 map is provided in this report as Figure 5.1.5.1-8 for comparison with the 2014 plume map (Figure 5.1.5.1-9). The major CCL4 sources include South Plants, CADT, Shell Disposal Trenches, and North Plants. The HBSF was located in the east end of South Plants, and is a minor source. CCL4 is a moderately mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. The 1994 CCL4 plume interpretation incorporated the current understanding of the groundwater contaminant migration between the CADT and HWL, based on the post-1994 project wells installed in the Bedrock Ridge, HWL, and ELF areas.

Decreases in the CCL4 plume extent and concentrations between 1994 and 2014 occurred in South Plants, South Lakes area, downgradient of BRES, downgradient of North Plants, and upgradient of NBCS. The areas where CCL4 concentrations are still above the CSRG of 0.3 µg/L have decreased in South Plants, South Lakes area, and downgradient of BRES.

The CCL4 sources within the CADT are located northeast of a groundwater divide such that CCL4 is not detected in the CADT dewatering well. The CADT/Bedrock Ridge CCL4 plume also migrates to the west of the North Plants plume and migrates under the northeast corner of the HWL. The CCL4 concentrations in the BRES downgradient performance wells have decreased since baseline sampling was conducted in 1998 and all wells are below the CSRG. Thus, the BRES has cut off the CCL4 plume.

Between 1994 and 2014, an increase in the CCL4 plume extent occurred downgradient of the HBSF in Section 1, and the plume extends to well 36069, which is east of the CADT, and then to the BRES. Also, the downgradient extent of the Bedrock Ridge/North Plants CCL4 plume in Section 24 is shown to increase between 1994 and 2014, and extend to the NBCS in 2014, but this intersection with the NBCS may have existed in 1994 based on NBCS extraction well data.

Site wide, the average of the CCL4 concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 increased because of higher MRLs in 2014 when dilutions were necessary in high VOC-concentration well samples. For the subset of wells with CCL4 detections in 1993/1994, the average CCL4 concentration decreased from 21.4 µg/L in 1994/1994 to 13.3 µg/L in 2014/2015, which is a 38 percent decrease. The CCL4 plume area above the CSRG of 0.3 µg/L decreased from 529 acres in 1994 to 501 acres in 2014, which is a five percent decrease. The former PQL concentration of 0.99 µg/L was not mapped in 2014, so the percentage decrease at a concentration of 0.99 µg/L probably was greater than five percent.

For 1994/2014 treatment system comparison, the NBCS is the only system where CCL4 was present during both time periods. With decreases in the CCL4 concentrations upgradient of the NBCS, the NBCS treatment plant influent concentrations have decreased from 1.4 µg/L in FY1995 (LT 5 µg/L in FY1994) to 0.436 µg/L in FY2014. Table 5.1.5.1-6 shows the CCL4 concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-6. Carbon Tetrachloride Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01101/01104	310	6.25
02065	11.7 (1992)	1.04
35013	54.3	21.9
South Lakes		
02525	2.64	LT 0.263
02597	4.3	0.311
CADT/Downgradient		
36201	220	167
36594	7.2	0.623
36069	LT 0.99	2.55

Dithiane

The dithiane MRL was lower in 2014 than in 1994 (i.e., 1.34 µg/L in 1994 and 0.4 µg/L in 2014). Figure 5.1.5.1-10 is the 2014 dithiane plume map. The 1994 plume map consisted of summed dithiane and oxathiane concentrations, but Army and Shell and the Regulatory Agencies determined that only dithiane should be mapped in 2014. Dithiane was chosen for mapping in 2014 because it is a control compound for BANS treatment, and oxathiane is a small component of the sum. The major dithiane sources include the M-1 pits in South Plants, former Basins A and F, and CADT. Dithiane is a mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. The Dithiane plume does not occur in areas where changes in the well network would affect the interpretation.

Decreases in the Dithiane plume extent and concentrations between 1994 and 2014 occurred in South Plants, portions of former Basin A, former Basin F, north of former Basin F, and downgradient of BANS. The dithiane plume was relatively stable in portions of former Basin A and the CADT. The areas where dithiane concentrations are still above the CSRG of 18 µg/L have decreased dramatically in the former Basin F area, north of former Basin F, and downgradient of BANS.

Site wide, the average of the dithiane concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 226.5 µg/L to 135.1 µg/L, which is a 40 percent decrease. For the subset of wells with detections in 1993/1994, the average dithiane concentration decreased from 634.1 µg/L to 379.5 µg/L, also a 40 percent decrease. The dithiane plume area above the CSRG of 18 µg/L decreased from approximately 703 acres in 1994 to 262 acres in 2014, which is a 63 percent decrease. As discussed above, the dithiane and oxathiane concentrations were summed in the 1994 map, but only dithiane was mapped in 2014. Oxathiane comprised a small portion of the sum in 1994. Also, the concentration contour intervals at the dithiane CSRG of 18 µg/L were different (10-100 µg/L in 1994 and 18-100 µg/L in 2014). These differences are not considered significant for the plume-area comparison, however.

The average dithiane concentrations in the BANS influent have decreased slightly from 174.3 µg/L in 1994 to in 147 µg/L in 2014. Dithiane was not detected in the NWBCS and NBCS influents in both time periods.

Table 5.1.5.1-7 shows the dithiane concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the covers were constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-7. Dithiane (DITH) Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01078	22.3	1.89
01525	78	25.4
Lime Basins		
36109/36631	74	33.8

Table 5.1.5.1-7. Dithiane (DITH) Concentrations in Selected Wells in 1993/1994 and 2014/2015 (Concluded)

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
Basin A		
36056/36627	5500	4510
36108/36630	1700	314
36177/36632	2800	2620
36599/36633	240	214
36538	3500	815
CADT		
36189	1700	1500
BANS/Downgradient		
26006	140	7.65
Basin F/Downgradient		
26133	99	4.22
26163	97	16.9
23095	88	5.23
23142	21.3	LT 0.4
23231/23160	40	LT 0.4

Arsenic

The arsenic MRLs were lower in 2014 than in 1994 (i.e., 1.8 to 6.5 µg/L in 1994 and 1 µg/L in 2014). Figure 5.1.5.1-11 is the 2014 arsenic plume map. The major arsenic sources include the M-1 Pits in South Plants, Lime Basins, former Basins A and F, and CADT. Arsenic is a moderately mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. Areas where changes in the arsenic plume interpretation are affected by changes in the well network after 1994 include the area south of the ELF, with post-1994 project wells installed in the ELF area.

Decreases in the arsenic plume extent and concentrations between 1994 and 2014 occurred in South Plants, former Basins A and F, north of former Basin F, downgradient of BANS, upgradient of the NWBCS, and upgradient of NBCS. Arsenic concentrations in the former Basin A and CADT areas are lower due to mass extraction and mass removal by the CADT and BANS dewatering systems and treatment at BANS. The areas where arsenic concentrations are still above the CSRG of 2.35 µg/L have decreased dramatically in the former Basin F area, and north of former Basin F.

The additional project-specific and site-wide monitoring data created a better understanding of arsenic plume migration between former Basin A and the ELF. Although the alluvium is unsaturated, the arsenic plume appears to have migrated through the subcropping A Sandstone in the Denver Formation bedrock at the north end of Basin A. This migration pathway explains the arsenic detections in wells located south of the ELF. At the request of the Regulatory Agencies, additional evaluation of this migration pathway is provided in Appendix F. The resulting conclusions and recommendations are provided below.

In developing the remedy for RMA, Basin A was determined to be a natural groundwater containment feature, with the only known outlets for contaminated groundwater flow assumed to be toward BANS and BRES. A third outlet for contaminated groundwater north of former Basin A is interpreted to exist that is not intercepted by BANS or BRES.

Arsenic has been detected historically in wells upgradient of the ELF and can now be attributed to the north Basin A pathway. The north Basin A arsenic plume is interpreted to only migrate a short distance and does not appear to reach the First Creek alluvium east of the ELF. If the arsenic plume would migrate into the First Creek alluvium, it potentially would migrate to the NBCS and be intercepted and treated to meet remediation goals. Additionally, the arsenic concentrations in well 25106 are below the BANS CSRG and are decreasing. Therefore, based on the arsenic treatment criteria at BANS, no further action would be required for the north Basin A arsenic plume.

The presence of arsenic in wells upgradient of the ELF affects the ELF groundwater monitoring program, but is addressed by the upper prediction limit statistical evaluation of the ELF groundwater data, and does not significantly hinder the landfill performance evaluations.

The arsenic mass flux is estimated to be extremely low (0.007 to 0.03 lb/year) and the contaminant migration does not affect remedy protectiveness. Therefore, in Army and Shell's opinion, additional remedial action for the north Basin A pathway is not warranted.

Future monitoring of this migration pathway is appropriate, however. Wells 25022 and 25106, which are located upgradient of the ELF, are sampled under the ELF Post-Closure Plan (PCP). Monitoring of wells 25004 and 36112, which are screened in the A Sandstone and located upgradient of wells 25022 and 25106, is proposed and would be conducted under the LTMP Water Quality Tracking category (twice in five-year frequency) to obtain additional groundwater quality data for this recently identified migration pathway. Water levels are already monitored for these wells under the LTMP and ELF PCP. If this proposal is acceptable to the Regulatory Agencies, an OCN will be issued to amend the LTMP.

The sources of the highest arsenic concentrations are the M-1 Pits in South Plants and the Lime Basins. A significant amount of arsenic mass is contained within the Lime Basins slurry wall and will be extracted and treated at BANS. The Lime Basins portion of the GWMR Project, which was completed in 2010, also removed significant arsenic mass prior to installation of the Lime Basins slurry wall. Approximately 106 kg (234 pounds) of arsenic were removed during the GWMR Project. Significant arsenic mass is contained by the CADT slurry wall/dewatering system.

Site wide, the average of the arsenic concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 145.7 µg/L to 14.4 µg/L, which is a 90 percent decrease. For the subset of wells with detections in 1993/1994, the average arsenic concentration decreased from 255.5 µg/L to 24.7 µg/L, also a 90 percent decrease. The arsenic CSRG is 50 µg/L at BANS and 2.35 µg/L at the boundary systems. The arsenic plume area above the CSRG of 2.35 µg/L decreased from 996 acres in 1994 to 463 acres in 2014, which is a 52 percent decrease.

With decreases in the arsenic concentrations upgradient of the treatment systems, the treatment plant influent concentrations have decreased at BANS, NWBCS, and NBCS. The average arsenic concentrations in the BANS influent decreased from 37.4 µg/L in 1994 to in 26.5 µg/L in 2014. The average arsenic concentrations in the NWBCS influent decreased from 2.0 µg/L in 1994 to in LT 1 µg/L in 2014. The average arsenic concentrations in the NBCS influent decreased from 3.1 µg/L in 1994 to LT 1 µg/L in 2014.

Table 5.1.5.1-8 shows the arsenic concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the covers were constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-8. Arsenic Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01078	14.9	9.4
01525	65 (1989)	17.5
36054	52.7	28.4
Lime Basins/Downgradient		
36109/36631	54.1	34.8
36210	319	63.7
36212	7500	343
36056/36627	67.4	101
Basin A		
36108/36630	78	36.8
36177/36632	100	53.7
36599/36633	88.3	33
CADT		
36189	58.5	39.5
36594	5.61	LT 1
BANS/Downgradient		
26006	29.4	13.3
27025	9.59	1.74
27082	16	2.06
Basin F/Downgradient		
26163	170	2.46
26157	30.8	2.24
23095	22	5.89
23231/23160	21.3	LT 1

Dibromochloropropane (DBCP)

The DBCP MRL was an order-of-magnitude lower in 2014 (i.e., 0.13 to 0.195 µg/L in 1994 and 0.0194 µg/L in 2014). Figure 5.1.5.1-12 is the 2014 DBCP plume map. The major DBCP sources include South Plants, former Basin F, and the Shell Disposal Trenches. The Rail Classification Yard (Railyard) also is a source of DBCP in groundwater. DBCP is a moderately mobile compound, and decreases in the plume extent and concentrations due to remedy implementation are expected. Areas where changes in the DBCP plume interpretation are affected by changes in the well network after 1994 include the area between the CADT and BRES, with post-1994 project wells installed in the Bedrock Ridge area.

Decreases in the DBCP plume extent and concentrations between 1994 and 2014 occurred in South Plants, former Basin F, north of former Basin F, upgradient and downgradient of the RYCS, and upgradient of NBCS. DBCP in the CADT area groundwater migrated from the Shell Disposal Trenches area before the slurry walls were installed. DBCP concentrations in the CADT are lower due to mass extraction and mass removal by the CADT dewatering system and treatment at BANS. The areas where DBCP concentrations are still above the CSRG of 0.2 µg/L have decreased in South Plants and upgradient and downgradient of the RYCS. The DBCP concentrations have decreased dramatically in the former Basin F area, and north of former Basin F, and are below the CSRG in all the wells sampled. The RYCS met the criteria for commencing the LTMP shut-off process in 2013. A RYCS pre-shut-off monitoring program was successfully completed in 2014, and the shut-off process will proceed with development of a Shut-Off SAP for Regulatory Agency review and approval.

The DBCP concentration in South Plants well 01078 increased from 610 µg/L in 1994 to 1,980 µg/L in 2014, but is within the historical range, and likely occurred because of a localized change in the groundwater flow direction. The high DBCP concentrations in South Plants (over 1,000 µg/L) continue to migrate to the north, consistent with historical migration. The historical attenuation of DBCP continues to occur north of South Plants with the concentrations decreasing to less than the CSRG of 0.2 µg/L far upgradient of the BANS. A significant amount of DBCP mass is contained within the Lime Basins slurry wall and will be extracted and treated at BANS. The Lime Basins portion of the Groundwater Mass Removal Project, which was completed in 2010, also removed significant DBCP mass prior to installation of the Lime Basins slurry wall. Significant DBCP mass is contained within the Shell Disposal Trenches slurry wall and by the CADT slurry wall/dewatering system.

The additional project-specific and site-wide monitoring data created a better understanding of DBCP plume migration in the Bedrock Ridge area. It appears that DBCP migrates from the CADT to the BRES, where it is captured and treated at BANS.

Site wide, the average of the DBCP concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 decreased from 3.7 µg/L to 1.9 µg/L, which is a 49 percent decrease. For the subset of wells with detections in 1993/1994, the average DBCP concentrations decreased from 17.3 µg/L to 9.2 µg/L, which is a 47 percent decrease. Only 15 of the wells sampled in both time periods had DBCP detections in 1993/1994. The data for well 01078 (discussed above) skew the data, and it was excluded from the average calculations. The DBCP plume area above the CSRG of 0.2 µg/L decreased from 403 acres in 1994 to 148 acres in 2014, which is a 63 percent decrease.

The average DBCP concentrations in the NBCS influent were LT 0.13 µg/L in 1994 and LT 0.0194 µg/L in 2014. DBCP was not detected in the BANS and NWBCS influents in 1994 and 2014.

Table 5.1.5.1-9 shows the DBCP concentrations in selected monitoring wells for 1993/1994 and 2014/2015 in the areas indicated. Where wells were closed and replaced after the Integrated Cover System was constructed or where adjacent wells were sampled, both well numbers are shown.

Table 5.1.5.1-9. Dibromochloropropane (DBCP) Concentrations in Selected Wells in 1993/1994 and 2014/2015

Well	1993/1994 Concentration, µg/L	2014/2015 Concentration, µg/L
South Plants		
01041	0.752	0.0207
01078	610	1980
01525	1.91	0.118
36054	66	18.5
36181	69	48.2
Lime Basins/Basin A		
36212	9.84	4.53
36056/36627	LT 0.195	0.101
Basin F/Downgradient		
26157	19	LT 0.0194
23096	3.67	0.115
24101	0.649	0.0329
Railyard		
03523	22	0.0392

Comparison of Average Concentrations in 1994 and 2014

The site-wide average concentrations for the same group of wells sampled in 1993/1994 and 2014/2015 are tabulated below for the nine analytes (Table 5.1.5.1-10). The subset of wells with detections in 1993/1994 is included. The range in the decrease in the average concentrations was from 17 percent for benzene to 90 percent for arsenic. The average decrease in concentrations for the nine analytes was 55 percent for all wells and 53 percent for the wells with detections in 1994.

Table 5.1.5.1-10. Comparison of Average Concentrations in 1994 and 2014

Analyte	CSRG/PQL, µg/L (Former PQL)	1994 Average Concentration, µg/L (all wells/1994 detections)	2014 Average Concentration, µg/L (all wells/1994 detections)	Percent decrease (all wells/1994 detections)
DIMP	8	1,116/1,640	387/569	65/65
Dieldrin	0.013 (0.05)	0.625/1.08	0.323/0.51	48/53
Chloroform	6	26,434/46,046	11,911/20,749	55/55
Benzene	3	2,979/17,689	2,462/14,634	17/17
NDMA	0.018 (0.033)	0.66/1.52	0.178/0.41	73/73
Carbon Tetrachloride	0.3 (0.99)	NA/21.4	NA/13.3	NA/38
Dithiane	18	227/634	135/380	40/40
Arsenic	2.35	146/256	14.4/24.7	90/90
DBCP	0.2	3.7/17.3	1.9/9.2	49/47
Average Change				55/53

Comparison of On-post Plume Areas in 1994 and 2014

Table 5.1.5.1-11 shows the On-post plume areas above CSRGs/PQLs in 1994 and 2014. Where the PQLs were lower in 2014, the plume areas above the former PQL are included. The percentage change ranged from a 63 percent decrease for DBCP and dithiane to a 5 percent decrease for CCL4. There was a 47 percent increase for dieldrin; however, a comparison of the dieldrin plume areas above the former PQL is more meaningful, and is estimated to be a 16 percent decrease in the area. On average, the On-post plume areas above CSRGs/PQLs decreased by 33 to 42 percent.

Table 5.1.5.1-11. Comparison of On-post Plume Areas in 1994 and 2014

Analyte	CSRG/PQL, µg/L (Former PQL)	1994 Plume Area > CSRG/PQL, acres	2014 Plume Area > CSRG/ PQL, acres	2014 Plume Area > former PQL, acres	Change, percent (current/former PQL) (negative = decrease, positive = increase)
DIMP	8	1,179	560		-53
Dieldrin	0.013 (0.05)	1,902	2,804	1,606	+47/-16
Chloroform	6	1,222	690		-44
Benzene	3	424	285		-33
NDMA	0.018 (0.033)	732	530	349	-28/-52
Carbon Tetrachloride	0.3 (0.99)	529	501	Not mapped	-5
Dithiane	18	703	262		-63
Arsenic	2.35	996	463		-52
DBCP	0.2	403	148		-63
Average Change					-33/-42

2014 On-post Plume Mapping Summary

Significant decreases in contaminant concentrations and plume extents for the nine analytes were observed between 1994 and 2014. The average concentrations for the same wells sampled in 1994 and 2014 decreased for all the analytes, both for all wells sampled, and for the subset of wells with detections in 1994. The average decrease in the average concentrations in the wells with detections in 1994 ranged from 17 percent for benzene to 90 percent for arsenic, with an average decrease of 53 percent for the nine analytes.

The areas of the plumes for the concentration intervals above the CSRGs/PQLs decreased between 1994 and 2014. The decrease in the plume areas above CSRGs/PQLs ranged from 5 percent for CCL4 to 63 percent for DBCP and dithiane. The average decrease in the on-post plume areas for the nine analytes was 42 percent. The areas where the plume concentrations above CSRGs/PQLs significantly decreased in extent include former Basin F, between former Basin F and the NBCS, downgradient of BANS, and downgradient of BRES.

With decreasing concentrations upgradient of the on-post groundwater mass removal and containment systems, the treatment plant influent concentrations for most of the analytes also decreased between 1994 and 2014. For example, at BANS the average DIMP concentration in the influent decreased from 980 µg/L in 1994 to 25.6 µg/L in 2014, and at NBCS the average DIMP concentration decreased from 95 µg/L to 3.1 µg/L. Both are 97 percent reductions. DIMP was not detected in the NWBCS influent in both years. Reducing the extent and concentrations of contaminant plumes upgradient of the boundary systems meets the Remedial Action Objective for on-post groundwater.

The results of the 2014 on-post plume mapping project may warrant some revisions to the LTMP monitoring networks. A few recommendations for additions to the LTMP Water Quality Tracking network have been made in Sections 5.1.3.1 and 5.1.5.1. Revision of the 2010 LTMP is being considered for 2017. A more complete evaluation of the LTMP well networks will be conducted at that time.

5.1.5.2 Post-Shut-Off Monitoring

Post-Shut-Off Monitoring was conducted in two areas during this FYR period; the STF portion of the GWMR Project and the MPS/ICS.

GWMR Project STF Post-Shut-Off Monitoring

The GWMR Project in the Lime Basins and STF was completed in 2010. Operations and monitoring for the Lime Basins Slurry Wall Dewatering System and DNAPL Remediation Project are ongoing. Consequently, no GWMR Project post-shut-off monitoring for the Lime Basins was required.

Due to changes in the hydrology in the STF area caused by South Plants remediation and cover construction, a post-shut-off monitoring program was developed to monitor the STF benzene plume and assess potential impacts on Lower Derby Lake for a period of five years. This monitoring program is described in the GWMR Project Post-Shut-Off Monitoring Sampling and Analysis Plan (URS 2012c) and summarized below. The data are reported in the ASRs for

Groundwater and Surface Water, and the long-term concentration trend is evaluated in the Five-Year Groundwater Summary Report. Consultation with the Regulatory Agencies will be conducted to discuss the monitoring results when the five years of post-shut-off monitoring is complete in 2016.

Monitoring wells 01600, 01670, and 01687 are to be sampled annually for five years, and extraction well 01312 is sampled twice-in-five years under the LTMP water quality tracking category (sampled in FY12 and FY14). Benzene is the only COC for the GWMR Project post-shut-off monitoring. Figure 5.1.5.2-1 is the well location map, and also shows September 2010 water-table contours and the 2009 high-concentration benzene plume (greater than 50 mg/L) for reference. The GWMR Project post-shut-off water level network consists of fewer wells than in 2010 when the GWMR Project was in operation, and includes wells in the 2010 LTMP water level tracking network, which are measured and mapped annually. The 2010 water-table contours are shown on Figure 5.1.5.2-1 because the well network was larger, and it provides more detail on the flow directions under natural gradient conditions.

The FY14 water-table contours in the STF area on Figure 5.1.3-6 are similar to those shown on Figure 5.1.5.2-1 (September 2010). Water levels in the sampled wells were higher in FY14 compared to FY13 by a range of 4.0 to 9.3 ft. The higher water levels in FY14 were caused by the historic September 2013 rain/flood event, followed by heavy rains during May 2014. No significant changes in flow directions are indicated, however.

The data quality objectives in the SAP specify that no additional action (besides continued monitoring per the SAP) is required if the benzene concentrations in monitoring wells 01600, 01670, and 01687 do not indicate an increasing trend above 80 percent of the historical maximum concentration for each well. These maximums and the FY12 through FY14 benzene results are provided in Table 5.1.5.2-1 below.

