ROCKY MOUNTAIN ARSENAL

Fiscal Year 2022 Annual Summary Report for Groundwater and Surface Water

October 1, 2021 – September 30, 2022

Revision 1
January 8, 2024

U.S. Department of the Army
Shell Oil Company

Prepared by:

Navarro Research and Engineering, Inc.

00061280 24496-3

TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS

OVERVIEW OF APPENDICES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF ELECTRONIC FILES

Folder	Files
Report Text and Tables	FY22 ASR Text-Tables Rev 0.pdf
Appendices	FY22 ASR Appendices A-K Rev 0.pdf
Data and Quality Control Review	See list in Appendix I
FY22 BANS-BRES-CADT-Lime Basins	FY22 BANS Contaminant Removal Report.pdf
	FY22 BANS-LB-BRES-CADT Water Management Report.pdf
	FY22 BANS Mass Removal Rev0 07-19-23.xlsx
FY22 North Boundary Containment System	FY22 NBCS Contaminant Removal Report.pdf
	FY22 NBCS System Water Management Report.pdf
	FY22 NBCS Vertical Gradient Data.xlsx
FY22 Northwest Boundary Containment System	FY22 NWBCS Contaminant Removal Report.pdf
	FY22 NWBCS Water Management Report.pdf
FY22 First Creek Treatment System	FY22 FCTS Contaminant Removal Report.pdf
	FY22 FCTS Mass Removal Rev0 07-19-23.xlsx
FY22 Northern Pathway Treatment System	FY22 NPTS Contaminant Removal Report.pdf
	FY22 NPTS Mass Removal Rev0 07-19-23.xlsx
FY22 Water Quality Tracking Network	WQ Tracking Basic Statistics FY03-FY22.pdf
	WQ Tracking Mann-Kendall Tests FY22.pdf
FY22 Quarterly Treatment Plant Effluent Water Quality Reports	Effluent Report_FY22_QTR1_Rev 0.pdf
	Effluent Report_FY22_QTR2_Rev 0.pdf
	Effluent Report_FY22_QTR3_Rev 0.pdf
	Effluent Report_FY22_QTR4_Rev 0.pdf

GENERAL ACRONYMS

ACHD	Adams County Health Department
amsl	above mean sea level
Army	U.S. Department of the Army
ARAR	Applicable or Relevant and Appropriate Requirements
ASR	Annual Summary Report for Groundwater and Surface Water
BANS	Basin A Neck System
BRES	Bedrock Ridge Extraction System
CADT	Complex Army Disposal Trenches
CBSG	Colorado Basic Standard for Groundwater
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFS	Confined Flow System
CSRG	Containment System Remediation Goal
DAR	Design Analysis Report
DNAPL	dense non-aqueous phase liquid
DoD	U.S. Department of Defense
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FCS	First Creek System
FCTS	First Creek Treatment System
FY	Fiscal Year (see note at end of list)
FY22	Fiscal Year 2022
FYSR	Five-Year Summary Report
gpm	gallons per minute
ICS	Irondale Containment System
IQR	interquartile range
IRA	Interim Response Actions
LCS	laboratory control spikes
LNAPL	light non-aqueous phase liquid
LT	Less Than (boolean for nondetect values from chemical analysis)
LTMP	*Long-Term Monitoring Plan for Groundwater and Surface Water*

GENERAL ACRONYMS

MPS	Motor Pool System
MRL	method reporting limit
MS	matrix spike
Navarro	Navarro Research and Engineering, Inc.
NBCS	North Boundary Containment System
NEE	Northeast Extension
NPS	Northern Pathway System
NPTS	Northern Pathway Treatment System
NWBCS	Northwest Boundary Containment System
OCN	Operational Change Notice
OCP	organochlorine pesticides
OGITS	Off-Post Groundwater Intercept and Treatment System
OMC	Operations and Maintenance Contractor
O&M	operations and maintenance
OU	Operable Unit
PE	Performance Evaluation
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PQL	practical quantitation limit
QC	quality control
RAO	Remedial Action Objective
RI/FS	Remedial Investigation/Feasibility Study
RMA	Rocky Mountain Arsenal
RMAED	Rocky Mountain Arsenal Environmental Database
ROD	Record of Decision
RPD	relative percent difference
RSL	Regional Screening Level
RVO	Remediation Venture Office
RYCS	Railyard Containment System
RYCS Shut-off SAP	*Railyard Containment System Shut-Off Sampling and Analysis Plan*
SAP	Sampling and Analysis Plan

GENERAL ACRONYMS

Shell	Shell Oil Company
SQAPP	*Sampling Quality Assurance Project Plan*
SWE	Southwest Extension
TCHD	Tri-County Health Department
UFS	Unconfined Flow System
µg/L or UGL	micrograms per liter
UV	ultraviolet
VOC	volatile organic compound

Notes:

Numeric fiscal years are identified by the prefix “FY” followed by the last two digits of the four-digit year (e.g., Fiscal Year 2022 is indicated as FY22).

CHEMICAL ACRONYMS

111TCE	1,1,1-Trichloroethane
11DCE	1,1-Dichloroethylene
11DCLE	1,1-Dichloroethane
12DCE	1,2-Dichloroethylene
12DCLB	1,2-Dichlorobenzene
12DCLE	1,2-Dichloroethane
12DCLP	1,2-Dichloropropane
13DCLB	1,3-Dichlorobenzene
14DCLB	1,4-Dichlorobenzene
14DIOX	1,4-Dioxane
ACLDAN	alpha-Chlordane
ALDRN	Aldrin
AS	Arsenic
ATZ	Atrazine
C6H6	Benzene
CCL4	Carbon tetrachloride
CH2CL2	Methylene chloride
CHCL3	Chloroform
CL	Chloride
CL6CP	Hexachlorocyclopentadiene
CLC6H5	Chlorobenzene
CPMS	p-Chlorophenylmethyl sulfide
CPMSO	p-Chlorophenylmethyl sulfone
CPMSO2	p-Chlorophenylmethyl sulfoxide
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethyl phosphonate
DITH	Dithiane
DLDRN	Dieldrin
ENDRN	Endrin

CHEMICAL ACRONYMS

ETC6H5	Ethylbenzene
F	Fluoride
GCLDAN	gamma-Chlordane
HFPODA	Hexafluoropropylene oxide dimer acid
HG	Mercury
ISODR	Isodrin
MEC6H5	Toluene
MLTHN	Malathion
NNDMEA or NDMA	n-Nitrosodimethylamine
NNDNPA or NDPA	n-Nitrosodi-n-propylamine
OXAT	1,4-Oxathiane
PFBS	Perfluorobutanesulfonic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PPDDE	Dichlorodiphenyldichloroethene
PPDDT	Dichlorodiphenyltrichloroethane
SO4	Sulfate
TCLEA	1,1,2,2-Tetrachloroethane
TCLEE	Tetrachloroethylene
TRCLE	Trichloroethylene
XYLEN	Xylenes

Note:

Chemical acronyms listed are those that may be referenced in the text, tables, and other components of the ASR. A full list of chemical acronyms utilized within the Rocky Mountain Arsenal Environmental Database is provided in Appendix I2.

EXECUTIVE SUMMARY

This Fiscal Year 2022 (FY22) Annual Summary Report for Groundwater and Surface Water (ASR) includes an evaluation of the data collected and an evaluation of the compliance and performance criteria required for the operating systems; system-specific and site-wide groundwater and surface water hydrology; other monitoring conducted during FY22; as well as any Consultative Process notifications. The regulatory agencies are required to be notified of performance issues in accordance with the consultation triggers presented in the Consultative Process tables presented in Sections 4, 5 and 6 of the *Long-Term Monitoring Plan for Groundwater and Surface Water* (LTMP) (Navarro 2021). The ASR has been prepared to document and evaluate monitoring data collected at Rocky Mountain Arsenal (RMA) for the period October 2021 through September 2022 for the systems and programs below and as noted in Figure ES-1:

- Northwest Boundary Containment System (NWBCS)
- North Boundary Containment System (NBCS)
- Basin A Neck System (BANS)
- Bedrock Ridge Extraction System (BRES)
- Complex Army Disposal Trenches (CADT)
- Shell Oil Company (Shell) Disposal Trenches
- Lime Basins Slurry Wall Dewatering System and Dense Non-Aqueous Phase Liquid (DNAPL) Remediation Project
- North Plants Light Non-Aqueous Phase Liquid (LNAPL) Pilot Removal Action
- First Creek Treatment System (FCTS)
- Northern Pathway Treatment System (NPTS)
- LTMP Off-Post Surface Water Monitoring
- Railyard Containment System (RYCS)
- Motor Pool System (MPS)/Irondale Containment System (ICS)

The current system-related and site-wide monitoring categories, as shown in the LTMP and reported in the FY22 ASR, include the following:

System-Related Monitoring

- Effluent Compliance Monitoring
- Groundwater Performance Monitoring
- Pre-Shut-Off Monitoring
- Shut-Off Monitoring
- Post-Shut-Off Monitoring
- Operational Monitoring

Site-Wide Monitoring

- Water Level Tracking
- Water Quality Tracking
- Confined Flow System (CFS) Monitoring
- Exceedance Monitoring
- Off-Post Water Level Monitoring
- Surface Water Monitoring

The data used for this ASR were collected pursuant to the 2021 revision of LTMP (Navarro 2021), the Sampling and Analysis Plans (SAP) issued as part of the Operations and Maintenance 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* (Navarro 2019a).

The long-term groundwater monitoring program described in the LTMP satisfies the requirements of the On-Post and Off-Post RODs (Foster Wheeler 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 requirements for waste left in place, and to provide data for five-year reviews. The main component of the remedy related to groundwater is continued operation of the groundwater extraction and treatment systems.

Summarized below are the results and conclusions for system-specific operational compliance monitoring and performance monitoring relative to the criteria presented in Table ES-1.