Table 5.1.5.2-1. GWMR Project Post-Shut-Off Benzene Results

Well	Historical Maximum Benzene Concentration, μg/L	Fiscal Year	Benzene Concentration, μg/L	Exceeds 80% of Historical Maximum
01600	3.1	2012 2013 2014	LT 0.2 LT 0.2 LT 0.2	No No No
01670	3,040	2012 2013 2014	LT 0.2 LT 0.2 LT 0.2	No No No
01687	78.2	2012 2013 2014	1,170 LT 5 LT 0.2	Yes No No
01312	Not Applicable	2012 2013 2014	1,130,000, 1,270,000 (D) Not sampled 1,320,000	Not Applicable
01049 (added in FY13)	LT 2.7	2012 2013 2014	Not sampled LT 0.2 LT0.2	Not sampled No No

The benzene concentration in monitoring well 01687 exceeded the historical maximum in FY12. Consequently, monitoring-well 01049 was added to the network in FY13 to monitor the area downgradient of well 01687. The benzene concentrations in all monitoring wells sampled in FY13 and FY14 were below the MRLs, which ranged from LT 0.2 to LT 5 μg/L. Former GWMR Project extraction well 01312 is also sampled for benzene and monitored for water levels and the presence of benzene LNAPL. The benzene concentrations were 1,130,000 in FY12 and 1,320,000 μg/L in FY14, and were similar to previous concentrations. No LNAPL was detected in well 01312 in FY12 and FY14. Well 01312 was not monitored for water levels and LNAPL thickness in FY13. The Regulatory Agencies were notified about the missed data collection and corrective actions were taken.

The long-term benzene concentration trends in the monitoring wells either are stable or decreasing. The benzene concentration trend in well 01312 is stable. These data indicate that the STF benzene plume is stable or receding and is not migrating toward the South Lakes.

MPS/ICS Post-Shut-Off Monitoring

Three wells were sampled for MPS/ICS post-shut-off monitoring during the FYR period. Wells 04535 and 33081 were sample annually in FY12 through FY14 and well 04021 was sampled in FY12 and FY14. Figure 5.1.5.2-2 shows the well locations. Wells 04021 and 04535 are downgradient of the MPS and were sampled for TCE. Well 33081 is between the RYCS and former ICS, and was sampled for DBCP. The concentrations in all three wells were below the respective CSRGs (5 µg/L for TCE and 0.2 µg/L for DBCP). The DBCP and TCE concentrations are provided in Table 5.1.5.2-2. In 2014, all three wells were sampled for both analytes under the on-post plume mapping project. DBCP was not detected in wells 04021 and 04535, and TCE was not detected in well 33081.

Table 5.1.5.2-2. MPS/ICS Post-Shut-Off Results

Well	Fiscal Year	DBCP Concentrations, µg/L	TCE Concentrations, µg/L
04021	2012 2013 2014	 LT 0.0194	0.812 Not sampled 0.201
04535	2012 2013 2014	 LT 0.0192	3.11, 3.0 (D) 2.13, 2.16 (D) 1.05, 1.06 (D)
33081	2012 2013 2014	LT 0.02, LT 0.02 (D) LT 0.02, LT 0.02 (D) LT 0.0198, LT 0.0198 (D)	 LT 0.2

In the MPS/ICS Post Shut-Off Monitoring SAP (URS 2012d), the goals of the study are to determine if concentrations are above the CSRGs or are increasing or migrating offpost. The TCE concentrations in well 04535 decreased from 3.11 µg/L in 2012 to 1.06 µg/L in 2014, and the TCE concentration in well 04021 decreased from 0.812 µg/L to 0.201 µg/L in 2014. DBCP was not detected in well 33081. Therefore, the DBCP and TCE concentrations are below the CSRGs, and either are decreasing or not detected.

5.1.5.3 On-Post 1,4-Dioxane Characterization

Investigative samples were collected from 230 Army monitoring wells, two Army water supply wells located in Section 4, and 10 surface water sites according to the 1,4-Dioxane Characterization SAP (URS 2012b). The Tri-County Health Department (TCHD) sampled 18 private wells, one Denver Water monitoring well, and two surface water sites. The TCHD sampling program is not included in the 1,4-Dioxane Characterization SAP (URS 2012b), but the TCHD results will be included in the DSR (in progress) in order to provide a more complete assessment of the horizontal and vertical extent of 1,4-dioxane in groundwater near RMA.

The treatment plant influents and effluents at BANS, NBCS, NWBCS, OGITS, and RYCS were also sampled.

Deviations from the SAP include the following:

- Sampling of surface water sites SW020009, SW24004, SW24005, SW25101, and SW37001 occurred in FY2013 due to the lack of surface water or appropriate runoff conditions in FY2012.

- Addition of surface water sites SW02020, SW02021, and SW08003.

- Addition of Army water supply wells 04303 and 04305.

Horizontal Extent

Figure 5.1.5.3-1 shows the results of the well sampling program, and includes interpreted plume contours for the UFS. The investigative sample concentrations were above the MRL of 0.1 µg/L in the majority of samples for UFS wells, both on-post and off-post. Where detected, the minimum detected concentration of 0.1 µg/L was found in several wells. The maximum concentration was found in South Plants monitoring well 01078 at 266 µg/L in 2012 (324 µg/L in 2011). Data collected in off-post private wells by TCHD are included in Figure 5.1.5.3-1 and are identified by site IDs that differ from the Army's 5-digit well numbers that begin with "37."

The 1,4-dioxane concentrations in 60 on-post wells were above the Colorado Basic Standard for Ground Water (CBSG) of 0.35 µg/L, and nine off-post wells were above the CBSG, including two private wells. Only four of the off-post wells with concentrations above the CBSG were located downgradient of the OGITS extraction and recharge systems. Although the OGITS does not treat 1,4-dioxane, the concentrations in the OGITS plant effluent have consistently been below the CBSG due to blending. Thus, OGITS reduces the concentrations of the discrete plumes it intercepts.

The concentrations in the two on-post Section 4 water supply wells (04303 and 04305) were above the CBSG, but these wells are located in a plume with sources located upgradient of RMA. The water supply wells are screened in the alluvial aquifer. This plume is separated from the RMA 1,4-dioxane contamination by an uncontaminated area between the plumes in Sections 3, 4, and 33. Based on the detection of 1,4-dioxane in two wells upgradient of RMA in Section 10, a narrow plume is interpreted to migrate onto RMA from the south and may be present on-post in Sections 3, 34, 33, and 28. Figure 5.1.5.3-1 shows the approximate location of the western plume that originates south and west of RMA, and the narrow plume in Section 10. Their interpretation is based on 1,4-dioxane data compiled by the EPA (Pacific Western Technologies 2013) and RMA water table maps and known flow directions. These additional 1,4-dioxane data points are not shown on the map because they are not part of the RMA sampling program, and have not been reviewed for quality assurance by the RMA. The EPA is in the process of evaluating these data as part of a 1,4-Dioxane Preliminary Assessment.

1,4-Dioxane was detected in groundwater in many of the same areas as other RMA groundwater contaminants that were mapped in 1994 (USGS 1997). However, 1,4-dioxane was not detected in any of the Railyard or Motor Pool wells. 1,4-Dioxane was detected upgradient of the BRES, but not in the downgradient performance wells. Thus, it appears that the BRES is intercepting the upgradient 1,4-dioxane plume, which migrates from the CADT area. The high concentration plume in the CADT area (e.g., 39.5 µg/L in well 36201) likely extends upgradient to the CADT dewatering trench, where the plume would be extracted. The concentration in the CADT dewatering well was 5.31 µg/L. Thus, the area of influence of the dewatering trench includes areas with lower concentrations.

The highest concentrations of 1,4-dioxane were found in areas that also have high historical concentrations of 111TCE and TCE and include South Plants, CADT, and North Plants. These areas may be considered as the primary sources of 1,4-dioxane. 1,4-Dioxane was also detected downgradient of Basin F. The concentrations near Basin F are lower than in the primary sources, but Basin F also appear to be a source of 1,4-dioxane contamination.

Sampling of some additional wells in a few areas was suggested by the Regulatory Agencies to better determine the plume extent. These areas include the eastern portion of South Plants, Basin F, and the CADT area. Sampling of these wells occurred in a second phase of sampling in 2015 and the results were incorporated into the plume map.

Further evaluation of the 1,4-dioxane data and general observations about the plume are provided below. An evaluation of the data for an emerging contaminant such as 1,4-dioxane, when the available data are limited, helps gain a better understanding of the contamination, and helps assess any potential impact on the effectiveness of the remedy for the Five-Year Review in 2015. Additionally, the SAP specifies that if 1,4-dioxane is detected above the MRL in groundwater, subsequent actions to monitor changes in the vertical and/or horizontal extent will be evaluated.

The 1,4-dioxane plume appears to be a very mature plume, which means that it has been migrating away from sources for an extended period of time and has achieved a relatively stable, and possibly maximum extent. These statements are based on the observation that the concentrations between sources and the RMA boundary systems are relatively uniform. The off-post concentrations downgradient of the RMA boundary systems also are relatively uniform. Thus, aside from localized concentration variability within the plume, groundwater concentrations in individual wells would not be expected to show significant increasing trends in the future. Also, there is a very low probability that a higher concentration plume or a new plume exists in areas outside of those shown on Figure 5.1.5.3-1. Any differences in the mapped plume extent in the future likely would be related to changes in the well network or minor localized changes in flow directions, not significant changes in the plume extent. The plume extent may also decrease in the future as it is extracted by the extraction/dewatering systems or flushed out of some areas (e.g., downgradient of the BRES and in the CADT).

While 1,4-dioxane has high mobility in soil and groundwater; residual contamination may be present in the finer-grained soils (silt and clay) in source areas, both above and below the water table, such that the sources could still be active. However, compared to other soluble RMA groundwater contaminants, the maximum groundwater concentrations of 1,4-dioxane are relatively low (266 to 324 µg/L in well 01078). For example, the maximum concentrations of 1,4-dioxane are three orders of magnitude above the CBSG. For other soluble groundwater contaminants such as benzene and chloroform, the maximum concentrations are six orders of magnitude above the CSRG/CBSG. Although there are no RMA Remedial Investigation data or concentration trend data to confirm this, based on the comparison with other contaminants, it appears that the 1,4-dioxane sources may be in a depleted state, and possibly highly depleted Thus, the concentrations downgradient of sources may decrease in the future.

Elements of the existing RMA remedy in the 1,4-dioxane source areas likely would have beneficial effects. These beneficial effects would include the reductions of contaminant volume and mobility, which are caused by reduced infiltration of precipitation and lower groundwater levels and hydraulic gradients in the soil cover and Integrated Cover System areas, and by dewatering in the CADT. Dewatering in the Lime Basins would also be beneficial if this site is a source of 1,4-dioxane.

Determining whether an association with 111TCE and/or TCE exists with 1,4-dioxane contamination at RMA is helpful for understanding the nature and extent of 1,4-dioxane when the data are limited. Determining whether 1,4-dioxane has similar sources and areal extents as other contaminants that were evaluated during the RI/FS (i.e., 111TCE and TCE) has implications for 1,4-dioxane plume interpretations, evaluating remedy effectiveness, subsequent actions, etc.

In the 2011 1,4-dioxane investigation, no current correlation between 1,4-dioxane and 111TCE concentrations appeared to exist, except that higher concentrations of both contaminants occur in or immediately downgradient of the 111TCE source areas (i.e., South Plants, CADT, and North Plants). The initial 1,4-dioxane investigation in 2011 was of a very limited nature (i.e., 18 wells) and only assessed an association with 111TCE. The more comprehensive sampling event in 2012 provides for a more comprehensive evaluation of an association with 111TCE and/or TCE. 111TCE is affected more by attenuation mechanisms, such as volatilization and biodegradation, than 1,4-dioxane and TCE. The greater attenuation of 111TCE probably explains why it generally is not detected farther downgradient of sources, and why there does not appear to be a current association between 111TCE and 1,4-dioxane in these downgradient areas.

1,4-Dioxane was not detected in any of the Railyard and Motor Pool wells. TCE is the primary RMA contaminant in the Motor Pool, and TCE is still detected in the two monitored Motor Pool wells at concentrations below the CSRG of 5 µg/L. Thus, there is no apparent relation between TCE and 1,4-dioxane concentrations in the Motor Pool area, which is located outside of central RMA where the sources of 1,4-dioxane are present. Since 111TCE and TCE have similar source areas in the central portions of RMA, it is difficult to determine whether the 1,4-dioxane contamination at RMA is associated with one or both contaminants.

Vertical Extent - CFS

1,4-Dioxane was not detected in any CFS wells. Therefore, the contamination is limited to the uppermost water-bearing zone or UFS. The depth from the top of bedrock to the top of the sandpack for the CFS wells ranges from 22.9 to 112.7 ft. The CFS wells are shown on Figure 5.1.5.3-1.

The wells in the 2010 LTMP CFS network were monitored for 1,4-dioxane. CFS monitoring in major source areas (i.e., South Plants, Basin A, and Basin F) was specified in the On-Post ROD, and the CFS well network was subsequently developed during remedial design, with concurrence by the Regulatory Agencies. This ROD CFS well network comprises the LTMP CFS network.

The CFS monitoring approach selected in the ROD was based on the conceptual model for the CFS developed during the RI/FS. The CFS conceptual model included the following components: 1) no CFS contaminant plumes are present, and 2) localized CFS contamination may exist adjacent to wells, but the contamination may be present because of well construction or well seal problems or because of limited communication with the UFS. The sites selected to satisfy the ROD CFS monitoring requirement were considered representative for the RMA contaminants evaluated during the RI/FS. Consequently, monitoring of the CFS well network should also be representative for monitoring the vertical extent of 1,4-dioxane. Additionally, since the CFS monitoring network includes wells in or downgradient of three of the four 1,4-dioxane source areas (i.e., South Plants, CADT, and Basin F), the CFS wells sampled are considered by Army and Shell to be adequately representative for determining the vertical extent of 1,4-dioxane in these worst-case locations. Three additional CFS wells that were included in the 2010 LTMP for monitoring at the NBCS were also sampled for 1,4-dioxane in 2012. 1,4-Dioxane was not detected in any of the CFS wells, including the NBCS wells. These results are consistent with the CFS conceptual model.

Vertical Extent - UFS

As discussed above, 1,4-dioxane was found to occur only in the uppermost water bearing zone, which is the UFS. Since hydraulic conductivity contrasts exist between the alluvial aquifer and the underlying upper weathered Denver Formation (both of which are in the UFS), differences in the vertical extent of 1,4-dioxane within the UFS may exist. Generally, the alluvial aquifer has higher hydraulic conductivity than the weathered Denver bedrock.

Wells screened in the alluvium, unconfined Denver Formation, and confined Denver Formation were sampled at the NBCS. 1,4-Dioxane was detected in all of the alluvial wells located adjacent to or near the Denver wells, in five of the eight unconfined Denver wells, and was not detected in the three confined Denver wells.

1,4-Dioxane was detected in unconfined Denver wells 23235, 23194, 23195, 23540, and 23541 at concentrations below the CBSG. Generally, the concentrations in the Denver wells are lower than in the adjacent alluvial or alluvial/Denver (A/D) well. 1,4-Dioxane was detected in the unconfined Denver wells that also have historical detections of other organic contaminants (e.g., chloroform, DIMP, tetrachloroethylene, etc.). There likely is a better vertical hydraulic connection between the alluvium and the unconfined Denver sandstones screened in these wells than exists where 1,4-dioxane was not detected. Consequently, some of the unconfined Denver wells may actually be semi-confined where 1,4-dioxane was not detected. The depth from the top of bedrock to the top of the sandpack for the unconfined Denver wells ranges from 6.4 to 24.4 ft.

1,4-Dioxane was not detected in the three CFS wells sampled at the NBCS. The depth from the top of bedrock to the top of the sandpack for the CFS wells ranges from 37 to 102 ft.

The 1,4-dioxane results for the NBCS UFS and CFS wells are consistent with the water quality data for other contaminants at the NBCS. Where 1,4-dioxane is present in the alluvial aquifer, 1,4-dioxane likely will also be detected in the underlying Denver Formation bedrock where the bedrock is weathered or where Denver sandstones subcrop, and are in contact with the alluvium, such that there is a vertical hydraulic connection between the alluvium and underlying bedrock. 1,4-Dioxane is also present in the upper weathered bedrock where the alluvium is unsaturated in areas that are in or downgradient of sources. Where the Denver sandstones are semi-confined or confined, 1,4-dioxane typically would not be present.

Treatment Systems

Table 5.1.5.3-1 shows average annual 1,4-dioxane concentrations for the treatment plant influents and effluents for FY12, FY13, and FY14. Except for the RYCS, 1,4-dioxane was detected at or above the MRL in one or both sample locations at each system. The average annual influent and effluent concentrations were below the CBSG of 0.35 µg/L, except at BANS, which is an internal mass removal system. Although not part of the 1,4-Dioxane Characterization SAP, the treatment plants have been sampled quarterly for 1,4-dioxane since April 2012.

Although none of the RMA treatment systems include a treatment process for 1,4-dioxane, the concentrations downgradient of the two boundary containment systems (NWBCS and NBCS) and downgradient of the OGITS extraction and recharge systems generally are below the CBSG and lower than upgradient concentrations (Figure 5.1.5.3-1). This is caused by the blending effect of extracting groundwater in wells where the concentrations are above the CBSG in some wells and below the CBSG in other wells, which is then combined in the plant influent sumps.

Table 5.1.5.3-1. Treatment Plant Influent and Effluent Results for 1,4-Dioxane

System	Location	Site ID	FY12 Average Concentration, µg/L	FY13 Average Concentration, µg/L	FY14 Average Concentration, µg/L
BANS	Influent	PAININ	1.02	1.64	1.87
BANS	Effluent	PAEFEF	1.21	1.28	1.25
NBCS	Influent	PNININ	0.32	0.38	0.288
NBCS	Effluent	PNEFEF	0.30	0.29	0.218
NWBCS	Influent	PWININ	0.26	0.31	0.28
NWBCS	Effluent	PWEFEF	0.25	0.30	0.28
OGITS	Influent	PPININ	0.14	0.17	0.16
OGITS	Effluent	PPEFEF	0.15	0.15	0.15
RYCS	Adsorber Influent	PR302IN	LT 0.1	LT 0.1	LT 0.1
RYCS	Effluent	PREFEF	LT 0.1	LT 0.1	LT 0.1

Note: “LT” denotes Less Than the MRL.

Surface Water

Table 5.1.5.3-2 provides the results for the surface water sampling sites. The 1,4-dioxane concentrations were below the MRL of 0.1 µg/L at all of the sites, except Lake Ladora site SW020009. The site SW020009 concentration was 0.48 µg/L in 2013, which is slightly above the current groundwater standard of 0.35 µg/L. A Colorado Human Health Based standard of 0.35 µg/L exists for surface water segments classified for Water Supply (5 Code of Colorado Regulations 1002-31). There are no Colorado Aquatic Life Based surface water standards for 1,4-dioxane (5 Code of Colorado Regulations 1002-31). As a follow-up action, Lake Ladora sites SW02020 and SW020009 will be sampled again in 2015.

Table 5.1.5.3-2. Surface Water Results for 1,4-Dioxane

Location	Site ID	Sample Date	Concentration, µg/L
Borrow Area 5	SW24005	9/12/2013	LT 0.1
Former Basin E Pond	SW26002	9/12/2012	LT 0.1
North Plants	SW25101	9/11/2013	LT 0.1
Lower Derby Lake	SW01006	9/13/2012	LT 0.1, LT 0.1 (D)
Lake Ladora	SW02020	9/12/2012	LT 0.1
Lake Ladora	SW02021	9/12/2012	LT 0.1
Lake Ladora	SW020009	5/13/2013	0.48
First Creek at Buckley Rd.	SW08003	8/21/2013	LT 0.1
First Creek at 96th Ave.	SW24004	2/7/2013 8/21/2013	LT 0.1 LT 0.1
First Creek at Hwy. 2	SW37001	2/7/2013 8/21/2013	LT 0.1 LT 0.1

Note: "LT" denotes Less Than the MRL.

Conclusions and Recommendations

The data indicate that the horizontal extent of 1,4-dioxane contamination in the UFS is above the MRL in RMA groundwater. 1,4-Dioxane was not detected in the CFS wells. An assessment of whether 1,4-dioxane should become an RMA COC will be conducted in the FYRR. Additional monitoring is warranted to evaluate changes in the horizontal extent as discussed in the SAP. Given the apparently stable extent of the 1,4-dioxane plume and uniform concentrations between sources and boundary systems and off-post, a 1,4-dioxane sampling frequency of once in five years for selected LTMP UFS monitoring categories is proposed for evaluating changes in the extent. Proposed actions include adding 1,4-dioxane to the analyte list for LTMP Water Quality Tracking network wells, Performance wells (except at the RYCS), Groundwater Mass Removal Post-Shut-Off wells, and the Offpost Exceedance network wells in 2017, which is the next once in five-year sampling event in the 2010 LTMP. If 1,4-dioxane is added to the RMA COC list, then it will be added to the appropriate LTMP monitoring category analyte lists.

Because the data evaluation has not been completed, continued monitoring is recommended to assist in the final determination of whether 1,4-dioxane will be added to the RMA COC list. Accordingly, the Army and Shell have the following recommendations for the scope of monitoring in 2017: 1) the scope will be similar to that in 2012, including the wells added in 2015; 2) areas where 1,4-dioxane was not detected that will not need to be sampled in 2017 include the RYCS area and the upgradient NBCS performance wells on the east side of the NBCS; and 3) areas where additional wells should be included in 2017 are the east and west sides of South Plants (wells 01041, 02014, 02041, and 35013), the areas between the BANS and Basin F (wells 26051, 26071, and 26158), downgradient from Sand Creek Lateral in Section 35 (well 35037), and western Section 23 (well 23140).

Adding 1,4-dioxane to the analyte list for Motor Pool Post-Shut-Off wells is not necessary because it was not detected above the MRL in these wells. Adding 1,4-dioxane to the analyte list for the Lime Basins DNAPL Remediation wells is not necessary because these wells are within the defined plume extent, and the existing Lime Basins monitoring program meets the project objectives.

The data indicate that 1,4-dioxane contamination above the MRL was detected in one of the three Lake Ladora surface water samples (i.e., in SW020009). Subsequent actions include sampling of the two Lake Ladora sites where 1,4-dioxane groundwater contamination is present onshore (i.e., sites SW02020 and SW020009) in 2015 for confirmation. If 1,4-dioxane is detected above the CBSG at that time, then further investigation may be warranted.

The treatment plant data indicate that 1,4-dioxane was detected in some of the selected RMA treatment plant locations. Thus far, except for the internal BANS, the RMA treatment plant effluent concentrations have been below the CBSG of 0.35 µg/L. An assessment of whether treatment may be needed has not yet been conducted. Proposed actions include continued monitoring of the affected treatment plant influents and effluents (i.e., BANS, NBCS, NWBCS, and OGITS). Annual monitoring of 1,4-dioxane in the affected treatment plant influents and effluents is proposed. 1,4-Dioxane compliance issues will be addressed in the 2015 Five-Year Review Report.

Operations and Maintenance Change Notices will be prepared to document the changes in the affected analytical programs. Continued monitoring of 1,4-dioxane would be re-evaluated during the next CERCLA Five-Year Review in 2020. If 1,4-dioxane is added to the RMA COC list, then it will be added to the appropriate LTMP monitoring category analyte lists.

SUMMARY

The objective of the sampling program was to characterize the horizontal and vertical extent of 1,4-dioxane in groundwater at the RMA and assess the concentrations in the treatment plant influent and effluent. Selected surface water sampling locations were included to assess potential 1,4-dioxane contamination where surface water/groundwater interaction potentially occurs and in soil cover areas.

The investigative sample concentrations were above the MRL of 0.1 µg/L in the majority of groundwater samples for UFS wells, both on-post and off-post. The 1,4-dioxane concentrations in 60 on-post wells were above the CBSG of 0.35 µg/L, and nine off-post wells were above the CBSG, including two private wells. The two water supply wells in Section 4 were above the CBSG, but these wells are located in a plume with sources located upgradient of RMA. 1,4-Dioxane was not detected in any CFS wells. Therefore, the 1,4-dioxane contamination is limited to the uppermost water-bearing zone.

The apparent sources of 1,4-dioxane include South Plants, North Plants, CADT, and Basin F and are consistent with the known sources of 111TCE and TCE, which may be associated with 1,4-dioxane. Since 111TCE and TCE have similar source areas in the central portions of RMA, it is difficult to determine whether the 1,4-dioxane contamination at RMA is associated with one or both contaminants. Where only TCE is known to have been present historically in the Motor Pool area, 1,4-dioxane was not detected.

The treatment plant effluent concentrations were below the CBSG of 0.35 µg/L, except at BANS, which is an internal mass removal system.

The 1,4-dioxane concentrations were below the MRL of 0.1 µg/L at all of the surface water sites, except Lake Ladora site SW020009.

Evaluation of the 1,4-dioxane standard, effect on remedy protectiveness, and recommendation on whether to adopt the standard is ongoing and is included as an issue in the 2015 FYRR. Additional monitoring will be done, as discussed above, and will be specified and documented in OCNs.

5.1.5.4 Landfill Wastewater Treatment System Closure Monitoring

Twelve wells are in the LWTS monitoring network and are shown on Figure 5.1.4.1-1. Water level and water quality monitoring were conducted quarterly from October 2009 through January 2011 for closure monitoring at the LWTS. Three of the twelve wells were dry.

Groundwater flow directions under the LWTS were consistent over the six quarters of monitoring, and overall groundwater flow direction was consistent with previous groundwater monitoring within the CAMU.

Of the indicator compounds (ICs) detected in the downgradient wells, chloroform, lead, silver, endrin, and bromodichloromethane exceeded the calculated upper prediction limits during closure monitoring. The chloroform detections occurred in a downgradient well that were similar to the chloroform concentrations in an upgradient well in a similar flow path. The other detections are considered anomalous or suspect because of blank contamination, detection in a CFS well, but not in the adjacent UFS well, and one-time detections. For example, the lead detections only occurred during one (April 2010) of the six sampling events.

5.2 Off-Post Data Review, Evaluation, and Assessment

The off-post data review includes evaluations of the following:

- Groundwater monitoring results and operational data for groundwater mass removal system.
- Groundwater monitoring results for the off-post exceedance monitoring program conducted according to the LTMP.
- Surface water monitoring results. Chemical data included in this assessment have been determined to meet the quality requirements for usability. The chemical data were validated in accordance with the processes outlined in the RVO CQAPs or the SQAPP in effect at the time of sampling (RVO 2009, Navarro 2014a) as well as the related applicable procedures.

A summary of the data validation results for data collected during future FYR periods will be presented in the ASRs.

5.2.1 Off-Post System Evaluation

As described in Section 1.4.2, the OGITS is a mass removal system designed to extract and treat contaminated alluvial groundwater from the First Creek and Northern Pathway alluvial channels, downgradient of the NBCS, and return treated water to the alluvial aquifer. Figure 5.2.1-1 is the well location map for the FCS, and Figure 5.2.1-2 is the well location map for the NPS.

Modifications to the NPS extraction and recharge systems were made in 2006 to accelerate the cleanup of groundwater between Highway 2 and the Original NPS extraction system (George Chadwick Consulting 2005). Modifying the NPS was not required to meet ROD requirements, but was funded by the property owner to develop the property. However, the RVO has sole responsibility for operating the modified NPS to meet ROD requirements. Six extraction wells, five recharge trenches, 24 monitoring wells, and 14 recharge trench piezometers were installed along Highway 2, upgradient of the Original NPS extraction wells. The new wells are shown on Figure 5.2.1-2. The NPS Modifications began operation in September 2006.

Consistent with the on-post groundwater systems, the ASRs are referenced for information regarding the effectiveness of the OGITS (RVO 2011, 2012, Army and Shell 2013, Navarro 2015a, 5015b). The information in the ASRs is summarized for OGITS in the following sections addressing treatment system effluent compliance monitoring, influent and upgradient performance well concentrations, mass removal performance, and downgradient performance well water quality monitoring results.

As documented in the ASRs, the only CSRG exceedances in the OGITS effluent were exceedances of chloride and sulfate, which have future attenuation requirements. Chloride and sulfate are not treated by the OGITS treatment system and the chloride and sulfate CSRGs will be met in the OGITS effluent by attenuation, consistent with the on-post remedy. The average chloride concentration in the OGITS effluent was 288,132 µg/L for the FYR period. The chloride concentrations decreased to below the CSRG in the OGITS effluent during the FYR period, and the FY14 moving average was below the CSRG. The sulfate concentrations averaged 559,974 µg/L in the effluent for the FYR period and the FY14 moving average also was below the CSRG. Because the OGITS is a mass removal system, maintaining reverse hydraulic gradients and plume capture are not required. Table 5.2.1-1 shows that the contaminant removal decreased from 15.9 to 5.9 lbs during the review period. The majority of the reduction is attributed to decreasing concentrations of DIMP and DCPD in the plumes upgradient of the system.

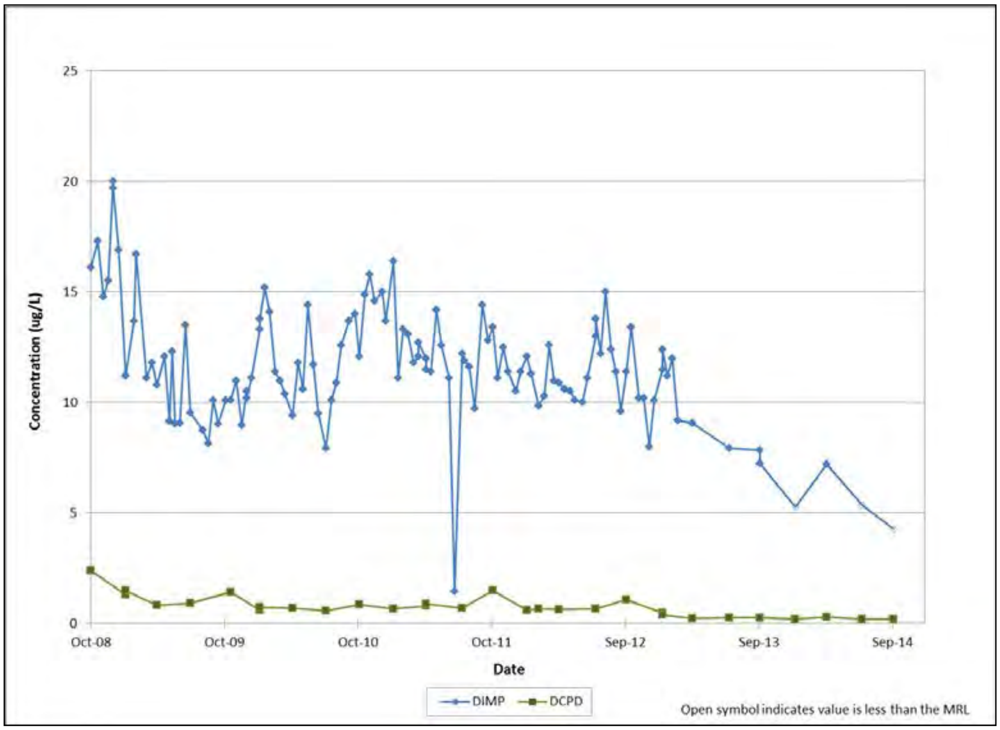
Table 5.2.1-1 OGITS Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total volume treated (gal)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2010	271	142,992,893	15.9	DIMP 12.8 DCPD 0.9 PCE 0.6 Chloroform 0.9	60,000	$915,252
2011	232	122,475,051	12.9	DIMP 11.3 DCPD 0.7 PCE 0.4 Chloroform 0.5	80,000	$1,145,850
2012	199	104,699,520	11	DIMP 9.4 DCPD 0.7 Chloroform 0.5 PCE 0.4	80,000	$1,130,127
2013	166	87,349,464	6.9	DIMP 6.0 DCPD 0.3 Chloroform 0.3 PCE 0.3	60,000	$881,544
2014	205	107,663,904	5.9	DIMP 5.3 DCPD 0.08 Chloroform 0.2 PCE 0.2 MEC6H 5 0.1	40,000	$615,507
Total	215 (avg.)	565.2 million	52.6		320,000	$4,688,280

The treatment plant influent concentration data indicate the general trends in plume concentrations upgradient of the system. DIMP, DCPD, dieldrin, and chloroform are the CSRG analytes of greatest extent upgradient of the OGITS. Most of the CSRG analytes showed decreasing concentration trends during the review period.

DIMP and DCPD concentrations in the OGITS influent decreased steadily during the FYR period (Figure 5.2.1-3), with DIMP ranging from 15.2 µg/L in FY10 to 5.27 µg/L in FY14 and averaging 10.3 µg/L, which is above the CSRG of 8 µg/L. DIMP concentrations were above the CSRG in only 3 of the 16 operating OGITS extraction wells in FY14, and all of the wells above the CSRG are in the FCS. Figure A-18 shows the DIMP concentrations in the upgradient performance wells for the FCS and NPS in FY10 and FY14. The DIMP concentrations in the majority of wells were lower in FY14 than in FY10.

Figure 5.2.1-3. OGITS Influent Concentrations for DIMP and DCPD



DCPD concentrations in the OGITS influent decreased overall from 1.48 µg/L in FY10 to LT 0.2 µg/L in FY14 and averaging 0.63 µg/L, which is well below the CSRG of 46 µg/L. DCPD concentrations were below the CSRG in all 16 operating OGITS extraction wells in FY14. The DCPD concentrations in the upgradient performance wells decreased from FY09 to FY14 and were below the CSRG in both years. DCPD is only detected in the FCS wells (Figure A-19).

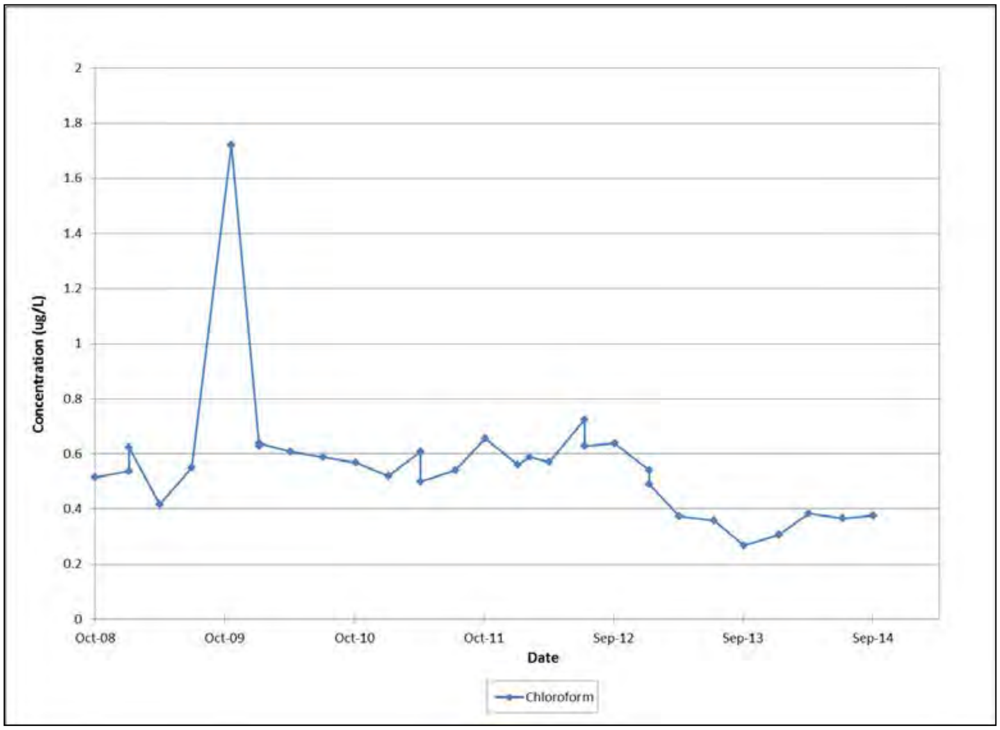
Dieldrin concentrations in the OGITS influent were relatively stable, averaging 0.0192 µg/L, which is below the former PQL of 0.05 µg/L, but above the current PQL of 0.013 µg/L. Dieldrin concentrations were above the PQL in five of the 16 operating OGITS extraction wells in FY14.

Figure A-20 shows the upgradient performance wells in FY10 and FY14. The dieldrin concentrations were similar or lower in most of the wells in FY14 than in FY10, but with the lower PQL in FY14, more wells were above the PQL in FY14 than in FY10.

Chloroform concentrations in the OGITS influent decreased overall during the FYR period (Figure 5.2.1-4), ranging from 1.728 µg/L in FY10 to 0.268 µg/L in FY14, and averaging 0.57 µg/L, which is below the CSRG of 6 µg/L. Chloroform concentrations were below the CSRG in all 16 operating OGITS extraction wells in FY14. The NPS chloroform plume appears wider in FY14 than in FY10, but all upgradient performance wells were well below the CSRG in FY14 (Figure A-21).

Chloride concentrations in the OGITS influent decreased to below the CSRG during the FYR period, averaging 276,825 µg/L. Sulfate concentrations also decreased to below the CSRG during the FYR period, averaging 550,925 µg/L.

Figure 5.2.1-4. OGITS Influent Concentrations for Chloroform



OGITS Mass Removal

One performance criterion for the OGITS is to demonstrate effective mass removal of each organic CSRG analyte. Prior to 2010, there were no quantitative mass removal criteria for evaluating the performance of the OGITS. In the 2010 LTMP, 75 percent mass removal was set as the goal, pending further evaluation after collecting additional data for five years. As opposed to treatment system compliance with CSRGs, the mass removal criterion refers to removing at least 75 percent of the contaminant plume mass migrating toward the system during a specified time period (mass flux). Wells were added to the FCS and NPS upgradient performance well networks in the 2010 LTMP to provide more data for estimating the mass removal.

Due to limited data for estimating the mass flux along a transect of the FCS upgradient performance wells, the mass flux is estimated using a combination of well capture and transect methods. Not all of the groundwater flow in the First Creek Pathway is captured by the extraction system. Thus, the well capture method is used to estimate the mass flux within the system capture zone and the transect method is used to estimate the mass flux outside of the capture zone. The flow outside the capture zone is north of recharge trench RT-1 near well 37076. In FY12, RT-1 was shut down to improve the mass removal performance. The transect method is used for estimating the mass flux in the NPS because sufficient data are available for a transect of wells upgradient of the extraction systems.

Since the OGITS treatment plant treats the combined flow from the FCS and NPS, the treatment plant monitoring data are not FCS- or NPS-specific. Thus, the mass removed by the FCS and NPS is calculated separately based on the difference between the annual average concentrations for the FCS and NPS extraction wells and the OGITS treatment plant annual average effluent (PPEFEF) concentrations, multiplied by the average annual flow rates for the extraction wells. The equivalent calculations are done for the FCS and NPS influents (PPINFC and PPINNP) for comparison to the sums of the individual extraction well data for the FCS and NPS. The mass removed for the combined flow from the FCS and NPS also is calculated for the OGITS treatment plant using the combined influent (PPININ) and effluent (PPEFEF) concentration data and flow rates (Table 5.2.1-2).

Mass Flux and Mass Removal Estimates

The estimated mass flux, mass removed and mass removal percentage for the NPS, FCS, Summed NPS and FCS, and the OGITS treatment plant for FY10 through FY14 are provided in Table 5.2.1-2.

The estimated total mass flux for the NPS decreased from 2.2 lbs/year in FY10 to 1.1 lbs/year in FY14. The estimated mass removal of the total mass flux for the NPS ranged from 42 to 109 percent. However, only a portion of the total mass flux is present at concentrations above the CSRGs/PQLs. The 2010 LTMP mass removal performance criteria for OGITS did not distinguish between CSRG analytes above and below the CSRG/PQL, but only discussed a comparison of the total mass flux approaching the system and the total calculated mass removed for the CSRG analytes. However, the mass removal performance of the system can be underestimated when the upgradient concentrations are below the remediation goals. During the previous FYR period, the majority of the NPS mass flux and mass removed was for DIMP and chloroform, which were below CSRGs in all the upgradient monitoring wells and extraction wells in FY08 and FY09. The FYSR stated that, "…the future performance evaluations should consider whether the upgradient concentrations of individual compounds are below CSRGs when the mass removal performance is evaluated."

During this FYR period, the NPS mass removal was calculated using the total mass flux for FY10 through FY12, and the NPS mass removal was calculated two ways for FY13 and FY14; using the total mass flux and the mass flux of analytes above CSRGs/PQLs. In FY13, DIMP comprised 58 percent of the total mass flux, but the upgradient concentrations were below the CSRG. The OGITS average effluent concentration of DIMP was 1.47 µg/L and was higher than the NPS influent concentration (0.927 µg/L). Consequently, there was no net removal of DIMP for the NPS in the mass removal calculations, and the mass removal was estimated to be 42 to 58 percent of the total mass flux, well below the 75 percent goal. However, if DIMP is excluded from the calculation, the mass removal was at least 98 percent of the mass flux, which is a more realistic estimate of the performance, and is more consistent with the downgradient performance well water quality data, which shows effective capture of the plumes.

In FY14, the mass flux of the analytes above CSRGs/PQLs in the upgradient performance and operational wells was only two percent of the total mass flux and was estimated to be only 0.024 lb/year. Of the organic CSRG analytes, only carbon tetrachloride and dieldrin concentrations were above the CSRG/PQL in upgradient wells in FY14. In Table 5.2.1-2, the mass removal for the total mass flux (82-95 percent) and the mass removal for analytes above CSRGs/PQL (83 percent) were more similar. Based on the removal of the total mass flux in FY10 through FY12 and removal of the mass flux of analytes above CSRGs/PQLs in FY13 and FY14, the NPS met the 75 percent mass removal goal.

Prior to FY14, the ASRs discussed concerns about decreasing extraction-well capacity and decreasing mass extraction/mass removal for dieldrin in the NPS (e.g., the dieldrin mass removal had decreased to 76 percent in FY13). The capacity of NPS Modifications well 37818 that pumps from the dieldrin plume has declined over the years, primarily due to biofouling, and pumps a smaller percentage of the dieldrin plume mass (i.e., 56 percent in FY10 and 11.5 percent in FY14). However, the mass removal for dieldrin was estimated to be almost 100 percent or greater in FY14. The increased dieldrin mass removal in FY14 is explained by lower upgradient dieldrin concentrations, lower dieldrin mass flux, and higher pumping rates in extraction wells other than well 37818. The dieldrin mass removal will continue to be evaluated separately for the annual NPS assessments.

In the FCS, the total mass flux decreased from 16.7 lbs/year in FY10 to 4.9 to 6.1 lbs/year in FY14. The FCS mass removal ranged from 69 to 92 percent. The total mass flux vs. mass flux of analytes above CSRGs is less of an issue in the FCS because the primary mass component is DIMP, which is still above the CSRG. As Table 5.2.1-2 shows, the FCS mass removal was near or below the 75 percent goal during FY10 through FY12. Except for FY12, the mass removal for the combined NPS and FCS (Summed NPS and FCS and OGITS) was greater than 75 percent.

When it became apparent in FY12 that the mass removal might be less than 75 percent, recharge trench RT-1 was turned off near the end of FY12 to improve the FCS performance. Supplemental water level monitoring was conducted to determine if the resulting changes in the water elevations would have the desired effect. The preliminary results were positive and indicated that the resulting mass removal would increase to about 90 percent. Consequently, RT-1 has remained off line. The estimated FCS mass removal in FY13 and FY14 was approximately 90 percent. Thus, the FCS met the mass removal goal after the operational change was made in FY12.

The summed NPS and FCS mass removal and the OGITS treatment plant mass removal are included in Table 5.2.1-2 to provide the overall system performance estimates. The Summed NPS and FCS results compare favorably with the combined OGITS treatment plant results, which indicate that the NPS and FCS calculation methods are sufficiently accurate.

As stated previously, the 75 percent mass removal goal would be reviewed after five years of data have been collected. Based on the performance during this FYR period, increasing the performance goal to greater than 75 percent was considered. However, as contaminant concentrations decline in the future, the contaminant concentrations in the upgradient wells may approach the CRSGs/PQLs. Meeting the 75 percent mass removal goal could then become more difficult because of limitations in the calculations when the dewatering well and FCS- and NPS-specific influent concentrations approach the CSRGs/PQLs, and may also be unnecessary to meet ROD compliance requirements. For example, when the upgradient concentrations of a groundwater contaminant decrease to below the remediation goal (CSRG/PQL), treatment of that analyte and further removal of its contaminant mass no longer are required. Thus, calculating the mass flux/mass removal for analytes below CSRGs/PQLs in the upgradient wells should be discontinued for determining the mass removal performance of OGITS. Consequently, as concentrations decline in the future, lowering the mass removal goal may be appropriate to be consistent with ROD compliance. Additionally, as contaminant concentrations decline, the treatment efficiencies may also decline, which may make attainment of 75 percent mass removal more difficult. Army and Shell will continue to optimize the system operation for mass removal, and proposes to retain the 75 percent mass removal goal.

Table 5.2.1-2. Mass Flux, Mass Removed, and Mass Removal Percentage.