ES.1 ON-POST EXTRACTION AND TREATMENT SYSTEMS

All of the groundwater containment and mass removal systems met the compliance monitoring criteria presented in the LTMP (Navarro 2021) in FY22. In addition, the groundwater containment and mass removal systems predominantly met the performance criteria presented in the LTMP (Navarro 2021), and the objectives identified in the On-Post ROD (Foster Wheeler 1996) and Off-Post ROD (HLA 1995).

In FY22, some specific performance criteria were not met in some portions of the NWBCS, BRES, and Lime Basins systems. Table ES-1 presents a summary of the compliance criteria and the system- and project-specific performance criteria and whether these criteria were met in FY22. In instances where performance criteria were not met, or data suggest that performance criteria are at risk of not being met, proposed or current actions are indicated and will be followed up in FY23, and documented in the FY23 ASR. Recommendations presented in previous sections of the report are also presented below, which will result in operational change notices to the LTMP.

Summarized below are the results and conclusions for system-specific operational compliance monitoring and performance monitoring relative to the performance criteria and goals as stated in the LTMP.

Northwest Boundary Containment System

- In FY22, the NWBCS operated at an average flow rate of 830 gallons per minute (gpm), pumping a total volume of 436,012,080 gallons and removing a total of 2.9 pounds of contaminant mass.
- The NWBCS met the compliance and the primary performance criteria for the Original System and objectives established in the LTMP. The NWBCS had no Containment

System Remediation Goal (CSRG)/Practical Quantitation limit (PQL) analyte exceedances for quarterly samples or the four-quarter moving averages in the treatment system effluent in FY22. A reverse hydraulic gradient was maintained within the system and plume capture was evident within the original system as well as within the northeast Extension (NEE) and Southwest Extension. The NWBCS functioned as intended in FY22.

- Dieldrin and n-nitrosodi-n-propylamine (NDPA) were detected above the PQL in Original System and NEE downgradient performance wells during the reporting period:
  - Original System downgradient well 37333 contained dieldrin above the PQL in FY22. However, the secondary performance criterion was met during the reporting period because the long-term trend was not increasing in downgradient performance wells.
  - NEE downgradient well 22512 and 22015 contained dieldrin, isodrin, and NDPA above the PQLs in FY22. However, the secondary performance criterion was met for dieldrin because the long-term trend was not increasing in downgradient performance wells. NDPA exceeded the PQL in downgradient NEE well 22512, and concentrations indicate an increasing trend in FY22.
- Dieldrin and NDPA above their respective PQLs in downgradient performance wells may be attributed to a variety of factors including contamination due to mobilization of residual contamination or possible system bypass around the north end of the NEE slurry wall. An investigation of potential bypass of the NEE slurry wall was conducted in FY22. While monitoring is ongoing within the NEE, preliminary data demonstrate that the water table is very low in the area north of the slurry wall, indicating limited groundwater flow in this area.

North Boundary Containment System

- In FY22, the NBCS operated at an average flow rate of 232 gpm and pumped a total volume of 121,766,632 gallons and removed a total of 9.2 pounds of contaminant mass.
- N-nitrosodimethylamine (NDMA) exceeded CSRG/PQL in the plant effluent—during the third quarter of FY22—although the moving average did not exceed the standard. 1,4-Dioxane also exceeded CSRGs in the plant effluent during the first, third, and fourth quarters, while the PQL was exceeded during the fourth quarter. As an emerging contaminant, 1,4-dioxane treatment was not part of the design for the NBCS and therefore is not treated by the system.
- Dieldrin, NDMA, and 1,4-dioxane concentrations are above their respective CSRGs/PQLs in downgradient performance wells but show non-discernible, stable, or decreasing trends in wells. Concentrations of anions chloride, fluoride, and sulfate exceeded CSRGs. Chloride and sulfate are expected to naturally attenuate to background levels. Based on the FY22 information, the contaminant plumes continue to be captured by the NBCS system.
- A reverse hydraulic gradient was maintained within the system during the first, second, and third quarters of FY22, with one well pair demonstrating a slight forward gradient during the fourth quarter. Although the reverse gradient was not maintained across the

system during the fourth quarter of FY22, plume capture is evident as indicated the potentiometric surface map and the evaluation of downgradient water quality data. Thus, the NBCS functioned as intended in FY22.

Basin A Neck System

- In FY22, the BANS operated at an average flow rate of 17 gpm and pumped a total volume of 9,132,842 gallons during FY22, removing a total of 59.4 pounds of contaminant mass. The BANS had no CSRG/PQL analyte exceedances for quarterly samples or the four-quarter moving averages in the treatment system effluent in FY22.
- The BANS met both performance criteria and objectives established in the LTMP. The 75 percent mass removal criterion was met in FY22, with mass removal estimated at 98.7 percent. Concentrations of analytes that remain above CSRGs/PQLs indicate stable or decreasing trends. The BANS functioned as intended in FY22.

Bedrock Ridge Extraction System

- In FY22, the BRES did not meet the plume capture performance criteria and objectives established in the LTMP. Analytes 1,2-dichloroethane and trichloroethylene in well 36566 show increasing concentration trends. Although the plume appears captured at both edges of the system, bypass may be occurring within the west-central portion of the extraction system.
- Evaluation of supplemental monitoring data collected 2019 through 2021 resulted in a recommendation to include installation of one additional extraction well and one downgradient well as part of the future optimization of the system in FY24.

ES.2 OTHER ON-POST SYSTEMS

Complex Army Disposal Trenches

- In FY22, the CADT system met the performance criteria and objectives established in the LTMP. The inward gradient was maintained across the slurry wall and hydraulic control was maintained in the vicinity of performance wells 36216 and 36217.

Shell Disposal Trenches

- In FY22, the Shell Disposal Trenches met the performance criteria and objectives established in the LTMP. All groundwater elevations were below the bottom of the trenches at all borehole performance goal locations.

Lime Basins Slurry Wall Dewatering System

- The first performance criterion requires that positive inward hydraulic gradient be maintained across the slurry wall. In FY22, an inward gradient was present in all well pairs on the southern side while an outward gradient was still present for all the well pairs on the northern side, consistent with results obtained since FY14. Groundwater elevations inside of the slurry wall have been steadily decreasing; however, progress toward meeting the goal is dependent on water level fluctuations outside the slurry wall.
- The second performance criterion requires that water levels inside the slurry wall are below the elevation of the bottom of the waste (5,242 feet above mean sea level). During all four quarters of FY22, the water elevation in each well inside the slurry wall was

below the bottom of waste elevation. Therefore, this dewatering performance criterion was met during FY22.

Lime Basins DNAPL Remediation Monitoring

- The water level data and DNAPL measurements for FY22 indicated that DNAPL was detected in well 36235 outside and/or adjacent to the slurry wall. DNAPL was detected within the slurry wall in extraction wells 36319 and 36320 and monitoring well 36248. The data indicate that the slurry wall has not been adversely impacted by historical DNAPL contamination. Consistent head differentials across the slurry wall have been maintained for all the well pairs showing that the DNAPL remediation system is functioning as intended.
- The observed presence of DNAPL has been consistent since FY13. No additional areas of DNAPL were identified in the vicinity of the Lime Basins slurry wall in FY22. Current data indicate that no additional DNAPL sources zones appear to exist within the Lime Basins slurry wall and that the extent of DNAPL is decreasing. Removal of recoverable DNAPL will take place in FY23.

North Plants LNAPL Pilot Removal Action

- Measurable LNAPL was detected in well 25301, and an LNAPL sheen was present in wells 25125, 25134, and 25138. Prior to FY22, measurable LNAPL was not present in wells within the North Plants area between FY13 and FY21. It is likely that LNAPL remained within the formation due to the capillary pressure of the wells and once the water table decreased, LNAPL became mobile, increasing the apparent thickness of LNAPL within the well.
- Considering 8.9 inches of LNAPL was measured in well 25301 during FY22, further evaluation will take place in FY23 to determine whether a continuing source is present within the unconfined flow system and recovery is feasible.

ES.3 OFF-POST EXTRACTION AND TREATMENT SYSTEMS

First Creek Treatment System

- The FCTS operated at an average flow rate of 60 gpm, pumping a volume of 27,716,181 gallons, and removing a total of 2.8 pounds of contaminant mass.
- Concentrations of chloride exceeded the CSRG during the first, third and fourth quarters of FY22, and the four-quarter moving average exceeded the CSRG during the fourth quarter. Chloride is not treated at the FCTS.
- Mass removal at the FCTS was 77 percent, meeting the performance goal of 75 percent removal in FY22.
- Detections DIMP above the CSRG in FCTS downgradient performance wells 37110 and 37163 will continue to be monitored to determine whether continuous operations of the system results in decreasing concentrations downgradient of the system. In addition, the presence of arsenic in well 37163 will continue to be monitored and evaluated with respect to the presence of arsenic in surface water adjacent to the well.

- The FCTS system met the performance criteria and objectives established in the LTMP. The FCTS functioned as intended in FY22.

Northern Pathway Treatment System

- The NPTS began operating on January 31, 2022 and met the treatment plant compliance requirements established in the LTMP. The NPTS operated at an average flow rate of 181 gpm, pumping a volume of 62,557,698 gallons, and removing 0.36 pounds of contaminant mass during FY22.
- There were no CSRG-analyte exceedances of the four-quarter moving averages in the NPTS effluent in FY22.
- The mass removal at the NPTS was 99.5 percent, meeting the performance goal of 75 percent removal in FY22.
- Chloride was the only contaminant detected above the CSRGs in FY22 in downgradient performance wells (wells 37012 and 37039). Chloride, fluoride, and sulfate were detected above CSRGs in FY22 in cross-gradient performance well 37027. Anions are not treated at NPTS, and the lack of organic contaminants detected at levels greater than CSRGs/PQLs indicate the system is effective.
- The NPTS met the performance criteria and objectives established in the LTMP. The NPTS functioned as intended in FY22.

ES.4 SITE-WIDE ON-POST MONITORING

Water Level Tracking

- Overall, groundwater flow directions and associated migration of contaminant plumes have not changed significantly during the FY22 reporting period. In some areas of the RMA, water levels continue to decrease due to lack of regional precipitation.

Water Quality Tracking

- The Water Quality Tracking Network was sampled in FY22 as part of the twice-in-five years monitoring program. Based on the evaluation of concentration trends in water quality tracking wells, there is no indication that remedy effectiveness has been adversely impacted. Sampling within the water quality tracking network will next take place in 2024, with further evaluation and review of long-term trends included in the FY24 ASR/Five-Year Summary Report.

Confined Flow System Monitoring

- CFS water quality sampling took place in FY22 as part of the twice-in-five-years monitoring program. The next CFS sampling event is scheduled for FY24.
- Based on the FY22 data, and noting the first-time presence of dieldrin in groundwater in CFS well 26150 associated with Basin F, monitoring data and well integrity will be evaluated under a future program to investigate the CFS contamination.
- Considering the known presence of elevated levels of chloride in well 35083, a future evaluation is planned to evaluate whether the chloride is the result of anthropogenic sources or can be attributed to natural background.

ES.5 SITE-WIDE OFF-POST MONITORING

Off-Post Exceedance Monitoring

- In FY22, ten analytes were detected in off-post groundwater at concentrations exceeding CSRGs in FY22, and represent the same analytes depicted in the FY19 ASR and FYSR. Six organic analytes were detected at concentrations exceeding CSRGs/PQLs including: 1,2-dichloroethane, 1,4-dioxane, carbon tetrachloride, DIMP, dieldrin, and NDPA. Arsenic and three anions—chloride, fluoride, and sulfate—were also detected at concentrations exceeding CSRGs.

Off-Post Surface Water

- In FY22, only arsenic was detected in off-post surface water samples at concentrations greater than the off-post CSRG. The concentration of arsenic has been generally higher in First Creek at SW37001, furthest downstream of RMA and is consistent with the historical trends detected within First Creek. Based on statistical trend analyses, arsenic concentrations demonstrate a stable trend since August 2013, Therefore, it is likely that the presence of this constituent in surface water at SW37001 is naturally occurring and not attributable to RMA activities.
- Dieldrin was detected in First Creek at locations SW37001 and SW24004 at concentrations less than the off-post CSRG. Dieldrin has previously been detected at concentrations less than the off-post CSRG at SW37001 in 2018 and 2019 and at SW24004 in 2019. Shallow groundwater is often in contact with surface water within the First Creek area, which may account for the occurrence of dieldrin in off-post surface water downgradient of RMA.
- Chloride and sulfate were detected at levels less than CSRGs, and concentrations continue to show stable and decreasing trends, respectively, since 2004.

Tri-County Health Department Off-Post Groundwater Monitoring

- Eight off-post private wells were sampled for DIMP, dieldrin, and 1,4-dioxane by TCHD in FY22. In FY22, well 359D had a DIMP detection of 15.3 micrograms per liter (µg/L), which exceeds the CSRG of 8 µg/L. No other analyte concentrations exceeded CSRGs/PQLs in off-post private wells in FY22.
- Well 359D was installed in November of 2016, and is screened in two separate zones in the Lower Arapahoe aquifer, similar to the well it replaced, 359A. In a report entitled *Well 359D Field Investigation Report* dated January 25, 2022. The Army recommended the installation of a small-scale “point of entry” carbon filtration system at the wellhead in order to provide uncontaminated water to the residents on the property. Bottled water is currently being provided to the residents and installation of the treatment system is anticipated to take place pending homeowner approval.

ES.6 POST-SHUT-OFF AND SHUT-OFF MONITORING

Railyard Containment System Shut-Off Monitoring

- During FY22, quarterly monitoring took place in accordance with the RYCS Shut-Off SAP, and the results indicate that there were no contaminants that exceeded CSRGs. The two primary contaminants of concern, dibromochloropropane and trichloroethylene, were not detected in any wells. Based on the monitoring to date, the first quarter of FY22 served as the last sampling event under the RYCS Shut-Off SAP.

- The RYCS was demolished during the fourth quarter of FY22. The treatment plant was removed from the site and wells were abandoned—including extraction, recharge, and some monitoring wells. Post-shut-off monitoring will be conducted twice every five years as part of the water quality tracking network beginning in 2024.

Motor Pool/Irondale Containment Post-Shut-Off Monitoring

- Review of water level data presented in the FY22 regional water level map and similar maps over the previous five years indicates that the groundwater flow direction in the area appears unchanged. Since the SAP criteria were met in FY22, post-shut-off monitoring will continue in accordance with the MPS/ICS SAP.

ES.7 PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES

- Per- and polyfluoroalkyl substances (PFAS) have been detected above health advisory levels or regional screening levels (RSL) in groundwater at RMA. PFAS sample analysis in annual treatment plant influent and effluent samples, and for select wells in the LTMP once-in-five-years sitewide water quality tracking network, has been implemented to continue to evaluate site conditions. Beginning in FY23, treatment plant influent and effluent will be sampled quarterly. In FY22, PFAS were analyzed under EPA Drinking Water Method 537. However, beginning in FY23, groundwater samples will be analyzed using EPA Method 1633 for non-drinking water samples.
- Influent and effluent samples were collected in July 2022 and analyzed for the expanded list of PFAS. PFAS were detected in the influent samples collected at all five treatment plants. Influent at NWBCS, BANS and NPTS exceeded the respective health advisory levels for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) published in June 2022 (EPA 2022a). No effluent samples exceeded the respective health advisory levels or RSL. Perfluorobutanesulfonic acid (PFBS) was the only PFAS-related contaminant detected in effluent samples, which were collected at the NPTS plant, and the levels were below the health advisory level.
- Groundwater was sampled in Water Quality Tracking wells 01525, 36181, 36210, 36627, and 36631 in accordance with the LTMP. Concentrations of PFOA and PFAS exceeded their respective U.S. Environmental Protection Agency health advisory levels in source area well 01525, located within the former South Plants area, and the four downgradient monitoring wells located closest to the source area. Concentrations of PFOA, PFAS, and PFHxS also exceed their respective RSL for drinking water exposure in these Water Quality Tracking wells.

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Northwest Boundary Containment System – Treatment System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Primary Performance Criteria [2] – Original System	
Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Secondary Performance Criterion [2] – Original System	
If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends, based on annual evaluations, over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Secondary performance criterion is not applicable since primary performance criteria were achieved. Continued monitoring will be conducted to evaluate performance wells where CSRG/PQL exceedances occurred.
Northwest Boundary Containment System – Northeast Extension	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	No. Dieldrin and NDPA were detected above CSRGs/PQLs in downgradient performance wells 22015 and 22512, however, the long-term trends for dieldrin are not increasing in downgradient performance wells. Emerging contaminant NDPA, first detected in FY22 in well 22512, indicates an increasing trend. The potential for contaminated flow toward the downgradient performance wells will be further evaluated based on semiannual monitoring continuing through FY23.

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells.	No. NDPA was detected three times in well 22512 in FY22, all at concentrations exceeding the PQL. Concentrations indicate an increasing trend through FY22.
Northwest Boundary Containment System – Southwest Extension	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Demonstrate decreasing concentration trends or that concentrations are at or below the CSRGs/PQLs in downgradient performance wells.	Yes
North Boundary Containment System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	No. Emerging contaminant 1,4-dioxane concentrations exceeded the CSRG/PQL in plant effluent during the first, third, and fourth quarters of FY22, with the fourth quarter moving average exceeding the CSRG/PQL.
Primary Performance Criteria [2]	
Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	No. Well pair 23528/23535 showed a slight forward gradient during the fourth quarter FY22.
Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps, and evaluation of water quality data from performance water quality wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes. The potentiometric surface map and the evaluation of water quality data indicate plume edge capture at both ends of the system.

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Secondary Performance Criterion [2]	
If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes. Analytes treated by the system, including dieldrin and NDMA, exceed CSRGs/PQLs and do not exhibit increasing trends.
Basin A Neck System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the BANS (OCN-LTMP-2023-005).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes
Bedrock Ridge Extraction System Performance Criteria	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	Yes
Demonstrate decreasing or stable concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.	No. Concentrations of 12DCLE and trichloroethylene are above CSRGs in well 36566 and exhibit increasing trends. Evaluation of supplemental monitoring data resulted in a recommendation to include installation of one additional extraction well and one downgradient well as part of the future optimization of the system.

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Complex Army Disposal Trenches Performance Criteria	
Demonstrate groundwater elevations in performance monitoring wells 36216 and 36217 are below the target elevations of 5226 and 5227 ft, respectively, or Demonstrate hydraulic gradient from the performance monitoring wells locations is toward the extraction trench.	Yes. The CADT system met the performance criteria and objectives established in the LTMP. Although the water levels remained above the trench-bottom elevation in well 36217, hydraulic control was maintained at both performance well locations.
Maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).	Yes
Shell Disposal Trenches Performance Criterion	
Demonstrate groundwater elevations are below the disposal trench bottom elevations within the slurry wall enclosure listed in the 2021 LTMP, Table 5.2-2.	Yes. Groundwater elevation is below the bottom of trenches at all borehole locations.
Lime Basins Slurry Wall Dewatering System Performance Criteria	
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).	No. Outward gradient is present in wells on the north side of the slurry wall; however, water levels inside the slurry wall continue to decline.
Maintain a groundwater level below the elevation of the Lime Basins waste (5242 feet) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).	Yes
Lime Basins DNAPL Remediation Monitoring Performance Criteria	
Primary Goals [3]	
To determine if additional DNAPL source zones exist in the Lime Basins area in addition to those previously identified.	Yes. No additional DNAPL source zones were identified based on measured DNAPL in wells.
To determine if the extent and nature of any discovered DNAPL source zones have the potential to adversely impact the slurry wall.	Yes. No adverse impacts to the slurry wall due to the presence of DNAPL have been observed.
To characterize DNAPL, if present, for the purpose of correlation with groundwater characterization data as a tool in the identification of DNAPL source zones and for the purpose of waste disposal.	Yes. DNAPL continues to be characterized.