Fiscal Year	Total Mass Flux, lbs/year (Analytes > CSRGs)	Mass Removed, lbs/year (Analytes > CSRGs)	Mass Removal, percent (Analytes > CSRGs)
NPS			
2010	2.2	2.4	109
2011	1.8	1.6	89
2012	1.8	1.4-1.5	78-83
2013	1.2 (0.51)	0.5-0.7	42-58 (98-137)
2014	1.1 (0.024)	0.9-1.05	82-95 (83)
Average	1.62	1.36-1.45	80-86.8
FCS			
2010	16.7	11.9	71
2011	14.8	11.1	75
2012	12.9-13.6	8.9-9.7	69-71
2013	6.4-7.2	5.6-6.6	88-92
2014	4.9-6.1	4.4-5.5	90 (91-92)
Average	11.1-11.7	8.4-9.0	78.6-79.8
Summed NPS and FCS			
2010	18.9	14.3	76
2011	16.6	12.7	77
2012	14.7-15.4	10.3-11.2	70-73
2013	7.6-8.4 (6.9-7.7)	6.3-7.1	83-85 (91-92)
2014	6.0-7.2 (4.8-5.6)	5.3-6.6	88-92 (91-92)
Average	12.8-13.3	9.8-10.4	78.8-80.6

Table 5.2.1-2. Mass Flux, Mass Removed, and Mass Removal Percentage (Concluded)

Fiscal Year	Total Mass Flux, lbs/year (Analytes > CSRGs)	Mass Removed, lbs/year (Analytes > CSRGs)	Mass Removal, percent (Analytes > CSRGs)
OGITS			
2010	18.9	15.9	84
2011	16.6	12.9	78
2012	14.7-15.4	11.0	71-75
2013	7.6-8.4 (6.9-7.7)	6.9	82-91 (90-100)
2014	6.0-7.2 (4.8-5.6)	5.9 (5.3)	82-98 (95-111)
Average	12.8-13.3	10.5	79.4-85.2

The second performance criterion for OGITS is to demonstrate that concentrations of CSRG analytes are below the CSRGs/PQLs or are stable or decreasing in downgradient performance wells. Evaluation of the water quality data in the downgradient performance monitoring wells for each system shows that there were a few analytes with concentrations above CSRGs/PQLs in the downgradient wells during the review period. Table 5.2.1-3 summarizes the downgradient well data for all the CSRG analytes.

Table 5.2.1-3. Overview of CSRG Analyte Sampling from OGITS Downgradient Performance Wells

CSRG Analyte[1] (The concentration in parentheses is the CSRG or PQL for the respective analyte)		Concentrations above the CSRG or PQL/Number of Samples Collected											
		First Creek System				Northern Pathway System							
		37084	37110	37343	37027*	37008	37009	37010	37011	37012	37013	37039*	37452*
1,2-Dichloroethane	(0.40 µg/L)	0/5	0/6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
1,3-Dichlorobenzene	(6.5 µg/L)	0/5	0/6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
1,4-Oxathiane	(160 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Aldrin[a]	(0.002 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
Arsenic	(2.35 µg/L)	0/5	0/5	0/5	0/5	1/5	0/5	0/5	1/5	0/5	0/5	0/5	0/5
Atrazine	(3 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Benzene	(3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Carbon tetrachloride	(0.30 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Chlordane	(0.03 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
Chloride	(250 mg/L)	5/5	5/5	5/5	1/5	0/5	4/5	4/5	0/5	4/5	2/5	4/5	2/5
Chlorobenzene	(25 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Chloroform	(6 µg/L)	0/5	0/6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Chlorophenylmethyl sulfide	(30 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Chlorophenylmethyl sulfone	(36 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Chlorophenylmethyl sulfoxide	(36 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Dibromochloropropane	(0.2 µg/L)	0/5	0/6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/14	0/5
Dichlorodiphenyldichloroethane	(0.1 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	(0.1 µg/L)	0/1	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
Dicyclopentadiene (DCPD)	(46 µg/L)	0/5	0/6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5

Table 5.2.1-3. Overview of CSRG Analyte Sampling from OGITS Downgradient Performance Wells (Concluded)

CSRG Analyte[1] (The concentration in parentheses is the CSRG or PQL for the respective analyte)	Concentrations above the CSRG or PQL/Number of Samples Collected											
	First Creek System				Northern Pathway System							
	37084	37110	37343	37027*	37008	37009	37010	37011	37012	37013	37039*	37452*
Dieldrin[b] (0.002 µg/L)	1/5	0/5	2/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
Diisopropylmethyl phosphonate (DIMP) (8 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Dithiane (18 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/2	0/2	0/2	0/1	0/1
Endrin (2 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Ethylbenzene (200 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Fluoride (2 mg/L)	0/5	5/5	0/5	5/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Hexachlorocyclopentadiene (0.23 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Isodrin (0.06 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
Malathion (100 µg/L)	0/2	0/2	0/2	0/0	0/2	0/2	0/2	0/5	0/2	0/2	0/1	0/1
n-Nitrosodimethylamine[c] (NDMA)[c] (0.007 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Sulfate (540 mg/L)	5/5	5/5	5/5	1/5	0/5	1/5	4/5	0/5	0/5	0/5	1/5	1/5
Tetrachloroethylene (PCE) (5 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Toluene (1000 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Trichloroethylene (3 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5
Xylenes (1000 µg/L)	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/21	0/5

Notes:
1. The ROD lists the following certified reporting limits or PQLs as readily available:
[a] PQLs = 0.05 and 0.014 µg/L [b]PQLs = 0.05 and 0.013 µg/L [c]PQLs = 0.033 and 0.018 µg/L
A PQL study of aldrin, dieldrin, and NDMA was conducted in 2012.
* Cross-gradient

Aldrin, arsenic, chlordane, chloride, dieldrin, fluoride, isodrin, DDE, DDT, and sulfate concentrations were above the CSRGs/PQLs in one or more wells. The OCP detections in NPS well 37039 (aldrin, chlordane, dieldrin, isodrin, DDE, and DDT occurred in FY12 and were suspect based on historical data in well 37039 and contemporaneous adjacent-well data. The detections in well 37039 occurred for the first time in FY12 and were not repeated in FY13 or FY14. Thus, the FY12 detections likely were erroneous.

Of the CSRG analytes that were detected more than once, dieldrin was above the PQL in FCS well 37343 in two of five samples. The dieldrin trend in well 37343 is decreasing overall. Fluoride is consistently above the CSRG in NPS cross-gradient well 37027 and FCS downgradient well 37110. These wells are located at the edge of the First Creek and Northern Pathway and First Creek and paleochannels, respectively, where the groundwater flow appears to be discharging from the weathered bedrock into the alluvium and/or may be stagnant. Fluoride concentrations are higher in the bedrock and the concentrations in these two wells are higher than in the upgradient wells. Thus, the fluoride concentrations do not appear to be representative of system performance. The chloride and sulfate concentrations are above the CSRGs in several FCS and NPS wells, but are decreasing. The OGITS effluent concentrations of chloride and sulfate decreased to below the CSRGs in FY14. Thus, the concentrations in the downgradient wells should continue to decrease in the future.

OGITS Evaluation Conclusions

Based on criteria in the Off-Post ROD, Off-Post RS/S, 1999 LTMP, and 2010 LTMP, the OGITS functioned as intended in the Decision Documents during most of the FYR period. The mass removal performance of the FCS was below the 75 percent goal in FY10 and FY12, and the combined FCS and NPS was below the goal in FY12. An operational change made in FY12 improved the FCS performance, and it met the mass removal goal in FY13 and FY14. Chloride and sulfate concentrations exceeded CSRGs in the OGITS effluent during four of the five years, but these analytes are not treated by OGITS and will meet CSRGs in the effluent by attenuation, consistent with the on-post remedy. In FY14, the chloride and sulfate moving average concentrations were below the CSRGs. For the other CSRG analytes, the concentrations were below CSRGs/PQLs in the treatment plant effluent.

The contaminant concentrations either are stable, decreasing, or are below CSRGs/PQLs in the downgradient wells. Arsenic was detected above the CSRG once in two wells downgradient of the NPS (in FY10). While the arsenic detected in downgradient wells 37008 and 37011 may be related to the upgradient plume, other explanations suggest that the arsenic plumes are separate and different sources of arsenic may exist downgradient of the NPS extraction wells. Fluoride is present above the CSRG in one downgradient well in the FCS, and one cross-gradient well in the NPS. The higher fluoride concentrations in these wells appear unrelated to OGITs effectiveness.

As stated previously, the OGITS 75 percent mass removal goal would be reviewed after five years of data have been collected. Army and Shell will continue to optimize the system operation for mass removal, and proposes to retain the 75 percent mass removal goal. The 75 percent mass removal goal may need to be lowered in the future as carbon removal efficiencies will decrease. In Army and Shell’s opinion, calculating the mass flux/mass removal for analytes below CSRGs/PQLs in the upgradient wells should be discontinued for determining the mass removal performance of OGITS.

A revision to the 2010 LTMP is being considered for 2017. The OGITS 75 percent mass removal goal and associated methodology will be re-evaluated during the revision process. Until then, both the 75 percent goal and methodology will be retained. The mass removal will continue to be calculated by both methods with respect to the CSRGs/PQLs (total mass flux and mass flux for analytes above CSRGs/PQLs) and with respect to the two data sets (dewatering wells and FCS/NPS-specific influents).

5.2.2 Off-Post Exceedance and Water Level Monitoring

Off-post water level monitoring was conducted annually in the wells listed in Table 5.2.2-1. The table is updated from the 1999 LTMP well network to include revisions made in the Well Networks Updates included in the ASRs for FY10 through FY14. Water level data from water level monitoring wells are used to determine groundwater flowpaths in the off-post area and aid in mapping of the Off-post CSRG Exceedance areas. Figure 5.1.3-1 provides a comparison between on-post and off-post water levels measured in 2009 and 2014, which reflects the overall changes in water levels during the FYR period. Individual water-level maps for 2010, 2011, 2012, 2013, and 2014 are presented in Figures 5.1.3-2 through 5.1.3-6. Figure 5.1.3-7 illustrates the change in water elevations between 2009 and 2014.

A comparison of water levels from FY09 to FY14 is shown in Figure 5.1.3-1. The figure shows that no significant changes in flow directions occurred off post upgradient of the OGITS FCS and NPS. A small groundwater mound near the RMA boundary at the NBCS is shown on the FY14 map. This mound was related to groundwater dewatering activities for construction of a natural gas pipeline. Figure 5.1.3-7 shows that off-post groundwater levels were higher in much of the offpost area in FY14 after the September 2013 and May 2014 rainstorms. Water levels were higher in the vicinity of O'Brian Canal where it is unlined, but not north the NPS where a portion of the canal is lined. Seepage from unlined portions of the irrigation canals recharges the groundwater and affects the groundwater elevations near the canals. A portion of O'Brian Canal near the NPS in Section 12 was relocated and lined in 2008. The flow in the canals is seasonal and varies from year to year.

Table 5.2.2-1. Off-Post Water Level Network (2010 LTMP and Well Networks Update Revisions)

Off-post Wells										
37008	37009	37010	37011	37012	37013	37027	37039	37041	37062	37063
37065	37070	37071	37073	37074	37075	37076	37080	37081	37083	
37084	37094	37095	37097	37103	37107	37108	37110	37125	37126	
37150	37151	37320	37323	37327	37328	37334	37335	37336	37337	37338
37339	37341	37342	37343	36346	37347	37348	37349	37350	37351	37353
37361	37362	37363	37367	37368	37369	37370	37373	37374	37377	37378
37379	37385	37387	37389	37391	37392	37395	37396	37397	37404	37405
37407	37428	37429	37430	37440	37441	37442	37451	37452	37457	37462
37463	37472									

As stated in the Off-Post ROD, off-post water quality monitoring is conducted to assess contaminant concentration reduction and remedy performance and to support the institutional control component of the off-post remedy (HLA 1995):

> *[T]he preferred alternative includes long-term monitoring of offpost groundwater and surface water to assess contaminant concentration reduction and remedy performance. Groundwater monitoring will continue utilizing both monitoring wells and private drinking water wells.*

The Off-Post RS/S (HLA 1996) added that the purpose of the off-post regional monitoring program is to provide data to:

(1) Assist in the assessment of the effectiveness of the remedy,
(2) assist in the assessment of contaminant concentration reduction,
(3) prepare the CSRG exceedance area map, and
(4) assist in the assessment of groundwater flow direction and hydraulic gradient.

The data needed to achieve this purpose were to be provided through a network of off-post monitoring wells and private wells. The regional monitoring category in the Off-Post RS/S is now called exceedance monitoring. Exceedance monitoring wells are sampled twice in five years. Water levels also are monitored annually in the monitoring wells.

Exceedance monitoring is also conducted in support of the institutional controls component of the off-post remedy. The purpose of the institutional controls is to restrict the use of contaminated groundwater, in particular the installation of new wells, within identified plume areas. This restriction is implemented in areas with contaminant concentrations that potentially exceed the CSRGs presented in Tables 1.3-1 and 1.3-5. According to the Off-Post ROD, Appendix B (HLA 1995):

> *The Army has provided the Office of the State Engineer, State of Colorado, a map identifying areas in the Off-Post Study Area where groundwater could potentially exceed CSRGs. This map will be updated based on each sampling round.*

The maps are intended for use by the SEO in the Well Notification Program. The CSRG exceedance area maps will continue to be submitted in the year following sample collection, as described in the Off-Post RS/S, and samples will be collected twice in each five-year period (HLA 1996).

The off-post CSRG exceedance data will also be used to monitor the extent and concentration trends of plumes upgradient and downgradient of the OGITS. These data will also be used to evaluate the OGITS monitoring networks, and will be considered during OGITS shut-off decisions.

The Army and Shell conducted exceedance monitoring in 2012 and 2014 and provided off-post exceedance maps to the SEO in support the Well Permit Notification Program. Table 5.2.2-2 (under Tables tab) provides a summary of the off-post wells included in the exceedance monitoring program during the past FYR period and Figure 5.2.2-1 depicts the exceedance monitoring network. The table and figure include all the off-post wells sampled during this FYR period. The table identifies the monitoring well locations and the analytical suites.

The exceedance monitoring program includes contaminants identified in the CSRG lists for the NWBCS, NBCS, and OGITS near the groundwater systems and a reduced analyte list for other wells based on sampling history and contaminant concentration trends. It should be noted that private well monitoring, described in Section 5.2.3, is conducted in addition to the program discussed here. Water quality data from monitoring wells and available private wells were used to construct the exceedance maps. In addition, Army and Shell used water level monitoring data to bolster the interpretation of flow direction and contaminant migration pathways in the off-post exceedance monitoring program.

The 2010 LTMP Exceedance Well Network consists of 58 monitoring wells. In FY12, 99 monitoring wells and 19 private UFS wells were sampled, and in FY14, 97 monitoring wells and 14 private UFS wells were sampled (Table 5.2.2-2). Additionally, 17 OGITS operating extraction wells were sampled during both fiscal years. The additional monitoring wells sampled in FY12 and FY14 are operational wells and performance wells located near the NWBCS, NBCS, and OGITS. Additional private wells were sampled to obtain more data in several areas of interest. There were only a few deviations from the planned sampling of the wells Nearby private wells 995A, 548B, and 538A, respectively, were sampled in the areas of the destroyed wells during this FYR.

The observations made based on evaluations of the 2012 and 2014 exceedance maps and a review of data in the RMAED are summarized below. The exceedance maps for 2012 and 2014 show contaminant distributions consistent with the previously mapped exceedance areas in most locations, and decreases in the exceedance areas for several analytes. The lower PQL for dieldrin in FY12 causes the exceedance areas in FY12 and FY14 to appear larger than in previous exceedance maps (e.g., FY09). The concentrations were similar or lower in FY12/FY14 than in FY09, but the lower PQL causes the plume extent to be larger and include more wells. Concentrations generally decreased during the FYR period and the number of analytes exceeding CSRGs in FY14 (10) was lower than in FY12 (15).

While water-level fluctuations occurred off post during the period, flow direction and contaminant migration pathways were not affected in most areas.

The Army and Shell mapped exceedance areas for 1,2-dichloroethane, aldrin, arsenic, carbon tetrachloride, chloroform, chloride, chlordane, DCPD, DIMP, dieldrin, fluoride, isodrin, NDMA, DDT, sulfate, and PCE during this FYR period and the resulting 2012 and 2014 exceedance maps are shown in Figure 5.2.2-2. Aldrin, chloroform, DCPD, NDMA, DDT, and PCE concentrations were below the CSRGs/PQLs in all wells sampled in FY14. Isodrin was below the CSRG in FY12, but above the CSRG in one well in FY14, and was included on the FY14 map.

A summary of the exceedance map information follows:

- Figure 5.2.3-3 shows the DIMP exceedance areas for 2009, 2012, and 2014 as well as the decrease in the size of the DIMP plume between 2009 and 2014. The DIMP exceedance area decreased from 152 acres in 2009 to 71 acres in 2014, which is a 54 percent decrease.
- DIMP concentration trends varied in individual wells within its exceedance area, but the total exceedance area has decreased over the FYR period, particularly downgradient of the FCS, where the plume is smaller than in FY09. The size of the DIMP exceedance area upgradient of the NPS also decreased between 2009 and 2014, and the DIMP

concentrations in all wells upgradient of the NPS in Section 12 are below the CSRG. The size of the DIMP exceedance area north of 96th Avenue, and northwest of the west end of the NBCS also decreased in 2014. The downgradient extent of this exceedance area has been based on an unconfined Denver well (37379). The DIMP concentrations in the adjacent alluvial well (37374) have been below the CSRG for DIMP since 1994. The underlying unconfined Denver formation has lower permeability and requires more time to clean up than does the overlying alluvium. In 2014, the DIMP in well 37379 was shown as an isolated exceedance instead of connecting the exceedance areas with upgradient alluvial wells.

- DIMP was the only organic contaminant that exceeded CSRGs downgradient of the OGITS.
- Most of the dieldrin exceedance areas were similar in 2012 and 2014, including a narrow exceedance area that extends from near the eastern end of the NBCS to the NPS. One of the dieldrin exceedance areas was larger in 2014 in the western part of the Northern Pathway because dieldrin concentrations increased and were above the PQL in more wells than in 2012. Dieldrin concentrations decreased in most wells between 2012 and 2014.
- Aldrin, chloroform, DCPD, NDMA, DDT, and PCE concentrations in wells evaluated in this review decreased to below CSRGs/PQLs during the current FYR period.
- The CSRG exceedance areas for chloride and sulfate did not change significantly during the FYR period. The chloride and sulfate concentrations decreased overall upgradient of the FCS and NPS during the FYR period.
- The fluoride exceedance areas showed little change during the current FYR period.

A summary of concentration data follows:

- Five wells (37094, 37150, 37471, 37818, and 37822) in the NPS were above the CSRG for carbon tetrachloride in FY12.
- Chloroform concentrations were below the CSRG upgradient and downgradient of the OGITS.
- PCE concentrations decreased to below the CSRG in wells upgradient of the NPS during the FYR period.
- DCPD concentrations decreased to below the CSRG in wells located upgradient of the FCS.
- Aldrin was below the PQL FY14.
- Dieldrin was detected above the PQL of 0.13 µg/L in 34 wells in FY12 and 40 wells in FY14. The dieldrin exceedance area was larger near the NWBCS, in the First Creek Pathway, and in the western part of the Northern Pathway in 2014. Higher groundwater levels occurred in FY14, which may have mobilized residual dieldrin to the groundwater in some of these wells.

- DDT was below the CSRG in FY14.
- 1,2-Dichloroethane was below the CSRG in FY14.
- Arsenic concentrations exceeded the CSRG in one well during FY12 and two wells in FY14. Both wells (37464 and 37809) are upgradient of the NPS extraction system. Downgradient NPS performance wells 37008 and 37011 were above the CSRG in FY10, but not in the subsequent years.

The contaminant trends downgradient of the NPS during the FYR period were as follows:

- The arsenic concentrations in wells 37008 and 37011 decreased to below the CSRG after FY10.

Downgradient of the First Creek Pathway extraction system, significant decreases in DIMP concentrations occurred during this FYR period, including:

- Well 37041 concentration decreased from 3.07 µg/L in FY09 to 1.18 µg/L in FY14.
- Well 37070 concentration decreased from 55.9 µg/L in FY09 to 13.8 µg/L in FY14.
- Well 37084 concentration decreased from 4.99 µg/L in FY09 to 2.01 µg/Lin FY14.
- Well 37097 concentration increased from 3.68 µg/L in FY09 to 10.5 µg/L in FY14. Some variation in the DIMP concentrations occurs in wells downgradient of O'Brian canal because the canal flow and associated groundwater recharge are variable.
- Well 37429 concentration decreased from 13.6 µg/L in FY09 to 0.55 µg/L in FY14. The well was discussed in the last FYR period because a possible lateral shift of the DIMP plume was suspected in 2007. The DIMP concentration was below the CSRG during this FYR period.
- Private well 986A concentration decreased from 8.03 µg/L in FY09 to 3.36 µg/L in FY14.
- Private well 1185C concentration decreased from 2.41 µg/L in FY09 to 1.2 µg/L in FY13.

The CSRG exceedance well network was reviewed and based on the water quality results during this FYR period, the following changes are proposed:

1) Dieldrin should be added to the analyte list for the following monitoring wells in the CSRG Exceedance network: 37080, 37150, 37367, and 37377. With the lower PQL, the offpost dieldrin exceedance area has a larger extent than previous dieldrin exceedance areas based on the previous PQL. Adding dieldrin to the analyte list for the wells listed above is proposed to better define the extent of the dieldrin exceedance area above the new PQL in the Northern Pathway. The wells in the CSRG Exceedance network are shown on Figure 5.2.2-1.

2) Monitoring wells 37125, 37334, 37335, 37336, 37337, 37385, 37430, and 37442 should be added to the CSRG Exceedance network, with DIMP and dieldrin on the indicator analyte list. These wells are shown on Figure 5.2.2-1 and are located downgradient of the NWBCS, where dieldrin has been detected above the new PQL in the downgradient performance wells. These wells represent all of the available monitoring wells downgradient of the NWBCS that either had historical dieldrin detections or dieldrin was not detected previously, but they help determine the plume extent based on the lower PQL. Most of these wells were last sampled in 1999, with no dieldrin detections and an MRL of 0.04 µg/L. They were also sampled in 1997 and/or 1998 and the dieldrin concentrations were below the MRL of 0.024 µg/L. Adding dieldrin to the analyte list for the wells above is proposed to better define the extent of the dieldrin exceedance area above the new PQL downgradient of the NWBCS. DIMP will also be analyzed because DIMP is a CSRG analyte at NWBCS and the 2010 LTMP stipulated that DIMP be analyzed for all CSRG Exceedance network wells.

3) Private well 1402B should be sampled for dieldrin by TCHD in 2017 and 2019, if possible. This well also is located downgradient of the NWBCS and is shown on Figure 5.2.2-1. The rationale for sampling well 1402B is similar to that for the wells in item 2) above.

5.2.3 Private Well Monitoring Program

The Off-Post Private Well monitoring is conducted by TCHD for the Army. As described in Section 3.3, TCHD samples off-post private wells to provide data to assist in refining the CSRG exceedance map, to determine the water quality of new off-post wells as required by the Off-Post ROD, to respond to citizen requests, and to determine whether CFS wells are acting as conduits for contaminant transport from the UFS to the CFS. Execution of the program depends on cooperation from the private well owners, and access to the wells is therefore not consistent. Approximately 30 wells are sampled for DIMP each year. No new wells were installed during the FYR period that required sampling by the Off-Post ROD.