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
First Creek Treatment System	
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the FCTS (OCN-LTMP-2023-004).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes
Northern Pathway Treatment System	
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the NPTS (OCN-LTMP-2023-004).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes

Table ES-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

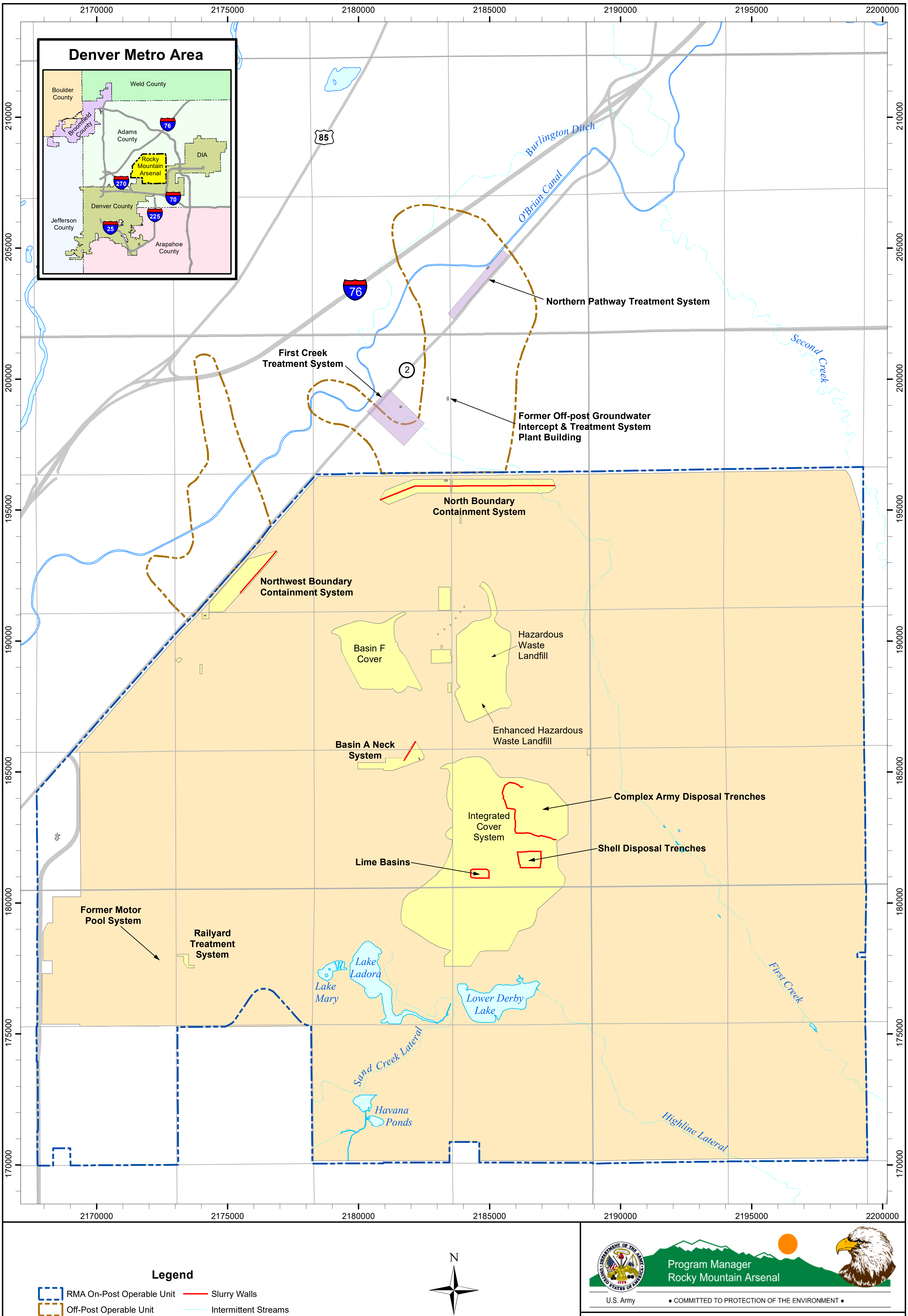
LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Railyard Containment System	
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Not Applicable. Annual shut-off monitoring concluded in FY22. The RYCS was shut off and demolished. Post-shut-off monitoring will commence in FY24.
Performance Criteria	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	Not Applicable. Annual shut-off monitoring concluded in FY22. The RYCS was shut off and demolished. Post-shut-off monitoring will commence in FY24.
Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.	

Notes:

[1] Criteria and goals are listed as presented in the LTMP and reflect any changes in accordance with OCNs as indicated. Primary criteria are provided unless otherwise noted. For systems without primary/secondary criteria, all criteria must be met.

[2] Only the NWBCS and NBCS are bound to secondary performance criteria, and only if primary performance criteria are not met.

[3] There are no performance criteria for the Lime Basins DNAPL Remediation Monitoring program, but goals are specified in the LTMP.



Program Manager Rocky Mountain Arsenal

U.S. Army • COMMITTED TO PROTECTION OF THE ENVIRONMENT •

Figure ES-1

Rocky Mountain Arsenal Site Locations

Note: Monitoring wells not shown for clarity. Location of monitoring wells is provided in the Long-Term Monitoring Plan for Groundwater and Surface Water (TtEC & URS 2010)

M:\projects\oars\fy22\mxds_rma_detail.mxd
10/5/2023

This page intentionally left blank.

1.0 INTRODUCTION

1.1 REPORT PURPOSE

This Fiscal Year 2022 (FY22) Annual Summary Report for Groundwater and Surface Water (ASR) includes an evaluation of the data collected and an evaluation of the compliance and performance criteria required for the operating systems; system-specific and site-wide groundwater and surface water hydrology; and any other supplemental monitoring conducted during the time period October 1, 2021 through September 30, 2022. In addition, the ASR includes data reporting for any site-wide monitoring conducted within FY22, project-specific monitoring, and any Consultative Process notifications (Table 1.1-1). The regulatory agencies are required to be notified of performance issues in accordance with the consultation triggers presented in the Consultative Process tables presented in Sections 4, 5 and 6 of the *Long-Term Monitoring Plan for Groundwater and Surface Water* (LTMP) (Navarro 2021).

This report has been prepared to document and evaluate annual monitoring data collected at the Rocky Mountain Arsenal (RMA) during FY22 for the following systems and programs:

- Northwest Boundary Containment System (NWBCS)
- North Boundary Containment System (NBCS)
- Basin A Neck System (BANS)
- Bedrock Ridge Extraction System (BRES)
- Complex Army Disposal Trenches (CADT)
- Shell Oil Company (Shell) Disposal Trenches
- Lime Basins Slurry Wall Dewatering System and Dense Non-Aqueous Phase Liquid (DNAPL) Remediation Project
- North Plants Light Non-Aqueous Phase Liquid (LNAPL) Pilot Removal Action
- First Creek Treatment System (FCTS)
- Northern Pathway Treatment system (NPTS)
- LTMP Off-Post Surface Water Monitoring
- Railyard Containment System (RYCS)
- Motor Pool System (MPS)/Irondale Containment System (ICS)

The current system-related monitoring categories, as presented in the LTMP, include the following:

- Compliance Monitoring
- Performance Monitoring
- Pre-Shut-Off Monitoring
- Shut-Off Monitoring

- Post-Shut-Off Monitoring
- Operational Monitoring

The site-wide monitoring programs included in the ASR, as identified in the LTMP, include the following programs:

- Water Level Tracking
- Water Quality Tracking
- Confined Flow System (CFS) Monitoring
- Off-post Water Level Monitoring
- Exceedance Monitoring
- Surface Water Monitoring

Also included in this ASR are data summaries for all site-wide Long-Term Monitoring Programs during years when monitoring is conducted. In FY22, the site-wide programs where monitoring was conducted included water level tracking, Water Quality Tracking, CFS Monitoring, Exceedance Monitoring, and Tri-County Health Department (TCHD) off-post private well sampling. Long-term off-post surface water monitoring of three locations along First Creek was also conducted.

Shut-off monitoring was conducted at the RYCS in the first quarter of FY22, which completed the required 5-year shut-off monitoring program. Annual post-shut-off monitoring of the MPS/ICS was also conducted in FY22. Results for these programs are presented in Sections 8.1 and 8.2, respectively.

In FY22, twice-in-five-year sampling was conducted for the Water Quality Tracking, CFS, and Exceedance monitoring networks. Results for these programs are presented in Sections 6.2, 6.3, and 7.1, respectively.

All water level measurements and water quality analyses for FY22 are included as an electronic file accompanying this report. Performance water quality monitoring results are provided as exhibits for each operating system in Appendices A through E.

1.2 MONITORING PROGRAMS OVERVIEW

The purpose of this report is to provide an integrated summary of monitoring for on-post and off-post treatment systems, post-closure sites, and the site-wide programs in FY22. This section presents an overview of each monitoring program.

1.2.1 Treatment Systems Operations and Monitoring Overview

The selected groundwater remedies from the On-Post and Off-Post Record of Decision (ROD) include the continued operation of all groundwater intercept and treatment systems and on-post groundwater Interim Response Action (IRA) systems until shut-off criteria are met, and an extended monitoring program is completed.

During the FY22 reporting period, the treatment systems were operated to reduce the concentrations of the Containment System Remediation Goal (CSRG) analytes in the effluent below their respective regulatory requirements. Quarterly effluent samples were collected from the treatment plants and analyzed for CSRG analytes and other analytes using U.S. Department of the Army (Army) methods specified in the RMA *Sampling Quality Assurance Project Plan* (SQAPP) (Navarro 2019a). Treatment system compliance is based on moving averages for the last four quarters instead of single samples. Treatment system statistics and operational information are reported in the quarterly RMA *Treatment Plant Effluent Water Quality Data Reports* for the NWBCS, NBCS, BANS, and off-post treatment systems.

The CSRGs presented in the FY22 ASR are those identified in the On-Post ROD (Foster Wheeler 1996), the Off-Post ROD (HLA 1995), the Remediation Scope and Schedule (HLA 1996), and subsequent modifications. Results of sampling for CSRG analytes retained for quarterly monitoring, as described in the LTMP, are presented in this report along with results for those analytes required by the ROD that are monitored annually (Navarro 2021).