The monitoring results for UFS private wells during the FYR period showed that DIMP concentrations have decreased steadily, and only one well (986A) contained DIMP concentrations above the CSRG during this FYR period (8.94 µg/L in 2010). The DIMP concentration in well 986A decreased to 3.36 µg/L in FY14. All of the UFS private wells sampled in FY11, FY12, FY13, and FY14, including well 986A, were below the CSRG. Well 986A historically has contained higher DIMP concentrations and been slower to clean up than nearby and upgradient wells, possibly because it is located in a lower permeability zone. The overall trend in well 986A is downward, however, because of treatment of the groundwater at RMA.

The monitoring of off-post CFS private wells has been reviewed in previous FYRRs, and evolved over the years as some of the wells were no longer used, or the wells met criteria for discontinuing monitoring. During this FYR period, the following CFS wells were sampled: 359A, 914B, 986B, 1070B, and 1171A. The DIMP results are provided in Table 5.2.3-1.

Table 5.2.3-1. Water Quality Data for the Off-Post Private CFS Well Network, FY10–FY14

Private Well ID	Aquifer	Sample Date	DIMP, µg/L (< = less than)
359A	Arapahoe	5/31/2011	10.5
		6/16/2011	< 0.5
		6/5/2012	2.17
		7/23/2013	2.02
		6/26/2014	7.32
		9/15/2014	7.07
		2/9/2015	6.13 (grab) 8.14 (post purge)
914B	Arapahoe	5/23/2012	<0.872
		6/25/2013	< 0.5
986B	Arapahoe	8/20/2014	< 0.5
1070B	Arapahoe	7/28/2010	1.77
		7/11/2013	0.927
1171A	Arapahoe	6/12/2013	0.815

Notes:
< – less than; µg/L – Micrograms Per Liter; Diisopropylmethyl Phosphonate – DIMP; RL – Reporting Limit;

Except for one sample in well 359A, all the results were below the CSRG for DIMP. The May 2011 DIMP concentration in well 359A was 10.5 µg/L. This was questionable because it was the highest concentration measured in the well since it was first sampled in 1991, and the DIMP concentrations in nearby alluvial wells were below the CSRG. Well 359A was re-sampled in June 2011, and the concentration was LT 0.5 µg/L. In subsequent samples during the FYR period, the concentrations remained below the CSRG. A sample collected in 2015 was above the CSRG and the resident was provided with bottled water.

5.2.4 Off-Post Surface Water Monitoring Program

Requirements for off-post surface water monitoring are discussed in Sections 1.3.2.2 and 3.4. Surface water monitoring was conducted in accordance with the Off-Post ROD to evaluate the effect of groundwater treatment on surface water quality. The Off-Post RS/S (HLA 1996) specified sampling at two surface water monitoring stations: SW24004 and SW37001. The 2010 LTMP revised the surface water sampling program to include annual sampling of these sites under low-flow conditions. The highest contaminant concentrations typically are present when groundwater is discharging into First Creek under low-flow or base flow conditions. The analyte list in the 2010 LTMP included DIMP and arsenic. In 2013, upstream site SW08003, located near the south boundary of RMA, was added to provide comparison data to the two downstream sites. These locations are shown on Figures 5.1.3.3-1 and 5.2.4-1. The analyte list was revised in 2013 to include aldrin, arsenic, chloride, dieldrin, DIMP, NDMA, and sulfate (Table 5.2.4-1). The PQLs for aldrin, dieldrin, and NDMA were lowered in 2012. These analytes had not been detected previously at the surface water sites, but were included to confirm that they are not present above the lower PQL levels. VOCs were analyzed for sites SW24004 and SW37001 in FY13 as part of the 1,4-dioxane sampling task.

Table 5.2.4-1. Off-Post Surface Water Monitoring Analytes and CSRGs

Analytical Group	Analyte	Containment System Remediation Goal/PQL (µg/L)
Organophosphorus compounds	Diisopropylmethyl phosphonate (DIMP)	8
Organochlorine pesticides	Aldrin	0.002/0.05/0.014
	Dieldrin	0.002/0.05/0.013
Volatile hydrocarbon compounds	N-nitorsodimethylamine (NDMA)	0.007/0.033/0.018
Metals	Arsenic	2.35
Anions	Chloride	250,000
	Sulfate	540,000

The monitoring results are to be compared with the off-post remediation goals, which consist of the CSRGs for groundwater, for this purpose. The CSRGs are provided in Table 5.2.4-1. The surface water data are reported in the ASRs. The results for the sampling sites are discussed below.

Five water quality samples were collected at station SW24004. There was no flow in First Creek during 2012, so no samples were collected. DIMP was not detected in any samples, and only arsenic concentrations were above the CSRG. Two of five arsenic samples were slightly above the CSRG. These arsenic concentrations were within the historical range of LT 1 to 9 µg/L for the upstream First Creek sites (URS 2013), located near the RMA south boundary. There were no other detections above the CSRG.

Five samples also were collected at station SW37001, with none collected in 2012. No samples were above the CSRG for DIMP. Only arsenic concentrations were above the CSRG. Three of five arsenic samples were slightly above the CSRG. These concentrations also were within the historical range for the upstream First Creek sites (URS 2013), located near the RMA south boundary. There were no other detections above the CSRG.

Two samples were collected at upstream site SW08003. There were no detections above CSRGs. Table 5.2.4-2 provides the DIMP and arsenic concentrations for sites SW08003, SW24004, and SW37001.

Table 5.2.4-2. DIMP and Arsenic Data at SW08003, SW24004, and SW37001

Site	Sample Date	DIMP (µg/L)	Arsenic (µg/L)
SW08003	8/21/13	LT 0.5	LT 1
	6/30/14	LT 0.5	LT 1
SW24004	6/8/10	LT 0.5	2.65
	3/24/11	LT 0.5	LT 1
	2//7/13	LT 0.5	1.54
	8/21/13	LT 0.5	2.6
	6/30/14	LT 0.5	1.78
SW37001	6/8/10	1.09	3.74
	3/24/11	7.07	LT 1
	2//7/13	LT 0.5	2
	8/21/13	0.57	3.8
	6/30/14	LT 0.5	LT 1

The arsenic concentrations in downstream sites SW24004 and SW37001 are within their historical ranges and within the historical range of LT 1 to 9 µg/L for the upstream First Creek sites (URS 2013). For downstream site SW37001, if the arsenic concentration is above the CSRG, the LTMP Surface Water SAP specifies determining whether the concentration is decreasing for a minimum of five years extending back to 1995. Overall, the concentration trend has decreased from 5.2 µg/L in 1996 to LT 1 µg/L in FY14.

The FY13 and FY14 arsenic concentrations at upstream site SW08003 were LT 1 µg/L, so the downstream site concentrations were higher. However, since arsenic is naturally occurring in soil at RMA, comparison of contemporaneous upstream and downstream data is not a conclusive indicator of RMA contamination, and comparison to the historical concentration range in the upstream sites may be more meaningful (URS 2013).

The concentrations of DIMP at SW37001 were below the CSRG during the FYR period. A long-term decrease in DIMP concentrations at SW37001 has been consistent with the gradual decrease in DIMP concentrations over time in groundwater in the wells in the area. Figure 5.2.4-2 shows the long-term trend in DIMP concentrations at SW37001 and FCS extraction wells 37801 and 37802. The well locations are shown on Figure 5.2.4-1. The DIMP concentrations in SW37001 are highest when First Creek is in a low-flow condition and groundwater is discharging into the creek. The maximum DIMP concentrations in SW37001 have been similar to the contemporaneous concentrations in nearby well 37802. Well 37801 is located farther upgradient where DIMP concentrations are higher. The DIMP concentrations in SW37001 and well 37802 have decreased from about 100 µg/L in 1995 to LT 0.5 µg/L and 9.78 µg/L, respectively, in 2014. Figure 5.2.4-3 shows the DIMP concentrations at SW37001 under low-flow conditions when the concentrations typically are highest. The DIMP concentrations at SW37001 have decreased and were below the CSRG during this FYR period. The decreasing trends in these graphs illustrate that groundwater treatment is affecting the surface water quality as intended in the Off-Post ROD.

Figure 5.2.4-2. DIMP Concentrations in Surface Water (SW37001) and Groundwater (Extraction Wells 37801 and 37802)

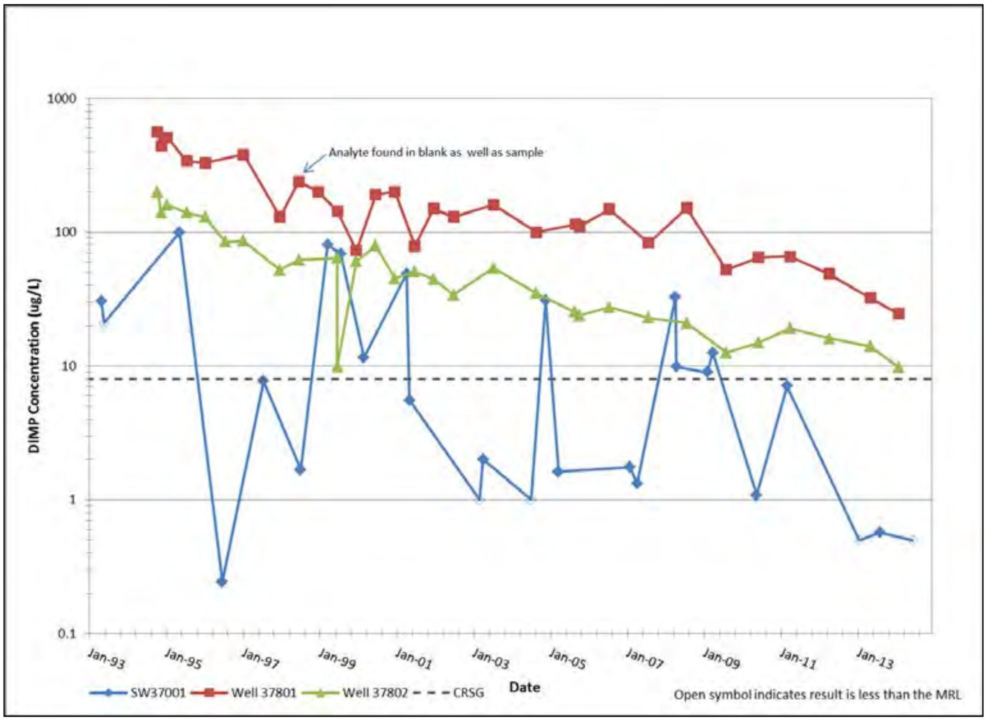
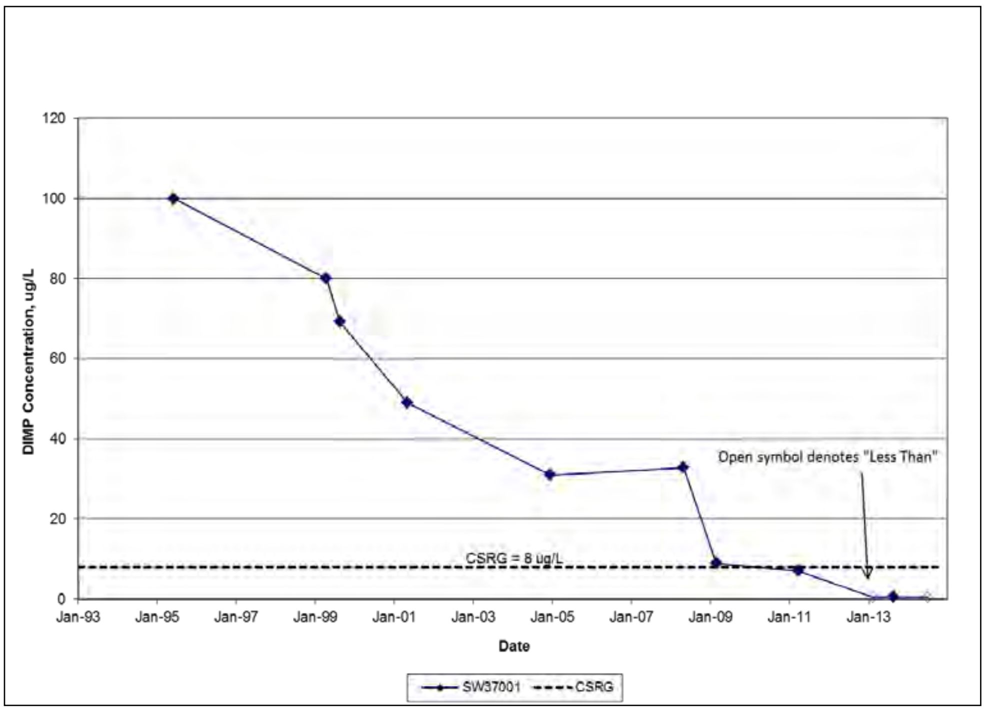


Figure 5.2.4-3. DIMP Concentrations in Surface Water (SW37001), First Creek under Low-Flow Conditions



Summary of Surface Water Results

During this FYR period, the concentrations of DIMP were below the CSRG at downstream sites SW24004 and SW37001. Arsenic concentrations were above the CSRG in some of the downstream samples. The arsenic concentrations in the downstream sites were within their historical ranges and within the historical range for the upstream First Creek sites. Surface water leaving RMA as measured at station SW24004 met applicable water quality standards for all of the target constituents, except arsenic. However, the arsenic concentrations are consistent with background concentrations.

With the continuing removal of organic contaminants from the groundwater in the area, concentrations of the target suite of organic constituents in surface water at off-post station SW37001 are expected to continue to decrease. Treatment of groundwater contaminants at the NBCS and the OGITS appear to be having a positive effect on First Creek water quality. Accordingly, the remedy is performing in accordance with the Off-Post ROD.

5.3 Off-Post 1,4-Dioxane Characterization

Figure 5.1.5.3-1 shows the results of the well sampling program, and includes interpreted plume contours for the UFS. The investigative sample concentrations were above the MRL of 0.1 µg/L in the majority of samples for UFS wells, both on-post and off-post. Data collected in off-post private wells by TCHD are included in Figure 5.1.5.3-1 and are identified by site IDs that differ from the Army's 5-digit well numbers that begin with "37."

The 1,4-dioxane concentrations in nine off-post wells were above the CBSG, including two private wells. Only four of the off-post wells with concentrations above the CBSG were located downgradient of the OGITS extraction and recharge systems.

Figure 5.1.5.3-1 shows the approximate location of the western plume that originates south and west of RMA. Their interpretation is based on 1,4-dioxane data compiled by the EPA (Pacific Western Technologies 2013) and RMA water table maps and known flow directions. These additional 1,4-dioxane data points are not shown on the map because they are not part of the RMA sampling program, and have not been reviewed for quality assurance by the RMA. The EPA is in the process of evaluating these data as part of a 1,4-Dioxane Preliminary Assessment.This page intentionally left blank.

6.0 Events and Follow-Up Actions

Monitoring and system events that would require Regulatory Agency notification based on the 2010 LTMP and Post-Closure Plans for Basin F, HWL, and ELF are identified as events in this report. These events are further evaluated as part of the FYR assessment in the FYRR. Table 6.0-1 describes the events for this FYR period.

Table 6.0-1. Events Requiring Regulatory Agency Notification

Date	Issue	Description	Corrective Action
04/01/2010	BANS quarterly effluent compliance sample exceeded the CBSG for 1,2-dichloroethane (12DCLE).	On February 11, 2010, the preliminary 12DCLE results for the effluent sample taken on January 11, 2010 were returned with a value of 1.14 µg/L. The CBSG for 12DCLE was lowered from 1.1 µg/L to 0.4 µg/L in the 2010 FYRR. Note: The FYRR was not finalized until 09/23/2011 so the new CBSG was not technically in effect until that time.	On February 15, 2010 the plant effluent was resampled based on the result received on February 11. Preliminary results of LT 0.245 µg/L were received on February 22, 2010 for the resampled plant effluent. Data from the two compliance samples were finalized in March and April of 2010 with no change to the preliminary results. Continued monitoring was proposed. No further effluent exceedances occurred during FY 2010 and the rest of the FYR period.
	OGITS Chlordane PQL Issue	The gamma chlordane MRL was above the CSRG of 0.03 µg/L during part of the previous FYR period.	The gamma chlordane MRL was lowered to 0.0185 µg/L in 2011.
05/20/2010	Dewatering system compromised, soil cover disturbance required. NRAP-2010-002	Components of the Lime Basins dewatering wells discharge piping deteriorated. The components were located immediately adjacent to each dewatering well, and were both within, and below, the Lime Basins RCRA-Equivalent Cover. Six wells, DW-5 through DW-10, were affected.	New components and piping were installed in the Lime Basins RCRA-equivalent cover soil.
08/02/2010	Modification of Lime Basins groundwater conveyance system piping, intrusive activity required. NRAP-2010-004	Removal of the CWTF required installation of new underground piping to convey groundwater from the Lime Basins site to the Basin A Neck Treatment Facility.	New piping was installed in the non-cover area of the Integrated Cover System AMA to convey Lime Basins groundwater to the Basin A Neck facility.

Table 6.0-1. Events Requiring Regulatory Agency Notification (Continued)

Date	Issue	Description	Corrective Action
09/30/2010	Damage to the CADT groundwater removal well 36305, soil cover disturbance required. NRAP-2010-008	A leak was identified at the CADT groundwater extraction wellhead (Well #36305). The groundwater conveyance piping was damaged at the well's pitless adaptor.	The CAT RCRA-equivalent cover was excavated at the well location. The conveyance piping was repaired and placed back into service October 7, 2010.
07/24/2012	Missed sample event for RYCS in FY11.	Missed RYCS effluent compliance sample for TCE in FY11. TCE was inadvertently removed from the 2011 RYCS SAP.	TCE was added to the RYCS SAP.
01/18/2012	Mislabel/mishandle of OGITS influent and effluent compliance samples.	Preliminary data from the January 5, 2012 OGITS compliance sample event indicated that the plant influent and effluent samples were mislabeled/ mishandled post sample collection, either during labeling, shipping, or at the lab. The initial influent data were all less than the MRL. The effluent data included detections that were above the MRL.	The OGITS influent and effluent were resampled on February 7, 2012 to meet the compliance sampling requirements. The February influent and effluent samples were consistent with normal operations with the MRL hits being in the influent sample.
04/02/2012	NWBCS quarterly effluent compliance sample exceeded the PQL for dieldrin.	On April 30, 2012, the preliminary dieldrin results for the effluent sample taken on April 2, 2012 were returned with a value of 0.0244 µg/L. The PQL for dieldrin was lowered from 0.05 µg/L to 0.013 µg/L as a result of the site specific PQL study completed and implemented in April 2012.	On May 1, 2012, the plant influent and effluent was resampled. On May 5, 2012 the two on-line adsorbers were pulsed with fresh carbon. Effluent results for the May 1, 2012 sample were reported as 0.0148 µg/L. Effluent results for the May 9, 2012 results were LT 0.0066 µg/L. Subsequent effluent results were below the trigger level for the remainder of the fiscal year.

Table 6.0-1. Events Requiring Regulatory Agency Notification (Continued)

Date	Issue	Description	Corrective Action
04/04/2012	NBCS quarterly effluent compliance sample exceeded the PQL for aldrin and dieldrin.	On April 30, 2012, the preliminary dieldrin results for the effluent sample taken on April 2, 2012 were returned with a value of 0.118 µg/L. The aldrin result was reported as 0.0244 µg/L. The PQL for dieldrin was lowered from 0.05 µg/L to 0.013 µg/L and for aldrin the PQL was lowered from 0.05 µg/L to 0.014 as a result of the site specific PQL study completed and implemented in April 2012.	On May 1, 2012, the plant influent and effluent was resampled. On May 5, 2012 the adsorbers were rotated and a fresh adsorber was brought on-line. Effluent results for the May 5, 2012 sample were reported as less than 0.008 µg/L for dieldrin and less than 0.0036 µg/L for aldrin. Effluent results for the May 9, 2012 sample were less than 0.0066 µg/L for dieldrin and less than 0.0029 µg/L for aldrin. Subsequent effluent results were below the trigger level for the remainder of the fiscal year.
10/03/2012	Shell Disposal Trenches water levels exceed dewatering goal.	The water elevation was above the trench-bottom elevation at one of the six compliance boreholes on October 2, 2012.	Continued monitoring with attainment of the dewatering goal expected in 2013. The goal was attained in July 2013.
04/11/2013	NWBCS downgradient performance wells exceed PQL for dieldrin.	Dieldrin was detected above the PQL in downgradient performance wells 22015 and 22512.	Recharge well flow rates were increased in this area, and the dieldrin concentrations in well 22512, which is sampled quarterly, decreased to below the PQL in May and August 2013.
04/21/2014	Upper prediction limit exceeded in HWL well. NRAP-2014-006	Dieldrin was detected in HWL downgradient well 25194 at a level of 0.0364 µg/L, which exceeded the upper prediction limit of 0.03 µg/L.	Investigated potential for leaks in the HWL liner system and other sources of dieldrin that could affect well 25194. Dieldrin likely is pre-existing contamination from the Basins C/F area.
11/1/2013	Missed sample event for RYCS in FY13.	Missed RYCS effluent compliance sample for TCE in FY13.	Sample collected on 10/28/2013.

Table 6.0-1. Events Requiring Regulatory Agency Notification (Continued)

Date	Issue	Description	Corrective Action
3/12/2014	CFS well concentration increases.	Concentration increases that met criteria for notification occurred in CFS wells 01067 (11DCLE), 02057 (CLC6H5), 26153 (DLDRN), and 35083 (Chloride). The concentrations were within or near the historical ranges. Some of the CFS wells may be semi-confined.	Adjacent UFS wells were sampled for comparison to the CFS well data, which will be evaluated further in the 2015 Five-Year Review.
3/21/2014	Shell Disposal Trenches water levels exceed goal.	Shell Disposal Trenches water levels exceeded water-level goal, January 2014. After meeting the Shell Disposal Trenches dewatering goal in July and October 2013, water levels rose above the target elevation at one of the six compliance boreholes. Higher water levels were caused by the 500- to 1000-year storm event in September 2013.	After the effects of the September 2013 storm event have passed, the water elevations inside the slurry wall should decrease and the water-level goal will be re-attained. Continued quarterly water level monitoring was proposed.
4/28/2014	CSRG exceedance in OGITS effluent.	Arsenic exceeded the CSRG in OGITS effluent, January 2014. Arsenic concentration in effluent was higher than in influent and was questionable.	OGITS effluent re-sampled on 3/19/2014 and arsenic was LT 1 µg/L. Subsequent arsenic sample on 4/3/2014 also was LT 1 µg/L. No further action was proposed.

Table 6.0-1. Events Requiring Regulatory Agency Notification (Continued)

Date	Issue	Description	Corrective Action
5/8/2014	NWBCS and OGITS downgradient performance wells exceed PQL for dieldrin.	Dieldrin concentrations in NWBCS and OGITS downgradient performance wells exceeded the PQL in March 2014. The dieldrin concentrations above the PQL at NWBCS likely are caused by a combination of higher water levels, concentrations near or at the PQL in the NWBCS effluent, and a small amount of contaminated flow from the NEE area. Higher water levels likely caused the increase in the OGITS well.	Additional sampling of two NWBCS wells was conducted in fourth quarter of FY14. Changes in NWBCS treatment operation have included more frequent pulsing of higher amounts of regenerated carbon, and use of virgin carbon. No further action besides continued annual monitoring was proposed at OGITS.
5/14/2014	Missed data collection in LTMP well 01312 in FY13.	Missed water level and LNAPL measurement in LTMP water level tracking well 01312 in FY13.	Data were collected in FY14. The RMAED and RMA Water Data sampling program were reviewed for completeness and inclusion of changes to the LTMP OCNs. OMC Sampling Manager and RMA Database Manager will be included in future OCN distributions.
7/7/2014	Dieldrin concentration exceeded PQL in NWBCS SWE cross-gradient performance well.	Dieldrin exceeded PQL in NWBCS SWE cross-gradient well 27516 in May 2014. Well is in capture zone, so plume capture was maintained.	Evaluated next quarterly sample in well 27516, which was below the PQL. No further action was needed.
7/7/2014	Shell Disposal Trenches water levels exceed goal.	Shell Disposal Trenches water levels exceeded water-level goal at one of the six compliance boreholes for second consecutive quarter, April 2014.	After the effects of the September 2013 storm event have passed, the water elevations inside the slurry wall should decrease and the water-level goal will be re-attained. Continued quarterly water level monitoring was proposed.

Table 6.0-1. Events Requiring Regulatory Agency Notification (Concluded)

Date	Issue	Description	Corrective Action
9/29/2014	Shell Disposal Trenches water levels exceed goal.	Shell Disposal Trenches water levels exceeded water-level goal at one of the six compliance boreholes for third consecutive quarter, July 2014. May 2014 storms caused additional rise in water levels.	After the effects of the September 2013 and May 2014 storm events have passed, the water elevations inside the slurry wall should decrease and the water-level goal will be re-attained. Continued quarterly water level monitoring was proposed and the status will be reported in the Quarterly Effluent Reports in lieu of notifications.
9/29/2014	CADT dewatering goal not met by projected LTMP date.	Due to a variety of factors, the dewatering goal in one of the two compliance wells has not been attained. Both long-term and short-term trends (i.e., during the five years since the Integrated Cover System was completed) show that progress is being made toward meeting the goal in the second compliance well, even with the September 2013 and May 2014 storms.	Continued quarterly water level monitoring was proposed and the status will be reported in the Quarterly Effluent Reports in lieu of notifications.
9/29/2014	Lime Basins dewatering goal not met by projected LTMP date.	Due to a variety of factors, the Lime Basins dewatering goals have not been attained. Monitoring data shows that significant progress is being made toward meeting the goals.	Transitioning the dewatering and treatment operations from batch mode to more continuous operation was implemented.
12/4/2014	Short-term surface water concentrations were above water quality criteria in FY13.	Surface water aquatic life standards were exceeded for copper at one site (North Plants) and copper, manganese, nickel, and zinc were exceeded at a second site (Former Basin E pond) in FY13.	Additional sampling will be conducted in FY15.
4/2/2015	Concentrations of several analytes increased above CSRGs/PQLs in two of the four BANS downgradient performance wells in FY14.	The concentrations of several analytes increased to above the CSRGs/PQLs in two downgradient performance wells (26505 and 35525). The reverse hydraulic gradient was reduced during part of FY14 due to historically high groundwater levels that were caused by the combined effects of the Sept. 2013 and May 2014 storms.	The BANS dewatering well pumping rates were increased in early FY15 to increase the extent and magnitude of the reverse gradient, which has been restored to the historical extent. No further adjustments appear necessary.

7.0 Conclusions

The conclusions of the on-post and off-post system operation and monitoring programs are presented below.

7.1 On-Post OU Monitoring Program

All the on-post groundwater extraction and treatment systems were found to be functioning as intended by the Decision Documents, with a few qualifications during the FYR period.

Dieldrin was detected above the PQL in the NWBCS effluent during one quarter of FY12, and treatment changes were successful in lowering the effluent concentrations to be equal to or below the PQL. The NWBCS downgradient performance well concentrations of dieldrin were above the PQL and additional monitoring data are needed to evaluate the long-term trend.

The extent of the BANS reverse hydraulic gradient was reduced in 2014 and concentrations of a few analytes increased above CSRGs in two of the four downgradient performance wells. The BANS met the performance criteria, however. Operational changes made in FY15 have restored the reverse gradient to its historical extent.

The GWMR Project was completed in 2010. The STF mass removal system component of the GWMR Project removed 2,264.9 kg (4,988.8 lbs) of contaminant mass. The Lime Basins System, which is part of the same project, removed 892.7 kg (1,966.3 lbs) of contaminant mass.

The LNAPL Pilot System, installed to remove LNAPL found in the North Plants area, was initiated in February 2009. Since that time, LNAPL has not accumulated to levels that allowed for removal.

The CADT dewatering system had not attained the dewatering goal in one of the two compliance wells by the end of the FYR period. Progress toward meeting the goal is being made and the protectiveness of the remedy is not adversely affected because the contamination is contained within the slurry wall and significant mass removal is occurring.

The Shell Disposal Trenches containment remedy includes a slurry wall encircling the disposal trenches in addition to the cover. Water levels are to be lowered below the bottoms of the disposal trenches, which occurred in 2013, but was not maintained after the September 2013 and May 2014 storms caused water levels inside the slurry wall to rise. It is anticipated that water levels will fall and the water-level goal will be re-attained. The protectiveness of the remedy is not adversely affected because the contamination is contained within the slurry wall.

The Lime Basins Slurry Wall Dewatering Project had not attained the dewatering goals by the end of the FYR period. Significant progress toward meeting the goals has been made and the protectiveness of the remedy is not adversely affected because the Lime Basins contamination is contained within the slurry wall and significant mass removal is occurring. The Lime Basins DNAPL Remediation Project is functioning as intended.

The monitoring results from the on-post water level tracking over the five-year period show that the flowpaths are consistent with the previous review period and water quality tracking results show that groundwater conditions remain consistent with the initial assumptions used at the time of remedy selection.

The results of the CFS monitoring show that there have been no significant increases in concentrations of organic contaminants during the FYR period. The results indicate that migration to the CFS has not occurred during the current FYR period; one potential exception is reflected in elevated chloride concentrations in one well. Further monitoring showed that the elevated concentrations are not caused by vertical migration near the well.

The on-post surface water quality monitoring results showed that a few metals were present at concentrations above aquatic life standards at two surface water sampling sites. Additional monitoring will be conducted to further assess the sites.

Post-Shut-Off monitoring was conducted for the Motor Pool System/Irondale Containment System and the GWMR Project. The results were consistent with expectations; the concentrations were below CSRGs at MPS/ICS, and the STF benzene plume continues to be stable or is receding and is not migrating toward the lakes.

On-post plume-extent mapping was conducted in 2014 to evaluate the long-term progress of the remedy. Nine indicator analytes were selected for mapping, which included DIMP, dieldrin, chloroform, benzene, NDMA, carbon tetrachloride, dithiane, arsenic, and DBCP. The 2014 plumes were compared to the 1994 plumes, both qualitatively and quantitatively. The results showed significant reductions in concentrations and plume extents for the nine contaminants. With the lower MRL (0.0066 µg/L) and PQL (0.013 µg/L) in 2014, the 2014 dieldrin plume extent was larger than in 1994, but the 2014 plume extent was smaller than in 1994 when the plume extents above the former PQL/MRL of 0.05 µg/L were compared. Reducing the extent and concentrations of contaminant plumes upgradient of the boundary systems meets the Remedial Action Objective for on-post groundwater.

Characterization of the horizontal and vertical extent of 1,4-dioxane was conducted on-post and off-post during this FYR period. The investigative sample concentrations were above the MRL of 0.1 µg/L in the majority of groundwater samples for UFS wells, both on-post and off-post. There were relatively few off-post wells with concentrations above the CBSG, and only four of those wells were downgradient of OGITS. 1,4-Dioxane was not detected in any CFS wells. Therefore, the 1,4-dioxane contamination is limited to the uppermost water-bearing zone.

The apparent sources of 1,4-dioxane include South Plants, North Plants, Complex (Army) Trenches, and Basin F and are consistent with the known sources of 111TCE and TCE, which may be associated with 1,4-dioxane. The treatment plant effluent concentrations were below the CBSG of 0.35 µg/L, except at BANS, which is an internal mass removal system. The 1,4-dioxane concentrations were below the MRL of 0.1 µg/L at the surface water sites, except Lake Ladora site SW020009. Additional 1,4-dioxane sampling will be conducted in Lake Ladora.

Although an assessment of whether 1,4-dioxane should become an RMA COC has not yet been conducted, additional monitoring will be conducted during the next FYR period.

7.2 Off-Post OU Monitoring Programs

The OGITS continues to function as intended by the Decision Documents except the OGITS FCS did not meet the mass removal goal in FY12. Operational changes were successful in increasing the mass removal to meet the goal in the subsequent years. Chloride and sulfate concentrations exceeded CSRGs in the OGITS effluent, but these analytes are not treated by OGITS and are expected to meet CSRGs in the effluent by attenuation. The chloride and sulfate concentrations decreased and were below the CSRGs in FY14.

The **CSRG exceedance monitoring** results for this FYR period show contaminant reductions and shrinking plumes in the Off-Post OU. The total exceedance area for DIMP decreased, particularly downgradient of the First Creek System and upgradient of the Northern Pathway System.

The **Off-Post Private Well monitoring** conducted by TCHD for the Army continued during this FYR period. Approximately 30 wells are sampled for DIMP each year.

Surface water quality monitoring was conducted in accordance with the Off-Post ROD during this FYR period. Surface water leaving RMA met applicable water quality standards for the target constituents, except arsenic. Arsenic was detected intermittently above the CSRG, but the concentrations are consistent with the historical range of upstream sites. DIMP concentrations were below the CSRG during the FYR period.

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8.0 References

Army (U.S. Army)

2015 *Lime Basins DNAPL Remediation Project FY13 Monitoring Results, Conclusions, and Recommendations*.

2007 (Nov.) *Final 2005 Five-Year Review Report for Rocky Mountain Arsenal*. Final.

1989 *Basin A Neck Containment System IRA Decision Document*.

Army and Shell (U.S. Army and Shell Oil Company)

2013 (July) *Annual Summary Report for Groundwater and Surface Water*. FY2012.

CDLE (Colorado Department of Labor and Employment Division of Oil and Public Safety)

2005 (Oct.) *Petroleum Storage Tank Owner/Operator Guidance Document*. Effective 1999. Revised 2005.

CDPHE (Colorado Department of Public Health and the Environment)

2008 (July) *Practical Quantitation Limitation Guidance Document*. Prepared by Water Quality Control Division Laboratory Services Division.

EPA (U.S. Environmental Protection Agency) et al.

2001 (June) Comprehensive Five-Year Review Guidance, EPA 540-R–1-007, OSWER No. 9355.7-038-P.

1992 *Addendum to the Interim Final Guidance - Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities*.

1989 *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Interim Final Guidance*.

FWENC (Foster Wheeler Environmental Corporation)

2003 (Jun.) *Hazardous Waste Landfill Operations Manual, Operational Groundwater Monitoring Plan*. Revision D.3.

2002 (July) *Enhanced Hazardous Waste Landfill, Preoperational Groundwater Monitoring Plan*. Revision 0.

2001 (July) *Surface Water Monitoring Program and Sampling Analysis Plan*.

1999 (Dec.) *Rocky Mountain Arsenal Long-Term Monitoring Plan for Groundwater*. Final.

1996 (June) *Record of Decision for the On-Post Operable Unit*, Version 3.1, (3 Volumes).

1995 (Oct.) *Detailed Analysis of Alternatives Report*. Final. Prepared for the Program Manager for Rocky Mountain Arsenal, Version 4.1, 7 v. RTIC 95290R01.

George Chadwick Consulting

2005 (Nov.) *Final Conceptual Design of Proposed Modifications to the Northern Pathway Portion of the Offpost Groundwater Intercept and Treatment System (OGITS).* Prepared for Amber Homes, Inc.

HLA (Harding Lawson Associates)

1996 (Sept,) *Remediation Scope and Schedule for the Offpost Operable Unit, Rocky Mountain Arsenal, Commerce City, Colorado*.

1995 (Dec) *Rocky Mountain Arsenal Offpost Operable Unit, Final Record of Decision*.

1994 (Mar.) *Final Technical Report for Groundwater Data Evaluation*.

1989 (July) *Final Decision Document for the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal, Interim Response Action*.

MK Environmental Services

1990 (Mar.) *Final Decision Document for Other Contamination Sources, Interim Response Action, Rail Classification Yard, Rocky Mountain Arsenal*.

National Oceanic and Atmospheric Administration (NOAA)

2013 (Sep.) *Exceedance Probability Analysis for the Colorado Flood Event, 9-16 September 2013.* http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/8_Colorado_2013

Navarro (Navarro Research and Engineering, Inc.)

2015a (Mar.) *Annual Summary Report for Groundwater and Surface Water, FY2013*. Revision 1.

2015b (May) *Annual Summary Report for Groundwater and Surface Water, FY2014*.

2015c (Mar.) *Railyard Containment System Pre-Shut-Off Monitoring Report*. Revision 0.

2014a (Jan) *Rocky Mountain Arsenal Sampling Quality Assurance Project Plan*. Revision 0.

2014b (May) *2014 On-Post Plume Mapping Sampling and Analysis Plan*. Final.

2014c (June) *Long-Term Monitoring Plan for Groundwater and Surface Water Surface Water Sampling and Analysis Plan*. Revision 0.

Pacific Western Technologies, Inc.

2013 (Feb.) *1,4-Dioxane Split Sampling Results, RVO/PWT, RVO, SACWSD, and Chemical Sales Preliminary Map.*

PMRMA (Program Manager Rocky Mountain Arsenal)

2005a *Rocky Mountain Arsenal Containment/Treatment System Operational Assessment and Effluent Data Report, All Quarters FY02, All Treatment Systems*.

2005b *Rocky Mountain Arsenal Containment/Treatment System Operational Assessment and Effluent Data Report, All Quarters FY03, All Treatment Systems*.

2005c *Rocky Mountain Arsenal Containment/Treatment System Operational Assessment and Effluent Data Report, All Quarters FY04, All Treatment Systems*.

1997 (Aug.) *Memorandum of Agreement between Tri-County Health Department and Program Manager for Rocky Mountain Arsenal*.

RVO (Remediation Venture Office)

2012 (Sept.) *Annual Summary Report for Groundwater and Surface Water, FY2011*.

2011 (Sept.) *Annual Summary Report for Groundwater and Surface Water, FY2010*.

2009 (Jan.) *Remediation Venture Office Chemical Quality Assurance Plan*. Revision 4.

2004 (Sept.) *Memorandum for Record. Clarification of BANCS Requirements in ROD*.

1997 *Complex (Army) Trenches and Shell Section 36 Trenches Groundwater Barrier Proje*ct, *100% Design Package*. Revision 1.

TtEC and URS (Tetra Tech EC, Inc. and URS Corporation)

2012 (Apr.) *Lime Basins Dense Non-Aqueous Phase Liquid (DNAPL) Remediation Design Analysis Report*. Final.

2010 (Mar.) *Rocky Mountain Arsenal Long-Term Monitoring Plan for Groundwater and Surface Water*. Final.

TtEC (Tetra Tech EC, Inc.)

2012a (July) *Explanation of Significant Differences for Groundwater Remediation Requirements*. Revision 0.

2012a (Nov.) *Basin F Post-Closure Groundwater Monitoring Report 2012*. Revision 0.

2011a (Sept.) *Final 2010 Five-Year Review Report for Rocky Mountain Arsenal*.

2011b (Dec.) *Explanation of Significant Differences for Lime Basins DNAPL Remediation Project*. Revision 0.

2011c (Mar.) Hazardous Waste Landfill Post-Closure Groundwater Monitoring Plan. Revision 3. (*Appendix to HWL Post-Closure Plan*).

2011d (Oct.) *Basin F Post-Closure Groundwater Monitoring Plan*. Revision 0. (*Appendix to Basin F Post-Closure Plan*).

2011e (Mar.) *Hazardous Waste Landfill Post-Closure Plan*. Revision 3.

2011f (Oct.) *Basin F Post-Closure Plan*. Revision 0.

2011g (Sept.) *RCRA-Equivalent, 2-, 3-Foot Covers Long Term Care Plan*. Revision 2.

2011h (Sept.) *Landfill Wastewater Treatment System Closure Project Construction Completion Report*. Revision 0.

2011i (Apr.) *Miscellaneous RMA Structure Demolition and Removal Project – Phase IV and SQI Extension Sanitary Sewer Manhole Plugging Construction Completion Report*. Revision 0.

2011j (Nov.) *Basin F Post-Closure Groundwater Monitoring Report 2010-2011*. Revision 0.

2010a (May) *Enhanced Hazardous Waste Landfill Post-Closure Groundwater Monitoring Plan*, Revision 0. *(Appendix to ELF Post-Closure Plan).*

2010b (May) *Enhanced Hazardous Waste Landfill Post-Closure Plan*. Revision 0.

2010c (Nov.) *Lime Basins DNAPL Remedial Investigation Summary Report.* Final

2010d (July) *Section 36 Lime Basins Soil Remediation Project DCN-LB-027*.

2008 (Oct.) *North Plants Pilot Light Non-Aqueous Phase Liquid Removal System Action Plan*.

2007a (Dec.) *HWL Closure/Post-Closure Groundwater Monitoring Plan*. Revision 0.

2007b (Dec.) *North Plants Soil Remediation Project Interim Free Product and Groundwater Characterization Data Summary Report*.

2007c *Rocky Mountain Arsenal Section 36 Lime Basins Soil Remediation Project, Slurry/Barrier Wall Design, 100 Percent Design Package*. Revision 0.

2006a (Mar.) *Enhanced Hazardous Waste Landfill, Operational Groundwater Monitoring Plan.* Revision 1.

2006b (Mar.) *Explanation of Significant Differences for Groundwater Remediation and Revegetation Requirements*. Revision 0.

2005 (Oct.) *Amendment to the Record of Decision for the On-Post Operable Unit, RMA Federal Facility Site*. Revision 0.

TtFW (Tetra Tech FW, Inc.)

2004 (Dec.) *North Plants Soil Remediation Project Petroleum Release Evaluation Report*. Revision 0.

USGS (U.S. Geological Survey)

2005 *Surface Water-Quality and Water-Quantity Data from Selected Urban Runoff-Monitoring Sites at the Rocky Mountain Arsenal, Commerce City, Colorado, Water Years 1988–2004. U.S. Geological Survey Scientific Investigations Report 2005-5214*, 29 p. and appendices.

1997 *Ground-Water Monitoring Program Evaluation Report for Water Year 1994, Rocky Mountain Arsenal, Commerce City, Colorado*, Final. April 1997. U.S. Geological Survey Water Resources Division.

URS Corporation

2013 *2013 Surface Water Quality Monitoring Report (FY96 through FY11) for the Rocky Mountain Arsenal*.

2012a (Feb.) *North Plants Pilot Light Non-Aqueous Phase Liquid Removal Action 2010-2011 Evaluation Report*.

2012b (May) *1,4-Dioxane Characterization Sampling and Analysis Plan*. Revision 0.

2012c (Feb.) GWMR Project Post-Shut-Off Monitoring Sampling and Analysis Plan, Revision 0.

2012d *Motor Pool System/Irondale Containment System Post Shut-Off Monitoring Sampling and Analysis Plan*. Revision 0.

2011 (Sept.) *Motor Pool Extraction System Component of the Irondale Containment System Shut-Off Monitoring Project Construction Completion Report*. Final.

2010 (Feb.) *Offpost Groundwater Intercept and Treatment System, Northern Pathway Modifications Project, Startup Evaluation Report*. Draft Final.

URS Washington Division

2010a (Jan.) *Groundwater Mass Removal Project 2008 Annual Operations Report*. Final.

2010b *Groundwater Mass Removal Project 2009 Annual Operations Report*. Final.

2009a (Apr.) *North Boundary Containment Systems Enhancement for In-Situ Biodegradation Termination Report*. Revision. 0.

2009b (June) *Groundwater Mass Removal Project 2006-2007 Annual Operations Report*. Final.

URS Washington Division and TtEC (URS Washington Division and Tetra Tech EC, Inc.)

2011 (March.) Final Landfill Wastewater Treatment System Closure Plan. Revision 3.

2009 *North Plants Light Non-Aqueous Phase Liquid Removal Pilot Study Action Plan*. Revision 1.

Washington Group International

2008 (Sep.) *Rocky Mountain Arsenal, Section 36 Bedrock Ridge Groundwater Plume Extraction System, Construction Completion Report*.

2007 *Groundwater Mass Removal Project DCN-GWMR-032*.

2006 (Jan.) *Groundwater Mass Removal Project Treatment System Final Design Package*.

2005a (Dec.) *Groundwater Mass Removal Project Groundwater Extraction/Recharge System Design Analysis Report,* Final. Prepared for Rocky Mountain Arsenal Remediation Venture Office.

2005b (Sep.) *Termination of Operation at the Groundwater Intercept and Treatment System North of Basin F Well, Final Construction Completion Report*.