The Practical Quantitation Limits (PQL) for data collected in FY22 for most of the CSRG analytes are those readily attainable from a certified commercial laboratory. The PQLs for aldrin, dieldrin, and n-nitrosodimethylamine (NDMA) were developed during a site-specific PQL study, which became effective in April 2012 (TtEC 2012). For NDMA, an interim PQL was used beginning in April 2012 until the final PQL was adopted during the first quarter FY17 (Navarro 2019a).

The system-specific “overview” tables present the CSRG analytes for each system with an indication of CSRG or PQL exceedances and associated concentration trends in wells designated for performance monitoring. Blank cells indicate that reported concentrations for the performance well samples were lower than the CSRG or PQL for the respective analyte. A shaded cell indicates that the analyte concentration exceeded the CSRG/PQL in FY22. System-specific data summaries are provided as supporting documentation within their respective appendices.

Maps presented in Appendices A, B, C, and E include graphs depicting concentrations versus time for “select” analytes in wells in the vicinity of the NWBCS, NBCS, BANS, BRES, FCTS, and NPTS. The analytes selected for these maps were detected at levels exceeding their respective CSRGs/PQLs in upgradient and/or downgradient performance wells during FY22 and were depicted over a 20-year time period to demonstrate visual concentration trends. In a few instances, analytes detected at levels less than CSRGs/PQLs have been presented on these maps as follow-up to recent years where performance goals were not met relative to ROD-based standards.

Select CSRG-analyte concentrations in the treatment plants and in upgradient and downgradient performance monitoring wells are plotted on graphs for all systems in Appendices A, B, C and E. The graphs for the treatment plants are arranged so that the influent concentrations are plotted above the effluent concentrations, showing the amount of reduction in contaminant concentrations resulting from the treatment system. The graphs for the performance wells are arranged so that the upgradient well concentrations are plotted above the downgradient well concentrations and show the distribution of analyte concentrations along the line of upgradient and downgradient performance wells for each system.

System-specific statistics for FY22 are provided in Sections 3 and 5 for the NWBCS, NBCS, BANS, FCTS, and NPTS including:

- Downtime attributable to equipment failures, maintenance, and power failure
- Average annual flow rate
- Total treated volume of groundwater
- Total mass of contaminants removed with an indication of major contaminants
- Carbon usage
- Annual cost of operation

In FY22, there were no modifications made to any of the on-post treatment systems other than normal operations and maintenance (O&M). As described in Section 5, FCTS extraction well 37800 was discovered to be damaged and was replaced by well 37830 in October 2021. The new treatment plant at the NPTS began operations in January 2022.

1.2.2 On-Post Monitoring Overview

The data used to complete the FY22 ASR were collected under the LTMP (Navarro 2021) and SQAPP. The chemical analytes discussed in this report all have analyte-specific method reporting limits (MRL) established through a laboratory certification process described in the SQAPP (Navarro 2019a). The discussion of the monitoring results includes terms such as “not detected” or “nondetection,” which mean that the analyte in question was not detected at or above its MRL. Similarly, “detected” or “detection” refer to analyte concentrations detected at or above the MRL.

The long-term groundwater monitoring program described in the LTMP satisfies the requirements of the On-Post and Off-Post RODs (Foster Wheeler 1996; HLA 1995). The main objectives, as stated in the RODs, are to evaluate the effectiveness of the remedies, to satisfy Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requirements for waste left in place, and to provide data for the ASRs. The main component of the remedy that relates to groundwater is continued operation of the groundwater containment and treatment systems.

1.2.2.1 LTMP On-Post Monitoring

The 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 and are evaluated in this report:

- Compliance Monitoring – Quarterly monitoring of treatment system effluent water to confirm that CSRGs are met by on-post (and off-post) treatment systems. Compliance is based on running averages for the last four quarters.
- Performance Monitoring – Quarterly and annual water level and water quality monitoring performed to measure performance against specific criteria.

- Pre-Shut-Off Monitoring – Project- and system-specific monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated.
- Shut-Off Monitoring – Project- and system-specific water quality monitoring at containment systems that have met shut-off criteria defined by the RODs. Such monitoring is conducted for specified analytes for a period of five years to ensure that Applicable or Relevant and Appropriate Requirements (ARARs) continue to be met. This monitoring is to be conducted in accordance with a revised shut-off approach, where sampling frequencies are reduced from the current quarterly sampling for five years to quarterly sampling for the first and last years of the program and annual sampling within intervening years.
- Post-Shut-Off Monitoring – Project- and system-specific 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 – Annual 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 (RAO) are met.

The site-wide monitoring program categories are as follows:

- Water Level Tracking – Annual on-post water level monitoring used to track the effects of the soil remedy to groundwater migrating within RMA.
- Water Quality Tracking – On-post water quality monitoring of indicator analytes to track contaminant migration in and downgradient of the source areas within the identified plumes. Sampling is conducted once or twice in five years.
- CFS Monitoring – Monitoring in response to the On-Post ROD requirement to monitor water quality in the confined aquifer in three areas—Basin A, South Plants, and Basin F. Sampling is conducted twice in five years.

1.2.2.2 On-Post Groundwater Treatment Systems Operational Monitoring

Groundwater Treatment System operational monitoring includes monitoring of system extraction wells, recharge wells, recharge trench piezometers, and/or monitoring wells associated with the system. Data are collected from wells upgradient of, and within 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, monitoring 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.

The operational monitoring program for existing groundwater containment and treatment systems at RMA is well established and provides 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. In addition, influent and effluent samples are collected at various points in the treatment process to monitor treatment system performance. Water quality is also monitored in extraction wells and monitoring wells associated with the systems to optimize treatment system operation.

1.2.3 Off-Post Monitoring Overview

1.2.3.1 LTMP Off-Post Monitoring

The LTMP (Navarro 2021) identified the following eight monitoring categories that meet the monitoring requirements identified in the Off-Post ROD:

- Compliance Monitoring – Quarterly monitoring of treatment system effluent water to confirm that CSRGs are met by off-post (and on-post) treatment systems. Compliance is based on running averages for the last four quarters.
- Performance Monitoring – Quarterly and annual water level and water quality monitoring performed to measure performance against specific criteria.
- Pre-Shut-Off Monitoring – Project- and system-specific monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated.
- Shut-Off Monitoring – Project- and system-specific water quality monitoring at containment systems that have met 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, where sampling frequencies are reduced from the current quarterly sampling for five years to quarterly sampling for the first and last years of the program and annual sampling within intervening years.
- Post-Shut-Off Monitoring – Project- and system-specific 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 – System-specific 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 RAOs are met.
- Off-Post Water Level Monitoring – Annual water level monitoring 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.)

- Exceedance Monitoring – Long-term water quality monitoring conducted in compliance with the Off-Post ROD, to assess contaminant concentration reduction and remedy performance. These water quality data are also used to create groundwater CSRG exceedance area maps to support well permit institutional controls. The exceedance area maps are provided to the Office of the State Engineer, and to City of 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. Sampling is conducted twice in five years.
- Surface Water Monitoring – Annual off-post surface water monitoring to assess changes in surface water quality related to the RMA remedy.

1.2.3.2 Off-Post Groundwater Treatment System Operational Monitoring

Similar to the on-post systems, operational monitoring conducted for the off-post treatment systems in FY22 consisted of monitoring system extraction wells, recharge wells, recharge trench piezometers, and monitoring wells associated with the FCTS and NPTS. Data are collected from monitoring 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. Depending on the type of data and operational need, monitoring 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.

1.2.3.3 Private Well Monitoring

In accordance with the 1997 Memorandum of Agreement between TCHD and the Army (PMRMA 1997), TCHD conducts sampling of private wells in the Off-Post operable unit. 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. In accordance with the Off-Post ROD, owners of domestic wells with groundwater contaminants derived from RMA at concentrations at or above Colorado Basic Standard for Groundwater (CBSG) will be provided with an alternate water supply by the Army. In addition, wells that create a pathway for vertical migration of contaminants from the unconfined flow system (UFS) to the CFS will be closed if RMA-related contaminant concentrations in these wells exceed remediation goals.

To verify the suitability of their water supplies for use, owners of wells within the diisopropylmethyl phosphonate (DIMP) plume footprint, as defined in the On-Post ROD (Foster Wheeler 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. Beginning January 1, 2023, the Adams County Health Department (ACHD) assumed responsibility for private well sampling with the dissolution of TCHD.

1.2.3.4 Off-Post Surface Water Monitoring

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. Generally, sampling is conducted under low-flow conditions to provide more representative results. Conducting storm event monitoring at SW37001 was specifically identified in the *Off-Post Remediation Scope and Schedule for the Off-Post Operable Unit* (HLA 1996) to evaluate the effects of runoff and higher flows in First Creek. Since the on-post soil remedy was completed and all soil contamination was placed in landfills, or is in place under soil covers, surface water contamination from runoff is no longer likely.

In order to continue to evaluate the effect of groundwater treatment on surface water quality in the Off-post operable unit, surface water quality monitoring continues 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 the two downstream sites. Annual surface water quality samples are collected at these sites when there is low flow in First Creek, typically during the spring or summer. The target analyte list was expanded from arsenic and DIMP in FY13 to also include aldrin, chloride, dieldrin, NDMA, and sulfate. The requirements for sampling can be found in the LTMP, Section 6.3.

1.2.4 Site-Wide Monitoring Programs Overview

As presented in Sections 1.2.2 and 1.2.3, the following on-post and off-post site-wide monitoring programs are in place:

- Water Level Tracking
- Water Quality Tracking
- Confined Flow System Monitoring
- Exceedance Monitoring
- Off-Post Water Level Monitoring

Of these site-wide monitoring programs, all took place in FY22 in accordance with the LTMP. Water levels were measured in the on-post water level tracking network and the off-post water level monitoring network in order to draw the FY22 site-wide potentiometric [water level] contour map (Figure F-1, Appendix F). Results of the water level tracking program are presented in Section 6.1.