TABLES

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Table 5.1.3.1-3. Summary of Water Quality Trends

Well ID	Indicator Analytes and Trends
Upgradient of NWBCS	
03005	Chloroform, dieldrin
	Chloroform—concentrations below CSRG and decreased to below MRL
	Dieldrin—concentrations appear to be decreasing based on two detections
03015	Dieldrin
	Dieldrin—concentrations appear to stable based on two detections
03016	Dieldrin
	Dieldrin—concentrations appear to be decreasing
22001	DIMP, OCPs
	Dieldrin—concentrations appear to be increasing based on two detections
	DIMP—concentrations appear to be decreasing
	Isodrin—concentrations decreased to below CSRG
27002	Chloroform, dieldrin
	Chloroform—decreasing trend, below MRL in 2014
	Dieldrin—concentrations appear to be stable based on two detections
27025	Arsenic, chloroform, dieldrin, DIMP, NDMA
	Arsenic—decreasing trend; below CSRG in 2014
	Chloroform—decreasing trend below CSRG
	Dieldrin—slight decreasing trend at low concentrations
	DIMP—variable, decreasing overall trend below CSRG
	NDMA—variable; decreasing overall trend to below MRL in 2014
27037	Chloroform, dieldrin
	Chloroform—slight increasing trend below CSRG
	Dieldrin—increasing trend at low concentrations
27043	Dieldrin
	Dieldrin—concentrations stable based on two detections
27079	Arsenic, chloroform, dieldrin, DIMP
	Arsenic—decreasing trend based on two detections
	Chloroform—slight increasing trend at low concentrations; not detected in one of three sampling events
	Dieldrin— slight decreasing trend at very low concentrations
	DIMP—slight decreasing trend, low concentrations;
27082	Arsenic, chloroform, dieldrin, DIMP, NDMA
	Arsenic—decreasing trend based on two detections; below CSRG in 2014
	Chloroform—decreasing trend below CSRG
	Dieldrin—Slight decreasing trend; low concentrations
	DIMP—concentrations remained stable
	NDMA—variable; low concentrations; decreased to below MRL in 2014

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
27083	Chloroform, dieldrin
	Chloroform—variable to increasing;
	Dieldrin—concentrations remained stable
27091	Chloroform, dieldrin
	Chloroform—not detected during most of the four years; increased in 2014
	Dieldrin—not detected in five of 12 sampling events; concentrations remained stable
34005	Chloroform, dieldrin
	Chloroform—decreasing trend based on two detections
	Dieldrin—decreasing trend based on two detections
34008	Dieldrin
	Dieldrin—decreasing trend, not detected in 2014
34015	Dieldrin
	Dieldrin—appears stable at very low concentrations; based on two sampling events
34017	Chloroform, dieldrin
	Chloroform—not detected in any samples
	Dieldrin—slight increasing trend at very low concentrations; based on two detections
34020	Chloroform, dieldrin
	Chloroform—concentrations appear to be increasing at low concentrations below CSRG
	Dieldrin—variable to increasing at low concentrations
34508	Chloroform, dieldrin
	Chloroform—concentrations appear to be stable based on two detections
	Dieldrin—concentrations appear to be decreasing based on two detections
35058	Chloroform, dieldrin
	Chloroform—variable to stable
	Dieldrin—variable to increasing
Upgradient of NBCS	
23095	Arsenic, chloride, chloroform, dieldrin, DIMP, fluoride, NDMA, sulfate
	Arsenic—concentrations appear to be stable based on two detections
	Chloride—concentrations remained stable
	Chloroform—concentrations below CSRG and below MRLs in 2012 and 2014
	Dieldrin—decreasing trend at low concentrations
	Fluoride—concentrations remained stable below CSRG
	DIMP—variable, but decreasing trend overall
	NDMA—concentrations decreased steadily
	Sulfate—concentrations remained stable

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
23096	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA, sulfate
	Chloride—concentrations remained stable
	Chloroform—decreasing trend
	DBCP—decreasing trend; below CSRG in 2012 and 2014
	Dieldrin—slight decreasing trend
	DIMP—decreasing trend
	Fluoride—concentrations remained stable below CSRG
	NDMA—decreasing overall trend; stable levels at low concentrations near PQL in 2012 and 2014
	Sulfate—stable trend; anomalously high concentration in 2012 appears to be an outlier
23142	Chloride, chloroform, dieldrin, DIMP, fluoride, sulfate
	Chloride—concentrations remained stable
	Chloroform—variable below CSRG; not detected in one of three sampling events.
	Dieldrin—decreasing trend
	DIMP—decreasing trend; below CSRG in 2014
	Fluoride—decreasing trend
	Sulfate—concentrations remained stable
23548	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA
	Chloride—concentrations appear to be stable based on two detections
	Chloroform—Below CSRG in 2012 and 2014
	DBCP—below CSRG and decreasing
	Dieldrin—concentrations appear to be decreasing slightly based on two detections
	DIMP— concentrations decreasing based on two detections (from 324 to 27.4 µg/L in 2014)
	Fluoride— concentrations appear to be stable below the CSRG based on two detections
	NDMA— concentrations appear to be stable based on two detections
24092	Chloride, chloroform, DIMP, fluoride, sulfate
	Chloride—slight increasing trend; below CSRG
	Chloroform—variable concentrations; below CSRG
	DIMP—variable
	Fluoride—slight decreasing trend
	Sulfate—slight increasing trend
24094	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, sulfate
	Chloride—increasing trend; below CSRG
	Carbon tetrachloride—decreasing trend
	Chloroform—concentrations decreased; not detected in last of three sampling events
	DIMP—not detected in any sample
	Fluoride—concentrations appear stable; below CSRG
	Sulfate—slight increasing trend; below CSRG

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
North Plants	
24081	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, tetrachloroethylene
	Chloride—concentrations stable based on two detections; below CSRG
	Carbon tetrachloride—below CSRG; not detected in FY14 sample
	Chloroform—concentrations appear to be decreasing based on two detections; below CSRG
	DIMP—concentrations appear to be decreasing based on two detections
	Fluoride— concentrations increased in FY14; below CSRG
	Tetrachloroethylene—concentrations decreased in FY14; below CSRG
25059	Chloride, chloroform, DIMP, fluoride, tetrachloroethylene
	Chloride—concentrations appear to be stable based on two detections; below CSRG
	Chloroform—not detected in any sample
	DIMP—variable
	Fluoride—decreasing trend; below CSRG
	Tetrachloroethylene—not detected in any sample
Rail Yard System	
03523	DBCP
	DBCP—decreasing trend; below CSRG; not detected in 10 of 13 recent sampling events
Motor Pool	
04535	TCE
	TCE—variable; below CSRG
BANS/Basin A Neck	
26006	Arsenic, DIMP, dieldrin, dithiane, NDMA, DDT
	Arsenic—concentrations appear to be decreasing based on two detections
	DIMP—decreasing trend
	Dieldrin—decreasing trend
	Dithiane—decreasing trend; below CSRG
	NDMA—concentrations appear to be increasing, but at very low concentrations
	DDT—concentrations appear to be decreasing
35065	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
	Arsenic—concentrations appear to be stable based on two detections
	Benzene—stable at low concentrations below CSRG; not detected in one of four samples
	Chloroform—stable at low concentrations below CSRG; not detected in one of four samples
	Chloride— concentrations appear to be increasing based on two detections
	DBCP—not detected in any sample
	Dieldrin—concentrations appear to be decreasing; not detected in last two of three samples
	DIMP—variable, increased during FYR period, but decreasing long-term
	Dithiane—concentrations appear to be increasing based on two detections
	NDMA—not detected in any sample
	TCE—variable below CSRG; not detected in first of four sampling events;

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
Lime Basins/Basin A	
36210	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
	Arsenic—decreasing trend
	Benzene—decreasing trend
	Chloroform—concentrations stable
	Chloride—concentrations appear to be decreasing based on two detections
	DBCP—concentrations appear to be decreasing
	Dieldrin—concentrations appear to be increasing based on two detections
	DIMP—not detected in any sample (LT 25, LT 250 µg/L)
	Dithiane—concentrations appear to be increasing based on two detections; below CSRG
	TCE—not detected in any sample (LT 1000 µg/L)
Basin A Source	
36627	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
	Arsenic—variable; concentrations appear to be decreasing
	Benzene—concentrations stable
	Chloroform—concentrations stable
	Chloride—concentrations stable
	DBCP—not detected in first of four sampling events; increasing trend, but below CSRG
	Dieldrin—variable, but stable overall
	DIMP—not detected in any sample
	Dithiane—concentrations stable
	NDMA—not detected in any sample
	TCE—concentrations appear to be stable; not detected in last two of four sampling events
36629	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
	Arsenic—variable, decreasing trend overall
	Benzene—concentrations stable
	Chloroform—decreasing trend; not detected in one of four sampling events
	Chloride—concentrations stable
	DBCP—not detected in three of four samples; Below CSRG in 2014
	Dieldrin—variable; not detected in last of four sampling events
	DIMP—concentrations stable
	Dithiane—concentrations stable
	NDMA—concentrations appear to be decreasing; not detected in last two of three sampling events
	TCE—concentrations remained stable

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
36630	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
	Arsenic—variable, but stable overall
	Benzene—variable, but stable overall
	Chloroform—decreasing trend; below CSRG
	Chloride—slight decreasing trend
	DBCP—not detected in three of four sampling events
	Dieldrin—concentrations stable overall
	DIMP—variable, stable overall
	Dithiane—concentrations stable overall
	TCE—concentrations remained stable; below CSRG
36631	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
	Arsenic—variable, but stable overall
	Benzene—concentrations decreasing
	Chloroform—concentrations decreasing
	Chloride—concentrations appear to have been decreasing slightly since 2009
	DBCP—concentrations appear to have been increasing
	Dieldrin—variable, but stable overall
	DIMP—not detected in any sample
	Dithiane—variable, but stable overall
	NDMA—not detected in two of three sampling events, increased in 2014
	TCE—not detected in any samples (LT 5,000, LT 10,000 µg/L)
36632	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE
	Arsenic—variable, but stable overall
	Benzene—variable, but stable overall
	Chloroform—decreasing trend
	Chloride—concentrations remained stable
	DBCP—not detected in any samples
	Dieldrin—concentrations appear to be decreasing
	DIMP—variable, but decreasing overall
	Dithiane—variable, but stable overall
	NDMA—decreasing trend, not detected in last two of three sampling events
	TCE—variable, but stable overall

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
36633	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE
	Arsenic—concentrations remained stable
	Benzene—concentrations remained stable
	Chloroform—concentrations remained stable
	Chloride—concentrations remained stable
	DBCP—not detected in any samples
	Dieldrin—concentrations appear to be decreasing
	DIMP— concentrations remained stable
	Dithiane—concentrations increasing
	TCE—concentrations appear to be decreasing
Bedrock Ridge	
25502	Carbon tetrachloride, chloroform, DIMP, tetrachloroethylene
	Carbon tetrachloride—not detected in any samples
	Chloroform—decreasing trend
	DIMP—decreasing trend
	Tetrachloroethylene—decreasing trend
36552	Benzene, chloroform, TCE
	Benzene—not detected in any samples
	Chloroform—variable, below the CSRG
	TCE—decreasing trend
36594	Carbon tetrachloride, chloroform, dieldrin, DIMP, tetrachloroethylene, TCE
	Carbon tetrachloride—decreasing trend; not detected in one of four sampling events
	Chloroform—decreasing trend
	Dieldrin—concentrations appeared stable
	DIMP—decreasing trend
	Tetrachloroethylene—stable; not detected in one of four sampling events
	TCE—concentrations appear to be increasing
South Plants SPSA-2d Ditch Source	
01044	Aldrin, dieldrin
	Aldrin—not detected in any samples
	Dieldrin—detected in one of two sampling events
01047	Aldrin, dieldrin
	Aldrin—not detected in any samples
	Dieldrin—not detected in any samples
01101	Aldrin, dieldrin, chloride
	Aldrin—not detected in any samples
	Dieldrin—detected in one of two sampling events
	Chloride—concentrations appear to be stable based on two detections

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
01582	Aldrin, dieldrin
	Aldrin—not detected in any samples
	Dieldrin—concentrations appear to be increasing slightly based on two detections
01669	Aldrin, dieldrin
	Aldrin—concentrations appear to be decreasing based on two detections
	Dieldrin—concentrations appear to be decreasing based on two detections
01670	Aldrin, dieldrin
	Aldrin—detected in 2014; no data for 2012
	Dieldrin—detected in 2014; no data for 2012
Well ID	**Indicator Analytes and Trends**
South Plants Central Processing Area Source	
01078	Arsenic, benzene, chloride, chloroform, dieldrin
	Arsenic—concentrations appear stable based on two detections
	Benzene—variable
	Chloride—concentrations appear stable based on two detections
	Chloroform—variable, but slightly higher overall
	Dieldrin—concentrations appear to be decreasing
01525	Arsenic, benzene, chloroform, dieldrin
	Arsenic—concentrations appear to be decreasing based on two detections
	Benzene—variable, but stable overall
	Chloroform—variable, but stable overall
	Dieldrin—slight increase since 2009
South Tank Farm	
01312	Benzene, chloride, chloroform
	Benzene—concentrations appear to be stable
	Chloride—concentrations appear stable based on two detections
	Chloroform—not detected in any samples, high MRLs (LT 5,000, LT 10,000 µg/L)
South Plants	
02065	Benzene, chloroform, dieldrin
	Benzene—not detected in any samples
	Chloroform—concentrations appear stable based on two detections, below CSRG
	Dieldrin—concentrations appear to be decreasing based on two detections

Table 5.1.3.1-3. Summary of Water Quality Trends (Continued)

Well ID	Indicator Analytes and Trends
36181	Arsenic, benzene, chloride, chloroform, DBCP, dieldrin
	Arsenic—not detected in first of two sampling events, below CSRG
	Benzene—concentrations appear to be decreasing
	Chloride—concentrations appear to be increasing based on two detections
	Chloroform—concentrations appear to be decreasing; not detected in last of three sampling events
	DBCP—stable, not detected in first of three sampling events
	Dieldrin—concentrations appear to be decreasing based on two detections
South Lakes	
02034	Benzene, chloroform, dieldrin
	Benzene—not detected in any samples
	Chloroform—variable, decreased to below CSRG
	Dieldrin—concentrations decreased from 2009 to 2014
02505	Benzene, chloroform
	Benzene—not detected in any sample
	Chloroform—concentrations appear to have decreased and then remained stable
02512	Benzene, dieldrin
	Benzene—not detected in any sample
	Dieldrin—variable, increased in 2014
02523	Benzene, chloroform, dieldrin, TCE
	Benzene—not detected in any sample
	Chloroform—concentrations appear to be decreasing based on two detections
	Dieldrin—not detected in first of two sampling events, then increased
	TCE—concentrations appear to be stable based on two detections below CSRG
02524	Benzene, chloroform, dieldrin
	Benzene—not detected in any samples
	Chloroform—variable above and below CSRG; long-term trend is decreasing
	Dieldrin—concentrations remained stable
02525	Benzene, chloroform, dieldrin
	Benzene—not detected in any sample
	Chloroform—variable
	Dieldrin—concentrations remained stable
02597	Benzene, chloroform, dieldrin
	Benzene—not detected in any sample
	Chloroform—concentrations appear to be decreasing based on two detections
	Dieldrin—not detected in any sample

Table 5.1.3.1-3. Summary of Water Quality Trends (Concluded)

Well ID	Indicator Analytes and Trends
Former Basin F	
26015	Chloride, chloroform, dieldrin, DIMP, NDMA
	Chloride—concentrations indicate a decreasing trend
	Chloroform—not detected in two of five sampling events, below CSRG
	Dieldrin—concentrations indicate decreasing trend at low levels, below MRL in 2014
	DIMP—concentrations remained stable at low levels below CSRG
	NDMA—detected at concentrations near the detection limit
26017	Chloride, chloroform, dieldrin, DIMP, NDMA
	Chloride—concentrations remained stable through 2013 and increased in 2014
	Chloroform—below CSRG, not detected in last two sampling events
	Dieldrin—slight decreasing trend
	DIMP—concentrations remained stable and then decreased below CSRG in 2014
26157	Chloride, chloroform, dieldrin, DIMP, NDMA
	Chloride—concentrations remained stable
	Chloroform—decreasing trend; not detected in last sampling event
	Dieldrin—concentrations appear to be decreasing
	DIMP— concentrations appear to be decreasing
	NDMA—concentrations appear to be decreasing
26163	Chloride, chloroform, dieldrin, DIMP, NDMA
	Chloride—concentrations appear stable
	Chloroform—not detected in any sample
	Dieldrin—variable: not detected in two of six sampling events
	DIMP—concentration stable
	NDMA—slight decreasing trend

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
01067	CFS (D)	8/27/2009	5,282.2	41.5	5,240.7		
01068	UFS (D)	8/27/2009	5,282.4	36.9	5,245.5	4.9	Downward
01067	CFS (D)	8/18/2010	5,282.2	40.6	5,241.6		
01068	UFS (D)	8/18/2010	5,282.4	37.0	5,245.4	3.8	Downward
01067	CFS (D)	7/6/2011	5,282.2	42.0	5,240.2		
01068	UFS (D)	7/6/2011	5,282.4	37.9	5,244.5	4.3	Downward
01067	CFS (D)	7/13/2012	5,282.2	42.3	5,239.9		
01068	UFS (D)	7/13/2012	5,282.4	38.4	5,244.0	4.1	Downward
01067	CFS (D)	8/8/2013	5,282.2	44.1	5,238.2		
01068	UFS (D)	7/9/2013	5,282.4	39.0	5,243.4	5.3	Downward
01067	CFS (D)	7/29/2014	5,282.2	41.4	5,240.8		
01068	UFS (D)	7/28/2014	5,282.4	37.6	5,244.8	4.0	Downward
01102	CFS (D)	8/27/2009	5,272.5	31.4	5,241.1		
01534	UFS (D)	8/27/2009	5,271.4	24.2	5,247.2	6.1	Downward
01102	CFS (D)	8/18/2010	5,272.5	30.5	5,242.0		
01534	UFS (D)	8/18/2010	5,271.4	23.7	5,247.7	5.7	Downward
01102	CFS (D)	7/6/2011	5,272.5	31.8	5,240.7		
01534	UFS (D)	7/6/2011	5,271.4	25.4	5,246.1	5.3	Downward
01102	CFS (D)	7/13/2012	5,272.5	32.2	5,240.3		
01534	UFS (D)	7/13/2012	5,271.4	26.0	5,245.5	5.2	Downward
01102	CFS (D)	8/8/2013	5,272.5	33.8	5,238.8		
01534	UFS (D)	7/9/2013	5,271.4	26.9	5,244.5	5.8	Downward
01102	CFS (D)	7/29/2014	5,272.5	31.2	5,241.3		
01534	UFS (D)	7/28/2014	5,271.4	23.1	5,248.3	7.0	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver, C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
01109	CFS (D)	8/27/2009	5,278.4	69.7	5,208.7		
01101	UFS (D)	8/27/2009	5,277.5	32.7	5,244.9	36.2	Downward
01109	CFS (D)	8/18/2010	5,278.4	70.9	5,207.5		
01101	UFS (D)	8/18/2010	5,277.5	31.9	5,245.6	38.1	Downward
01109	CFS (D)	7/6/2011	5,278.4	71.4	5,207.1		
01101	UFS (D)	7/6/2011	5,277.5	33.2	5,244.3	37.2	Downward
01109	CFS (D)	7/13/2012	5,278.4	71.8	5,206.7		
01101	UFS (D)	7/13/2012	5,277.5	33.4	5,244.2	37.5	Downward
01109	CFS (D)	8/8/2013	5,278.4	72.5	5,206.0		
01101	UFS (D)	7/9/2013	5,277.5	34.4	5,243.1	37.2	Downward
01109	CFS (D)	7/29/2014	5,278.4	72.1	5,206.4		
01101	UFS (D)	7/28/2014	5,277.5	30.8	5,246.7	40.4	Downward
01300	CFS (D)	8/27/2009	5,289.6	47.3	5,242.3		
01078	UFS (D)	8/27/2009	5,289.7	43.5	5,246.1	3.9	Downward
01300	CFS (D)	8/18/2010	5,289.6	47.1	5,242.5		
01078	UFS (D)	8/18/2010	5,289.7	43.9	5,245.8	3.2	Downward
01300	CFS (D)	7/6/2011	5,289.6	47.6	5,241.9		
01078	UFS (D)	7/6/2011	5,289.7	44.4	5,245.3	3.4	Downward
01300	CFS (D)	7/13/2012	5,289.6	48.5	5,241.1		
01078	UFS (D)	7/13/2012	5,289.7	44.9	5,244.8	3.6	Downward
01300	CFS (D)	8/8/2013	5,289.6	49.6	5,240.0		
01078	UFS (D)	7/9/2013	5,289.7	45.4	5,244.2	4.2	Downward
01300	CFS (D)	7/29/2014	5,289.6	49.3	5,240.3		
01078	UFS (D)	7/17/2014	5,289.7	45.2	5,244.4	4.1	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver, C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
02057	CFS (D)	8/27/2009	5,258.7	17.9	5,240.8		
02058	UFS (A/D)	8/27/2009	5,258.5	18.3	5,240.2	-0.6	Upward
02057	CFS (D)	8/18/2010	5,258.7	17.0	5,241.7		
02058	UFS (A/D)	8/20/2010	5,258.5	18.3	5,240.2	-1.5	Upward
02057	CFS (D)	7/6/2011	5,258.7	18.4	5,240.4		
02058	UFS (A/D)	7/6/2011	5,258.5	21.3	5,237.2	-3.1	Upward
02057	CFS (D)	7/13/2012	5,258.7	18.7	5,240.1		
02058	UFS (A/D)	7/13/2012	5,258.5	22.6	5,235.9	-4.2	Upward
02057	CFS (D)	8/8/2013	5,258.7	20.4	5,238.4		
02058	UFS (A/D)	7/10/2013	5,258.5	22.9	5,235.6	-2.8	Upward
02057	CFS (D)	7/29/2014	5,258.7	17.7	5,241.0		
02058	UFS (A/D)	7/28/2014	5,258.5	17.2	5,241.3	0.3	Downward
35083	CFS (D)	8/24/2009	5,265.4	66.4	5,199.0		
35013	UFS (D)	8/24/2009	5,270.6	20.8	5,249.8	50.8	Downward
35083	CFS (D)	8/18/2010	5,265.4	66.0	5,199.4		
35013	UFS (D)	8/18/2010	5,270.6	21.7	5,249.0	49.6	Downward
35083	CFS (D)	7/13/2011	5,265.4	65.7	5,199.7		
35013	UFS (D)	7/13/2011	5,270.6	23.7	5,246.9	47.3	Downward
35083	CFS (D)	7/10/2012	5,265.4	66.1	5,199.3		
35013	UFS (D)	7/10/2012	5,270.6	25.6	5,245.0	45.7	Downward
35083	CFS (D)	8/8/2013	5,265.4	66.6	5,198.8		
35013	UFS (D)	7/16/2013	5,270.6	27.5	5,243.1	44.3	Downward
35083	CFS (D)	7/14/2014	5,265.4	65.5	5,199.9		
35013	UFS (D)	7/14/2014	5,270.6	21.3	5,249.3	49.3	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
36183	CFS (D)	8/27/2009	5,264.8	28.6	5,236.2		
36181	UFS (A/D)	8/27/2009	5,274.1	28.8	5,245.3	9.1	Downward
36183	CFS (D)	8/18/2010	5,270.8	32.4	5,238.4		
36181	UFS (A/D)	8/18/2010	5,274.1	29.6	5,244.5	6.1	Downward
36183	CFS (D)	7/7/2011	5,270.8	33.9	5,236.9		
36181	UFS (A/D)	7/7/2011	5,274.1	29.9	5,244.2	7.3	Downward
36183	CFS (D)	7/12/2012	5,270.8	35.1	5,235.7		
36181	UFS (A/D)	7/12/2012	5,274.1	30.3	5,243.8	8.0	Downward
36183	CFS (D)	8/8/2013	5,270.8	36.6	5,234.2		
36181	UFS (A/D)	7/16/2013	5,274.1	30.8	5,243.3	9.1	Downward
36183	CFS (D)	7/17/2014	5,270.8	36.7	5,234.1		
36181	UFS (A/D)	7/17/2014	5,274.1	30.8	5,243.4	9.3	Downward
23187	CFS (D)	8/20/2009	5,172.1	59.1	5,113.0		
23185	UFS (D)	8/20/2009	5,172.1	36.0	5,136.1	23.1	Downward
23187	CFS (D)	8/17/2010	5,171.5	58.0	5,113.5		
23185	UFS (D)	8/17/2010	5,172.1	30.9	5,141.3	27.7	Downward
23187	CFS (D)	7/7/2011	5,172.3	57.4	5,114.9		
23185	UFS (D)	7/7/2011	5,171.5	29.6	5,141.9	27.1	Downward
23187	CFS (D)	7/16/2012	5,172.3	57.2	5,115.0		
23185	UFS (D)	7/16/2012	5,171.5	31.1	5,140.4	25.4	Downward
23187	CFS (D)	8/3/2013	5,172.3	57.0	5,115.3		
23185	UFS (D)	7/15/2013	5,171.5	32.0	5,139.5	24.2	Downward
23187	CFS (D)	7/16/2014	5,172.3	56.5	5,115.8		
23185	UFS (D)	7/16/2014	5,171.5	30.4	5,141.1	25.3	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver, C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
23193	CFS (D)	8/20/2009	5,194.1	66.5	5,127.6		
23142	UFS (A/D)	8/20/2009	5,191.1	55.1	5,136.0	8.4	Downward
23193	CFS (D)	8/17/2010	5,194.1	66.6	5,127.5		
23142	UFS (A/D)	8/17/2010	5,191.1	53.7	5,137.4	9.9	Downward
23193	CFS (D)	7/7/2011	5,194.1	66.7	5,127.4		
23142	UFS (A/D)	7/7/2011	5,191.1	52.8	5,138.3	10.9	Downward
23193	CFS (D)	7/16/2012	5,194.1	66.7	5,127.3		
23142	UFS (A/D)	7/16/2012	5,191.1	52.7	5,138.4	11.0	Downward
23193	CFS (D)	8/8/2013	5,194.1	66.9	5,127.2		
23142	UFS (A/D)	7/15/2013	5,191.1	53.1	5,137.9	10.8	Downward
23193	CFS (D)	7/17/2014	5,194.1	66.5	5,127.6		
23142	UFS (A/D)	7/16/2014	5,191.1	52.9	5,138.2	10.6	Downward
26147	CFS (D)	8/25/2009	5,180.2	38.4	5,141.7		
26146	UFS (D)	8/25/2009	5,180.2	35.9	5,144.3	2.6	Downward
26147	CFS (D)	8/18/2010	5,180.1	38.2	5,141.9		
26146	UFS (D)	8/18/2010	5,180.2	35.7	5,144.5	2.6	Downward
26147	CFS (D)	7/13/2011	5,180.1	37.2	5,142.9		
23135[2]	UFS (A/D)	7/7/2011	5,187.1	42.4	5,144.1	1.2	Downward
26147	CFS (D)	7/17/2012	5,180.1	37.7	5,142.4		
26146	UFS (D)	9/19/2012	5,180.2	35.6	5,144.6	2.2	Downward
26147	CFS (D)	8/8/2013	5,180.1	37.5	5,142.6		
26146	UFS (D)	8/8/2013	5,180.2	35.7	5,144.5	1.9	Downward
26147	CFS (D)	7/15/2014	5,180.1	37.2	5,142.9		
26146	UFS (D)	7/15/2014	5,180.2	35.6	5,144.5	1.7	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver, C = confined flow system, UFS = unconfined flow system

[2] UFS well 26146 was not measured in 2011 likely due to program transition. Hence, well 23135 was used to calculate the vertical hydraulic gradient.