The Annual Well Networks Update Summary is included in the ASR as required by the LTMP (Appendix J). The FY22 Annual Well Networks Update Summary includes information on newly installed wells, closed wells, damaged/repaired network wells, and updates to the Rocky Mountain Arsenal Environmental Database (RMAED).

1.2.5 Emerging Contaminants Monitoring Overview

Perfluoroalkyl and polyfluoroalkyl substances (PFAS), n-nitrosodi-n-propylamine (NDPA), and 1,4-dioxane have been classified as emerging contaminants by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Defense (DoD). The Emerging Contaminants Monitoring Program included the collection of samples from the treatment plant influent/effluent locations, monitoring wells, and surface water locations (Navarro 2019b). Sampling was conducted in 21 wells from February 2017 through March 2018 for PFAS and NDPA analyses to characterize within and downgradient of potential source areas. Locations sampled for 1,4-dioxane included up to 228 wells and one surface water site as part of the emerging contaminants sampling network and their respective locations within the LTMP network (Navarro 2021). The results of the Emerging Contaminants Monitoring Program were finalized and presented in the *Emerging Contaminants Data Summary Report* in January 2019 (Navarro 2019b).

Since the completion of the monitoring program in early 2019, the LTMP was revised under three operational change notices (OCN)—OCN-LTMP-2019-001, OCN-LTMP-2019-002, and OCN-LTMP-2020-002—to add 1,4-dioxane and NDPA to select on-post water quality tracking wells and off-post CSRG exceedance network wells to monitor plume concentrations and extent. In addition, the CBSGs for these emerging contaminants were added as CSRGs for the NBCS and NWBCS treatment plant influent and effluent, and water quality performance wells, to ensure that the boundary systems protect groundwater quality off post. The CBSG for NDPA was also added as a CSRG for off-post treatment systems consistent with the system goal to provide beneficial impact on groundwater quality. Monitoring results for 1,4-dioxane and NDPA are provided in the fiscal year ASRs and quarterly treatment plant effluent water quality data reports. In this report, 1,4-dioxane and NDPA results are presented in Sections 3 through 7 for the relevant systems and monitoring programs.

Monitoring for PFAS continues once every five years for groundwater and annually for treatment plant influent and effluent. Beginning in FY23, treatment plant influent and effluent will be sampled quarterly. PFAS monitoring results are provided in the fiscal year ASRs and quarterly treatment plant effluent water quality data reports. Section 9 of this report provides a summary of the results for PFAS monitoring conducted during FY22.

1.3 REPORT ORGANIZATION

This report serves as an annual assessment for FY22 that summarizes annual site-wide and treatment systems groundwater monitoring, project-specific monitoring, and surface-water monitoring and is organized as summarized below:

- **Introduction.** Section 1 presents the overall purpose of the ASR evaluations, a description of the sources of contamination and overviews of the treatment systems operations and the site-wide monitoring programs, as well as the organization of this report.

- **Data Quality Assurance.** Section 2 includes a summary of data quality assurance review process conducted for data collected during the fiscal year supporting the annual assessment of groundwater and surface water.

- **On-Post Extraction and Treatment Systems.** Section 3 provides an assessment of system performance for the major on-post extraction/treatment systems including the NWBCS, NBCS, BANS, and BRES.

- **Other On-Post Systems.** Section 4 presents an assessment of system performance for other on-post systems including the CADT, Shell Disposal Trenches, Lime Basins Slurry Wall Dewatering System and DNAPL Remediation Project, and the North Plants LNAPL Removal Action.

- **Off-Post Extraction and Treatment Systems.** Section 5 provides an assessment of off-post system performance for the FCTS and NPTS.

- **Site Wide On-Post Monitoring.** Section 6 presents a discussion of on-post monitoring programs including water level and water quality tracking, and CFS monitoring.

- **Site Wide Off-Post Monitoring.** Section 7 presents the results for off-post monitoring programs including water level tracking, exceedance monitoring, off-post surface water quality, and off-post private well monitoring administered by TCHD.

- **Post-Shut-Off and Shut-Off Monitoring.** Section 8 presents the results of post-shut-off monitoring for the MPS/ICS and shut-off monitoring for the RYCS.

- **Perfluoroalkyl and Polyfluoroalkyl Substances.** Section 9 provides an overview of the PFAS monitoring program conducted during FY22.

- **Summary and Conclusions.** Section 10 summarizes the results, conclusions, and recommendations relative to meeting the performance criteria and goals identified in the LTMP and other relevant monitoring plans.

- **References.** Section 11 lists the references used in the preparation of this report.

This report was prepared by Ms. Carol Rieger, Ms. Nicole Luke, and Ms. Megan Edwards with Navarro Research and Engineering, Inc. (Navarro). Project management was provided by Mr. Tony LaChance and Mr. Scott Ache of Navarro. Navarro acknowledges the support and assistance of Ms. Shannon Gilbert and Ms. Kelli Schneider, with AECOM Technical Services, Inc., supporting the Rocky Mountain Arsenal Records Management and Information Technology System.

2.0 DATA QUALITY ASSURANCE

The data evaluated in this report were collected in accordance with the LTMP (Navarro 2021), the SQAPP (Navarro 2019a), and the following SAPs:

- MPS/ICS Post-Shut-Off Monitoring SAP
- LTMP Surface Water Monitoring SAP
- RYCS Shut-Off Monitoring SAP

Data review was limited to the respective CSRGs or LTMP analytes for each system or monitoring category. Monitoring program- and treatment system-specific data summary reports were not prepared as separate deliverables in FY22 but are included as narratives in this ASR.

The purpose of the data review is to evaluate data quality with respect to the established data quality objectives (DQO). Components of the data review process include evaluating the data against the data quality indicators of precision, accuracy/bias, representativeness, sensitivity, completeness, and comparability; review of field and laboratory quality control (QC) results; and evaluating the data for suitability based on the intended use. Data were reviewed according to the procedures specified in the SQAPP. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. The data review parameters and results are discussed below.

2.1 PRECISION

Results of laboratory and field duplicates were used to calculate precision. Note that laboratory duplicates are prepared by the laboratory and analyzed for inorganics only. Relative percent difference (RPD) values will be calculated for LTMP analytes. If one or both results are rejected or not analyzed, the RPD will not be calculated. The formula for calculating the RPD is:

$$RPD(\%) = \left(\frac{Difference\ between\ concentrations}{Average\ of\ concentrations}\right) \times 100$$

Where:

$$Difference\ between\ concentrations = Investigative\ value - Duplicate\ value$$

$$Average\ of\ concentrations = \frac{Investigative\ value + Duplicate\ value}{2}$$

The default RPD evaluation limit for analytes without detections above the MRL will be less than or equal to 30 percent. The performance criteria for analytes with detections above the MRL will be calculated from historical RPD values for each program-specific LTMP analyte. The data utilized for the historical RPD value calculations will be limited to data values from historical analytical methods with similar MRLs. The analytical data utilized to calculate limits for individual analytes is included as an electronic file accompanying this report.

For each site ID/LTMP analyte, the 25th and 75th percentile RPD values are calculated. The interquartile range (IQR) for each analyte is calculated by subtracting the 25th percentile value from the 75th percentile value. The acceptance, or upper, RPD limit is determined by adding 1.5 times the IQR to the 75th percentile value. The RPD evaluation limits are included as an electronic file accompanying this report .

The investigative and duplicate results will be considered comparable if any of the following statements are true:

- If both sample results are less than the MRL
- If both sample results are greater than the MRL, but less than or equal to twice the MRL
- If both sample results are greater than twice the MRL and the RPD is less than or equal to the specified upper RPD limit
- If both sample results are greater than the MRL, one result is less than or equal to twice the MRL, one result is greater than twice the MRL, and the RPD is less than or equal to the specified upper limit
- If one sample result is less than the MRL, and one result is greater than the MRL and less than or equal to twice the MRL

The investigative and duplicate results will be considered not comparable if any of the following statements are true:

- If both sample results are greater than twice the MRL and the RPD is greater than the specified upper RPD limit
- If both sample results are greater than the MRL, one result is less than or equal to twice the MRL, one result is greater than twice the MRL, and the RPD is greater than the specified upper limit
- If one sample result is less than the MRL, and one result is greater than twice the MRL

Duplicate samples determined to be not comparable will be subject to data qualification. The non-comparable investigative and duplicate data will be assigned a “Z” data qualifier with the comment “Duplicate and investigative values are not comparable.” The data are considered acceptable for their intended use and no additional action in addition to the data qualification is considered necessary.

A total of 691 field and laboratory duplicate analyses were performed. The data review identified 15 analyses as non-comparable. The non-comparable data were qualified with a “Z” data qualifier with the comment “Duplicate and investigative values are not comparable.” Precision data are included as an electronic file accompanying this report.

2.2 ACCURACY/BIAS

Accuracy is the degree of agreement between an observed value (sample result) and an accepted reference value. Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction (high or low). The terms accuracy and bias are used interchangeably. Accuracy/bias is indicated by percent recovery calculated from laboratory spike data using the following formula:

$$Recovery\ Rate\ (\%) = (Measured\ value)/(True\ value) \times 100$$

Where:
Measured value = Value after the spike minus the value before the spike
True value = Value of the spike added

Accuracy/bias will be determined based on the percent recovery results of laboratory control spikes (LCS) and matrix spikes (MS). Laboratory control spikes utilize laboratory grade water with some additions of inorganic constituents to mimic water native to RMA. Matrix spikes utilize water native to RMA to account for matrix-related interferences.

The calculated recovery rates are compared to the lower and upper recovery rate limits specific to each analyte. Evaluation limits are calculated for each LTMP analyte by monitoring program to account for matrix interference differences. A single set of limits is calculated for LCS recoveries as matrix interferences will not be present in LCS samples. The recovery rate limits are determined by calculating the 25th and 75th percentiles for each analyte using historical recovery rates. The IQR is calculated by subtracting the 25th percentile value from the 75th percentile value. The lower and upper recovery limits are determined by subtracting and adding 1.5 times the IQR to the 25th and 75th percentile value, respectively. Data will not be qualified solely on an individual recovery rate outside the calculated recovery limits. If an analysis is outside both the MS and LCS recovery limits, the analysis will be assigned a "Z" data qualifier with the comment "MS and LCS recoveries were outside evaluation limits". The MS and LCS recovery data, calculations, and evaluation limits are included in the electronic file accompanying this report.

The data utilized for the historical recovery rate calculations were limited to the spike values for the analytical lots of the associated investigative data. Spike recoveries were calculated for all LTMP analytes. Specific monitoring programs were assigned to required site IDs and analytes. Recoveries for LTMP analytes not required for specific locations are also included with the sampling program unspecified. Matrix spike values exceeding four times the spiked amount are excluded from the calculation since the MS could possibly be diluted out due to the high original concentration. Analyses with an "@" flag code (value is estimated) or "B" flag code (analyte found in the method blank or QC blank as well as the sample) were also excluded from recovery rate calculations. The historical spike recoveries used in the calculations are included as an electronic file accompanying this report.

For FY22, the average recovery rate for the 2,040 MS and LCS analyses was 91.1 and 94.8 percent, respectively. Upper and lower recovery rate limits are calculated for each analyte from historical recovery rates. Recovery rates outside the lower or upper limits were observed in 51 MS analyses and 50 LCS analyses. Recovery rates outside the limits for both MS and LCS were observed in four analyses and will be qualified with a "Z" data qualifier.

Analyst comments in the data packages note that Lot AKAA indicated NNDNPA spike recoveries exceeded the lab MS and LCS limits, but no NNDNPA was detected in the associated investigative samples so no further action was necessary. In lot AKEK the lab issued a non-conformance report for incorrect preparation of a spike solution. The affected samples were reextracted within holding time but there was insufficient volume to re-extract MS. CPMSO2 in investigative recovered within limits for re-extraction and no further action is necessary. Analysts notes in the data package AKWM indicated benzene recovered above normal range. There was no exceedance noted in the investigative sample and no further action was necessary. The lab issued a non-conformance report for lot number AKZX due to matrix interference which impacted multiple analytes. There was an insufficient sample volume for re-extraction and no further action is necessary.

The Performance Evaluation (PE) program was conducted as specified in the SQAPP. The PE program is used to evaluate the ability of the laboratory to analyze environmental samples and provide required deliverables accurately and completely. The PE samples were submitted in February 2022. The PE program evaluated the following methods: volatile organic compounds (VOC), DIMP, and organochlorine pesticides (OCP). The PE program reports and spreadsheets are included as electronic files accompanying this report in the Performance Evaluation folder. The PE program indicated the data are acceptable for their intended use.

2.3 REPRESENTATIVENESS

Representativeness is a qualitative term achieved by evaluating whether measurements were made, and samples were collected in a manner that the resulting data appropriately reflects the sampling unit. The performance criterion is a positive evaluation of representativeness. A review of field and laboratory documentation determined that samples were collected and analyzed as specified for each system or category. Field instruments utilized to collect field measurements were calibrated according to the respective instrument manual and recorded in the Operations and Maintenance Contractor (OMC) Groundwater Sampling Calibration Record database. As a result, the data appropriately reflects the operation of the RMA treatment systems. The representativeness criterion was met for FY22.

2.4 COMPLETENESS

Completeness is the measure of the amount of valid data obtained from a measurement system; it is expressed as a percentage of the number of valid measurements compared to the total number of measurements planned in the DQOs. Completeness is calculated using the following formula:

$$Completeness\ (\%) = \frac{Amount\ of\ valid\ data}{Amount\ of\ valid\ data\ expected} \times 100$$

Completeness calculations of greater than or equal to 90 percent are acceptable. Completeness was calculated at 100 percent for FY22, so the completeness criterion was met.

2.5 COMPARABILITY

Comparability is a qualitative term achieved by using standard techniques to collect and analyze representative samples and reporting data in appropriate units. Standard techniques as identified in the SQAPP (Navarro 2019a) were utilized to collect and analyze samples and the data were reported in the appropriate units. The analytical results reported are equivalent to data obtained from similar analyses and the MRLs met the project goals.

2.6 SENSITIVITY

Sensitivity is the ability of the method or instrument to detect the target analytes at the level of interest. The performance criterion for sensitivity is no analyte detections above the MRL in the laboratory method blank. Analytical lots with method blank detections of target analytes exceeding the MRL may be qualified.

Method blank samples are analyzed for each analytical lot. A total of 2,198 method blanks consisting of laboratory water were analyzed for LTMP analytes. There were no detections above the MRL for LTMP analytes. Sensitivity is considered acceptable.

Method blank counts are broken out per system in Appendix I. While the count per system is accurate a single method blank may be represented multiple times in this appendix leading to a total number higher than the correct total represented in this section. This can be explained by batching done at the lab to ensure efficiency. If the lab receives multiple samples to be run under a single method, they will be batched together (up to 20 samples excluding QC) regardless of what system they belong to on the RMA. Method blank data are included in the electronic file accompanying this report.

2.7 FIELD AND QUALITY CONTROL SAMPLES

Field QC samples collected include field blanks, rinse blanks, and duplicate samples. Duplicate sample results are discussed in Section I1, Appendix I. Laboratory QC samples include lab duplicates and method blanks in addition to the MS and LCS samples previously discussed. The FY22 field blank, rinse blank, and method blank data are included in the electronic file accompanying this report.

QC samples with values exceeding the MRL are evaluated according to the following criteria:

- If the associated investigative sample value is less than the MRL, then no action is required
- If the associated investigative sample value is greater than the blank value, then no action is required
- If the associated investigative sample value is less than the blank value, then validation of the analytical lot is requested

Field blanks are collected to determine if cross-contamination exists from ambient sources, such as engine exhaust or dust. In certain instances, field blanks may also be used as an indicator of contamination in the sample containers, or the deionized water used to decontaminate sample equipment and collect field QC samples. A total of 251 field blank analyses were performed with 5 analyses above the MRL. The five analyses that recovered above the MRL are discussed in Appendix I and QC sample information is included in the electronic file accompanying this report.

Rinse blanks were collected to determine whether the sampling equipment decontamination procedures were effective, thus preventing cross-contamination of samples and/or wells. A total of 277 rinse blank analyses were performed with 5 results above the MRL. The five analyses that recovered above the MRL are discussed in Appendix I and QC sample information is included in the electronic file accompanying this report. No qualification of the data is required for the analysis as the rinse blank values are less than the investigative sample values in all seven cases.

2.8 DATA USABILITY EVALUATION

The data usability determination evaluates data quality with respect to the established DQOs. Components of the data review process include 1) evaluating the data against the data quality indicators of precision, accuracy/bias, representativeness, completeness, comparability, and sensitivity; 2) review of field and laboratory QC results; 3) data verification and validation results; and 4) evaluating the data for suitability based on the intended use. Data were evaluated as specified in the SQAPP (Navarro 2019a).

Data verification was performed by the RMA Data Management Contractor as described in the SQAPP. Data verification was performed on all data prior to final submittal to the RMAED. Issues identified by the data verification process are addressed prior to the final submittal of the data into the RMAED. The data verification results are included in the electronic file accompanying this report in the Verification Validation Summary subfolder.

Data validation was performed on selected lots by the Operations and Maintenance Contractor (OMC) Chemist. Validation was performed as specified in the SQAPP. Issues identified during the data validation process are included in the electronic file accompanying this report in the Data and Quality Assurance folder within the Data Verification subfolder.

The suitability evaluation was conducted for only the CSRG or LTMP analytes specific to the sample location. In addition to the components specified above, the data were evaluated for potential outliers and trends. Data were evaluated using the U.S. Environmental Protection Agency software ProUCL, Version 5.2.0, Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations (EPA 2022b). The specifications for the data review include:

- Conduct an outlier test to evaluate the data for potential outliers using Dixon’s test (fewer than 25 values) or Rosner’s test (greater than or equal to 25 values). The use of either outlier test assumes that the data are normally or lognormally distributed.
- Conduct the Mann-Kendall test to evaluate the data for trends
- Identify compliance samples exceeding the CSRG

A data usability evaluation was conducted on 3,869 records. An evaluation was not performed on treatment plant process control samples because these data are closely tracked throughout the fiscal year. The individual data usability spreadsheets by monitoring program are included in the electronic file accompanying this report in the Data Usability subfolder.

The data usability evaluation identified nine analyses as statistical outliers. A listing of the results identified as outliers is included in the electronic file accompanying this report in the Data Usability subfolder.

The Mann-Kendall test for trends identified 326 decreasing trends and 124 increasing trends for analytes at specific well locations. No data quality issues were found with the identified trends. A listing of the identified trends is included in the electronic file accompanying this report in the Data Usability subfolder.

The data usability evaluation did not positively identify data quality issues; thus, the data are considered to be of acceptable quality and meets or exceeds the established DQOs. The data are of the correct type, quality, and quantity to support the intended use.

This page intentionally left blank.

3.0 ON-POST GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS

Performance monitoring is conducted in wells upgradient and downgradient of the containment and mass removal systems to evaluate system performance against established performance criteria and objectives provided in the LTMP (Navarro 2021). The performance criteria are specific to each system and depend on the location of the system and whether it is a containment or mass removal system. Depending on the criteria, performance monitoring includes water quality monitoring for all systems and in most cases water level monitoring. In some cases, operational wells are included in the performance monitoring networks as well, thereby serving a dual purpose.

Operational water level and/or water quality monitoring is conducted in extraction, recharge, and monitoring wells located near the containment or mass removal systems. Operational water quality monitoring is also conducted for the system influent and at sampling points within the system. Operational monitoring is conducted to:

- Evaluate and optimize system performance, and
- Ensure that RAOs are achieved.

Most of the operational wells are used for water level monitoring to ensure optimal extraction and recharge system operation. Selected wells are also used for water quality monitoring of indicator analytes. These monitoring data are used to evaluate and adjust the system to optimize operations for containment, capture, and treatment. As operating conditions change, the operational monitoring program may also change. Therefore, the operational monitoring program is flexible with respect to monitoring locations, frequencies, and chemical analyses, and is modified independently from the LTMP.