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
26150	CFS (D)	8/25/2009	5,221.0	49.2	5,171.8		
26158	UFS (D)	8/25/2009	5,214.9	35.2	5,179.7	7.9	Downward
26150	CFS (D)	8/18/2010	5,221.0	48.6	5,172.4		
26158	UFS (D)	8/18/2010	5,214.9	35.1	5,179.8	7.4	Downward
26150	CFS (D)	7/12/2011	5,221.0	48.4	5,172.5		
26158	UFS (D)	7/12/2011	5,214.9	35.2	5,179.7	7.2	Downward
26150	CFS (D)	7/11/2012	5,221.0	48.3	5,172.7		
26158	UFS (D)	7/11/2012	5,214.9	35.1	5,179.8	7.1	Downward
26150	CFS (D)	7/17/2013	5,221.0	48.8	5,172.2		
26158	UFS (D)	7/17/2013	5,214.9	35.5	5,179.4	7.3	Downward
26150	CFS (D)	7/15/2014	5,221.0	47.6	5,173.3		
26158	UFS (D)	7/16/2014	5,214.9	34.7	5,180.2	6.8	Downward
26152	CFS (D)	8/25/2009	5,196.7	44.2	5,152.5		
26154	UFS (A)	8/25/2009	5,198.3	26.9	5,171.4	18.9	Downward
26152	CFS (D)	8/18/2010	5,196.7	44.2	5,152.6		
26154	UFS (A)	8/18/2010	5,198.3	26.6	5,171.7	19.1	Downward
26152	CFS (D)	7/12/2011	5,196.7	44.7	5,152.0		
26154	UFS (A)	7/12/2011	5,198.3	27.4	5,170.9	18.9	Downward
26152	CFS (D)	7/17/2012	5,196.7	44.9	5,151.9		
26154	UFS (A)	7/17/2012	5,198.3	27.1	5,171.2	19.4	Downward
26152	CFS (D)	8/8/2013	5,196.7	45.5	5,151.2		
26154	UFS (A)	7/16/2013	5,198.3	28.1	5,170.2	19.0	Downward
26152	CFS (D)	7/15/2014	5,196.7	43.2	5,153.6		
26154	UFS (A)	7/15/2014	5,198.3	25.5	5,172.8	19.2	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
26153	CFS (D)	8/25/2009	5,190.9	53.0	5,138.0		
26015	UFS (A/D)	8/25/2009	5,190.0	45.3	5,144.7	6.8	Downward
26153	CFS (D)	8/18/2010	5,190.9	52.0	5,138.9		
26015	UFS (A/D)	8/18/2010	5,190.0	45.3	5,144.7	5.9	Downward
26153	CFS (D)	7/13/2011	5,190.9	51.7	5,139.2		
26015	UFS (A/D)	7/13/2011	5,190.0	45.3	5,144.7	5.5	Downward
26153	CFS (D)	7/16/2012	5,190.9	54.5	5,136.4		
26015	UFS (A/D)	7/10/2012	5,190.0	45.3	5,144.8	8.4	Downward
26153	CFS (D)	8/8/2013	5,190.9	51.9	5,139.0		
26015	UFS (A/D)	4/25/2013	5,190.0	45.3	5,144.7	5.8	Downward
26153	CFS (D)	7/16/2014	5,190.9	51.5	5,139.4		
26015	UFS (A/D)	7/16/2014	5,190.0	45.3	5,144.8	5.3	Downward
35063	CFS (D)	8/24/2009	5,239.6	44.4	5,195.1		
35061	UFS (A/D)	8/24/2009	5,238.8	15.9	5,222.9	27.8	Downward
35063	CFS (D)	8/18/2010	5,239.6	42.7	5,196.9		
35061	UFS (A/D)	8/18/2010	5,238.8	14.5	5,224.3	27.4	Downward
35063	CFS (D)	7/13/2011	5,239.6	42.5	5,197.1		
35061	UFS (A/D)	7/13/2011	5,238.8	14.1	5,224.7	27.6	Downward
35063	CFS (D)	7/11/2012	5,239.6	42.6	5,197.0		
35061	UFS (A/D)	7/11/2012	5,238.8	15.4	5,223.5	26.5	Downward
35063	CFS (D)	8/8/2013	5,239.6	43.6	5,195.9		
35061	UFS (A/D)	7/16/2013	5,238.8	17.2	5,221.6	25.7	Downward
35063	CFS (D)	7/14/2014	5,239.6	41.6	5,197.9		
35061	UFS (A/D)	7/14/2014	5,238.8	14.4	5,224.4	26.5	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
35067	CFS (D)	8/24/2009	5,233.4	28.6	5,204.8		
35065	UFS (A/D)	8/24/2009	5,235.3	12.3	5,223.0	18.2	Downward
35067	CFS (D)	8/18/2010	5,235.4	30.3	5,205.1		
35065	UFS (A/D)	8/18/2010	5,235.3	11.6	5,223.7	18.6	Downward
35067	CFS (D)	7/13/2011	5,235.4	30.3	5,205.1		
35065	UFS (A/D)	7/13/2011	5,235.3	11.8	5,223.6	18.4	Downward
35067	CFS (D)	7/11/2012	5,235.4	29.7	5,205.7		
35065	UFS (A/D)	7/11/2012	5,235.3	12.4	5,222.9	17.2	Downward
35067	CFS (D)	8/8/2013	5,235.4	31.2	5,204.2		
35065	UFS (A/D)	7/16/2013	5,235.3	13.7	5,221.6	17.4	Downward
35067	CFS (D)	7/14/2014	5,235.4	29.5	5,205.9		
35065	UFS (A/D)	7/14/2014	5,235.3	11.6	5,223.7	17.9	Downward
35068	CFS (D)	8/24/2009	5,237.0	43.0	5,194.1		
35065	UFS (A/D)	8/24/2009	5,235.3	12.3	5,223.0	28.9	Downward
35068	CFS (D)	8/18/2010	5,235.3	41.7	5,193.6		
35065	UFS (A/D)	8/18/2010	5,235.3	11.6	5,223.7	30.1	Downward
35068	CFS (D)	7/13/2011	5,235.3	41.7	5,193.7		
35065	UFS (A/D)	7/13/2011	5,235.3	11.8	5,223.6	29.9	Downward
35068	CFS (D)	7/11/2012	5,235.3	42.1	5,193.3		
35065	UFS (A/D)	7/11/2012	5,235.3	12.4	5,222.9	29.6	Downward
35068	CFS (D)	8/8/2013	5,235.3	42.5	5,192.9		
35065	UFS (A/D)	7/16/2013	5,235.3	13.7	5,221.6	28.8	Downward
35068	CFS (D)	7/14/2014	5,235.3	42.0	5,193.3		
35065	UFS (A/D)	7/14/2014	5,235.3	11.6	5,223.7	30.4	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Continued)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
36113	CFS (D)	8/25/2009	5,243.3	25.2	5,218.1		
36112	UFS (D)	8/25/2009	5,242.9	20.4	5,222.5	4.4	Downward
36113	CFS (D)	8/18/2010	5,243.3	24.8	5,218.5		
36112	UFS (D)	8/18/2010	5,243.0	18.5	5,224.4	5.9	Downward
36113	CFS (D)	7/12/2011	5,243.3	24.6	5,218.7		
36112	UFS (D)	7/12/2011	5,243.0	19.9	5,223.0	4.3	Downward
36113	CFS (D)	7/10/2012	5,243.3	24.8	5,218.5		
36112	UFS (D)	7/10/2012	5,243.0	20.3	5,222.7	4.1	Downward
36113	CFS (D)	8/8/2013	5,243.3	25.3	5,218.1		
36112	UFS (D)	7/16/2013	5,243.0	20.4	5,222.6	4.5	Downward
36113	CFS (D)	7/17/2014	5,243.3	24.5	5,218.8		
36112	UFS (D)	7/17/2014	5,243.0	18.7	5,224.2	5.4	Downward
36114	CFS (D)	8/25/2009	5,242.5	48.7	5,193.8		
36112	UFS (D)	8/25/2009	5,242.9	20.4	5,222.5	28.7	Downward
36114	CFS (D)	8/18/2010	5,242.5	49.0	5,193.5		
36112	UFS (D)	8/18/2010	5,243.0	18.5	5,224.4	30.9	Downward
36114	CFS (D)	7/12/2011	5,242.5	49.1	5,193.4		
36112	UFS (D)	7/12/2011	5,243.0	19.9	5,223.0	29.6	Downward
36114	CFS (D)	7/10/2012	5,242.5	49.5	5,193.0		
36112	UFS (D)	7/10/2012	5,243.0	20.3	5,222.7	29.6	Downward
36114	CFS (D)	8/8/2013	5,242.5	49.9	5,192.7		
36112	UFS (D)	7/16/2013	5,243.0	20.4	5,222.6	29.9	Downward
36114	CFS (D)	7/17/2014	5,242.5	49.4	5,193.1		
36112	UFS (D)	7/17/2014	5,243.0	18.7	5,224.2	31.1	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.2-1. Water Level Data and Hydraulic Gradients for the CFS and UFS (Concluded)

Site ID	Flow System[1]	Sample Date	Top of Casing Elevation	Depth to Water	Water Elevation	Head Differential, ft	Vertical Hydraulic Gradient
36159	CFS (D)	8/26/2009	5,254.5	56.0	5,198.5		
36158	UFS (D)	8/26/2009	5,259.9	39.7	5,220.2	21.7	Downward
36159	CFS (D)	8/18/2010	5,259.6	57.8	5,201.8		
36158	UFS (D)	8/18/2010	5,259.9	39.8	5,220.1	18.3	Downward
36159	CFS (D)	7/7/2011	5,259.6	58.6	5,201.0		
36158	UFS (D)	7/7/2011	5,259.9	39.9	5,220.0	18.9	Downward
36159	CFS (D)	7/12/2012	5,259.6	58.5	5,201.1		
36158	UFS (D)	7/12/2012	5,259.9	39.9	5,220.0	18.8	Downward
36159	CFS (D)	8/8/2013	5,259.6	59.7	5,199.9		
36158	UFS (D)	7/16/2013	5,259.9	40.0	5,219.9	20.0	Downward
36159	CFS (D)	7/17/2014	5,259.6	59.6	5,200.0		
36158	UFS (D)	7/17/2014	5,259.9	40.0	5,219.9	20.0	Downward
36171	CFS (D)	8/26/2009	5,252.3	53.7	5,198.7		
36169	UFS (A)	8/26/2009	5,251.9	16.7	5,235.2	36.5	Downward
36171	CFS (D)	8/18/2010	5,252.3	54.1	5,198.2		
36169	UFS (A)	8/18/2010	5,251.9	16.5	5,235.4	37.2	Downward
36171	CFS (D)	7/7/2011	5,252.3	54.3	5,198.0		
36169	UFS (A)	7/7/2011	5,251.9	17.1	5,234.8	36.8	Downward
36171	CFS (D)	7/13/2012	5,252.3	54.6	5,197.8		
36169	UFS (A)	7/13/2012	5,251.9	17.6	5,234.3	36.6	Downward
36171	CFS (D)	8/8/2013	5,252.3	54.8	5,197.5		
36169	UFS (A)	7/16/2013	5,251.9	19.1	5,232.9	35.3	Downward
36171	CFS (D)	7/17/2014	5,252.3	54.1	5,198.2		
36169	UFS (A)	7/17/2014	5,251.9	16.5	5,235.4	37.2	Downward

[1] Aquifer/Flow System designations: A = Alluvial, A/D = Alluvial/Denver, D = Denver,
C = confined flow system, UFS = unconfined flow system

Table 5.1.3.3-1. On-Post Surface Water Analytes and Standards

Analytical Group	Analyte	CBSMSW[1] Drinking Water Supply (PQL[2]), (µg/L[3])	CBSMSW Aquatic Life Acute (µg/L[3])	CBSMSW Aquatic Life Chronic (µg/L[3])
Organochlorine	Aldrin	0.002 (0.037)	1.5	--
Pesticides	Dieldrin	0.002 (0.05)	0.24	0.056
	2,2-bis(p-Chlorophenyl) -1,1-dichloroethene	0.1	1,050	--
	Endrin	2	0.086	0.036
	Hexachlorocyclopentadiene	50	7	5
	Isodrin	NA[5]	--	--
Anions	Bromide	NA[5]	--	--
	Chloride	250,000	--	--
	Fluoride	2,000	--	--
	Sulfate	250,000	--	--
Metals/Cations	Arsenic	10	340	150
	Barium	1000/490	--	--
	Cadmium	5	$(1.136672-[\ln(hardness)*(0.041838)]) *e^{(0.9151[\ln(hardness)]-3.1485)}$	$(1.101672-[\ln(hardness)*(0.041838)]) *e^{(0.7998[\ln(hardness)]-4.4451)}$
	Calcium	NA[5]	--	--
	Copper	1,000	$e^{(0.9422[\ln(hardness)]-1.7408)}$	$e^{(0.8545[\ln(hardness)]-1.7428)}$
	Magnesium	NA[5]	--	--
	Manganese	50	$e^{(0.3331[\ln(hardness)]+6.4676)}$	$e^{(0.3331[\ln(hardness)]+5.8743)}$
	Nickel	100	$e^{(0.846[\ln(hardness)]+2.253)}$	$e^{(0.846[\ln(hardness)]+0.0554)}$
	Potassium	NA[5]	--	--
	Selenium	50	18.4	4.6
	Sodium	NA[5]	--	--
	Zinc	5,000	$0.978 * e^{(0.8525[\ln(hardness)]+1.0617)}$	$0.986 * e^{(0.8525[\ln(hardness)]+0.9109)}$

Table 5.1.3.3-1. On-Post Surface Water Analytes and Standards (Concluded)

Analytical Group	Analyte	CBSMSW[1] Drinking Water Supply (PQL[2]), (µg/L[3])	CBSMSW Aquatic Life Acute (µg/L[3])	CBSMSW Aquatic Life Chronic (µg/L[3])
Nutrients	Ammonia	NA[5]	$(0.411/1+10^{7.204-pH}) + (58.4/1+10^{pH-7.204})$	(Apr1-Aug31)= $[(0.0577/1+ +10^{7.688-pH})+(2.487/1+10^{pH-7.688}]* MIN(2.85, 1.45*10^{0.028*(25-T)})$ (Sep1-Mar31)= $[(0.0577/1+ +10^{7.688-pH})+(2.487/1+10^{pH-7.688}]* 1.45*10^{0.028*(25-MAX(T,7)})$
	Nitrate	10	--	--
	Nitrite	1	--	--
	Orthophosphate	NA[5]	--	--
	Phosphorus	NA[5]	--	--
Other Parameters	Dissolved Organic Carbon	NA[5]	--	--
	Total Organic Carbon	NA[5]	--	--
Volatile Organic Compounds[4]	Benzene	5	5,300	--

Notes:
[1] CBSMSW – Colorado Basic Standards and Methodologies for Surface Water (5 Code of Colorado Regulations 1002-31, 2009).
[2] PQL – Practical Quantitation Limit.
[3] µg/L – micrograms per liter.
[4] Benzene analysis at stream sites only.
[5] NA – not applicable because there is not a CBSMSW for water supply for this analyte.

Table 5.2.2-2. Off-Post CSRG Exceedance Well Network

Well ID	Location	Analytes
23198	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
24162	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
24166	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
37008	Northern Pathway	OGITS CSRG analyte list
37009	Northern Pathway	OGITS CSRG analyte list
37010	Northern Pathway	OGITS CSRG analyte list
37011	Northern Pathway	OGITS CSRG analyte list
37012	Northern Pathway	OGITS CSRG analyte list
37013	Northern Pathway	OGITS CSRG analyte list
37027	Northern Pathway	Chloroform, tetrachloroethylene, DIMP, fluoride, chloride, sulfate
37039	Northern Pathway	Carbon tetrachloride, DIMP
37041	First Creek Pathway	DIMP, chloride
37065	First Creek Pathway	OGITS CSRG analyte list
37070	First Creek Pathway	DIMP, fluoride
37074	First Creek Pathway	DIMP, fluoride, chloride, sulfate
37076	First Creek Pathway	DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate
37080	Northern Pathway	DIMP, chloride
37081	First Creek Pathway	Fluoride, chloride, sulfate, dieldrin, DIMP, VOCs
37083	First Creek Pathway	DCPD, DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate
37084	First Creek Pathway	OGITS CSRG analyte list
37094	Northern Pathway	OGITS CSRG analyte list
37095	Northern Pathway	OGITS CSRG analyte list
37097	Off-Post Plume	DIMP
37108	Off-Post Plume	DIMP
37110	First Creek Pathway	OGITS CSRG analyte list
37126	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride
37150	Off-Post Plume	Carbon tetrachloride, DIMP, chloride
37151	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride
37320	Off-Post Plume	DIMP, dieldrin, chloride

Table 5.2.2-2. Off-Post CSRG Exceedance Well Network (Concluded)

Well ID	Location	Analytes
37328	Off-Post Plume	DIMP, dieldrin, fluoride, chloride, sulfate , VOCs
37338	North Boundary	DIMP, dieldrin, fluoride, chloride
37339	North Boundary	DIMP, fluoride, chloride, sulfate
37342	First Creek Pathway	Chloride, sulfate, DIMP, VOCs
37343	First Creek Pathway	OGITS CSRG analyte list
37347	Off-Post Plume	DIMP
37349	Off-Post Plume	DIMP
37351	Off-Post Plume	DIMP
37353	Off-Post Plume	DIMP
37367	Off-Post Plume	DIMP, chloroform, tetrachloroethylene, fluoride, chloride
37368	Northern Pathway	DIMP, chloroform, tetrachloroethylene, chloride, sulfate
37369	First Creek Pathway	DIMP, dieldrin, fluoride, chloride, VOCs
37370	First Creek Pathway	OGITS CSRG analyte list
37374	Off-Post Plume	Fluoride, chloride, sulfate, DIMP, dieldrin
37377	Off-Post Plume	DIMP, fluoride, chloride, sulfate, VOCs
37378	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride
37379	Off-Post Plume	DIMP, chloride, sulfate
37389	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride
37391	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride, sulfate
37392	Off-Post Plume	DIMP, dieldrin, chloride
37395	First Creek Pathway	OGITS CSRG analyte list
37396	First Creek Pathway	DIMP, chloride, sulfate
37397	Off-Post Plume	DIMP, chloroform, fluoride, chloride, sulfate
37404	Northern Pathway	OGITS CSRG analyte list
37405	Off-Post Plume	VOCs
37407	First Creek Pathway	DIMP, fluoride, sulfate
37428	Off-Post Plume	DIMP
37429	Off-Post Plume	DIMP
37452	Northern Pathway	DIMP, carbon tetrachloride, chloride

Notes:
See following page.

Notes:

[1] **OGITS CSRG Analyte List:** Diisopropylmethyl phosphonate (DIMP), aldrin, chlordane, DDE, DDT, dieldrin, endrin, hexachlorocyclopentadiene, isodrin, atrazine, malathion, 1,4-oxathiane, 4-chlorophenylmethyl sulfide (CPMS), 4-chlorophenylmethyl sulfoxide (CPMSO), 4-chlorophenylmethyl sulfone (CPMSO2), dithiane, benzene, ethylbenzene, toluene, xylenes, 1,2-dichloroethane, 1,3-dichlorobenzene, carbon tetrachloride, chlorobenzene, chloroform, tetrachloroethylene (PCE), trichloroethylene (TCE), dicyclopentadiene (DCPD), dibromochloropropane (DBCP), n-nitrosodimethylamine (NDMA), arsenic, chloride, fluoride, and sulfate.

[2] **VOCs** denotes Volatile Organic compounds, which include: benzene, ethylbenzene, toluene, xylenes, 1,2-dichloroethane, 1,3-dichlorobenzene, carbon tetrachloride, chlorobenzene, chloroform, tetrachloroethylene (PCE), trichloroethylene (TCE), dicyclopentadiene (DCPD).

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