3.1 NORTHWEST BOUNDARY CONTAINMENT SYSTEM

The NWBCS treatment facility consists of a groundwater extraction system, monitoring wells, pre-treatment filtration, granular activated carbon adsorption, post-treatment filtration and a groundwater recharge system. A slurry wall constructed of a soil-bentonite mixture was installed as part of the system to help contain contaminant migration. The NWBCS is designed to intercept contaminated groundwater from the upgradient side of the slurry wall, treat it to remove the organic contaminants, and inject the treated water back into the alluvial aquifer on the downgradient side of the barrier. The Original System, installed in 1984, consists of 15 extraction wells, 21 recharge wells, and the slurry wall, which measures approximately 1,425 feet. The recharge wells are located northwest (downgradient) of the extraction wells and slurry wall. The objective of the system is to create hydraulic control to contain the contaminant plumes.

Modifications to the NWBCS include the addition of the Northeast Extension (NEE) constructed in 1990 to intercept flow through a small alluvial channel north of the Original System, and the Southwest Extension (SWE) extraction and recharge system in 1991 to extract groundwater from the dieldrin plume originating in Section 2 on the RMA.

The NEE consists of a 660-ft extension of the Original System slurry wall and two additional extraction wells that were installed to intercept a small northwest-trending alluvial channel. The flow downgradient of the slurry wall is towards the Original System recharge wells. Maintaining a reverse hydraulic gradient, therefore, is not required for this portion of the NWBCS. Dieldrin is the primary contaminant at the NEE.

The SWE was installed in 1991 and consists of four additional extraction wells and four additional recharge wells located southwest of the Original System. No slurry wall was installed in this area. The recharge wells were installed in an uncontaminated zone between the SWE and Original System, cross-gradient of the extraction wells, to prevent the SWE and Original System plumes from shifting away from their respective extraction systems. Consequently, the SWE has a hydraulic capture system design. Historically, dieldrin has been the primary contaminant at the SWE. Between 2004 and 2012, dieldrin concentrations were below the PQL of 0.05 micrograms per liter (µg/L) in all four extraction wells and the associated upgradient and downgradient monitoring wells. The PQL was lowered to 0.013 µg/L in 2012, and the dieldrin concentrations have exceeded the PQL in some of the upgradient wells, although dieldrin concentrations in SWE wells did not exceed the PQL in FY22.

FY22 treatment system performance data for the NWBCS are provided in Table 3.1-1. The results of CSRG-analyte sampling in NWBCS performance wells in FY22 are presented in Table 3.1-2. Appendix A provides figures to illustrate the performance of the NWBCS during FY22. Groundwater monitoring and water level data are provided in the electronic file accompanying this report.

3.1.1 NWBCS Operations and Compliance

The NWBCS operated at an average flow rate of 830 gallons per minute (gpm), pumping a total volume of 436,012,080 gallons during FY22 and removing a total of 2.9 pounds of contaminant mass. The major contaminants removed via treatment included chloroform, dieldrin, endrin ketone, NDPA and dichlorodiphenyltrichloroethane (PPDDT). The total cost to operate the treatment plant in FY22 was $598,401 (Table 3.1-1).

Figure A-1 in Appendix A shows the NWBCS extraction and recharge wells, slurry walls, and associated monitoring wells.

Compliance for all treatment systems at RMA is based on quarterly effluent water quality monitoring. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The current CSRG list, including any revisions since the RODs were developed, is provided in the LTMP. The system effluent for the NWBCS was analyzed quarterly in FY22 using the LTMP routine CSRG analyte list for the NWBCS and annually using the complete CSRG list.

As presented in Table 1 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the NWBCS individual effluent concentrations and associated four-quarter moving averages showed no exceedances during FY22 (Navarro 2022b, 2022d, 2022f, 2022g).

The treatment plant influent and effluent concentrations for analytes with concentrations that exceeded CSRGs in treatment plant influent are shown in Figures A-2 and A-3 (Appendix A). The graphs indicate that treatment plant influent concentrations of dieldrin and NDPA exceeded their respective CSRG/PQL, while concentrations of both analytes in plant effluent did not exceed CSRGs/PQLs in FY22.

In FY22, the NWBCS demonstrated system effectiveness for analytes addressed by treatment technologies, showing concentrations in treatment plant effluent are less than CSRGs/PQLs.

3.1.2 NWBCS Performance Evaluation

The performance criteria for the NWBCS are designed to address future monitoring needs and facilitate the system performance evaluation. Criteria presented in the LTMP address the Original System of the NWBCS. The primary performance criteria for the NWBCS are presented below:

- Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.
- Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

A secondary performance criterion was established to address system performance in the event that a reverse hydraulic gradient could not be maintained, which provides assurance that downgradient water quality is not being adversely impacted:

- If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends, based on annual evaluations, over the previous period of at least five years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

The SWE and NEE were designed to capture groundwater that was not being captured by the Original System. Performance criteria established for each of these two system extensions are presented below and both criteria must be met:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.
- Demonstrate decreasing concentration trends, or that concentrations are at or below CSRGs/PQLs, in downgradient performance wells.

Flow rates in the NWBCS dewatering and recharge wells were adjusted and have successfully improved the plume-edge capture for the Original System (see Figure A-13). The concentrations of CSRG analytes in plume-edge monitoring well 27010 were below the CSRGs/PQLs for all of FY22.

A reverse hydraulic gradient was maintained within the system throughout FY22, and plume capture is evident as indicated by the potentiometric surface map and the evaluation of downgradient water quality data. Thus, the NWBCS functioned as intended in FY22.

Plume capture at the NEE is demonstrated by the southwesterly gradients shown on Figure A-13. To support system optimization, downgradient performance well water quality is monitored regularly in wells 22015 and 22512. Dieldrin, isodrin, and NDPA were the only contaminants detected above CSRGs/PQLs in downgradient performance wells 22015 and 22512 (Table 3.1-2). These data are consistent with data from previous years. Since FY12, the dieldrin concentrations in wells 22015 and 22512 have not shown increasing trends. Although the trends are not increasing, the prolonged detection of dieldrin contamination in these wells has prompted additional evaluation to determine probable causes. NDPA was detected for the first time in well 22512 in January FY22, and subsequently in April and August 2022, all at concentrations exceeding the PQL. Isodrin also was detected for the first time above the CSRG in well 22015.

Historically, a small amount of contaminated flow from the NEE area migrates on the downgradient side of, and parallel to, the slurry wall where it is extracted by well 22309. Flow in the recharge wells creates a hydraulic barrier to off-post migration of this contaminated flow. However, in FY15, several analytes in addition to dieldrin were detected in downgradient performance monitoring well 37333 that are similar to those detected in NEE well 22508, located downgradient of the slurry wall. This suggests that a migration pathway from well 22508 to well 37333 may exist. In FY22, except for well 37333, the dieldrin concentrations in the Original NWBCS downgradient performance wells were below the PQL. Mann-Kendall trend analyses were completed for downgradient well 37333 as part of the data quality assurance review indicating dieldrin concentrations are decreasing in this well. Concentrations above the PQL in well 37333 might be related to the NEE plume capture issue described above.

As presented in FY21, the presence of groundwater in well 22085 indicates that bypass may be occurring north of the slurry wall during periods where the water table rises enough to produce uninterrupted flow. The low volume of water within the apparent dip in the bedrock surface in the vicinity of well 22085 may not support extraction wells in this area to capture flow. In addition, the lack of groundwater at the north end of the slurry wall, predicated on continued decreasing water levels since FY21, indicates that persistent bypass at this location is unlikely. As recommended, water quality sampling was addressed in a 2021 OCN to the LTMP (OCN-LTMP-2021-001), requiring semiannual sampling of well 22085 if sufficient water is present in the well. In January and August 2022, sampling for OCPs was conducted with results indicating that dieldrin, isodrin, and NNDNPA concentrations exceeded CSRGs/PQLs. Semiannual sampling will continue through FY23, with an evaluation report to follow.

Plume capture at the SWE is demonstrated by the water elevation contours and flow directions indicated on Figure A-13. No analytes exceeded CSRGs/PQLs in performance wells at the SWE in FY22. Dieldrin concentrations have decreased in the upgradient performance well 27517 (Table 3.1-2 and Figure A-8). While the dieldrin concentration exceeded the PQL in downgradient well 27522 in FY18, concentrations have been decreasing and dieldrin was detected at a concentration less than the PQL in this well in FY22. Dieldrin concentrations in SWE cross-gradient wells 27516 and 28521 were also below the PQL in FY22.

Although primary performance criteria were met in FY22 for the NWBCS, evaluation of the system is ongoing relative to the secondary performance criterion. In the event that downgradient performance wells show analytes that are above CSRGs/PQLs, concentration trends are evaluated. Concentrations trends are determined by visual inspection of time versus concentration plots and supported by the use of Mann-Kendall statistical analysis as part of the data quality assurance review as options presented in the LTMP.

A summary of the NWBCS performance well concentration trend data is provided in Table 3.1-2 for contaminants detected above the CSRG. For dieldrin, Table 3.1-2 indicates that Original System downgradient performance well 37333 and NEE downgradient performance wells 22015 and 22512 were above the PQL. Figure A-14 illustrates the concentration trends versus time in NWBCS wells. Dieldrin is present at levels exceeding the PQL in upgradient wells but are not increasing in wells downgradient of the system. Isodrin demonstrates similar results (see Figure A-15). NDPA exceeded the PQL in downgradient NEE well 22512, and concentrations indicate an increasing trend in FY22 (Figure A-16).

1,4-Dioxane, arsenic, chloroform, and isodrin were also detected at levels exceeding CSRGs/PQLs in upgradient wells in FY22, but were not detected or detected at concentrations less than CSRGs/PQLs, in downgradient wells (Figures A-5 through A-7 and Figure A-9, respectively).

Figures A-11 and A-12 in Appendix A show that the reverse hydraulic gradient was maintained across the system for all quarters in FY22. Plume-edge capture at the NWBCS Original System can be verified in the overview of sample results for cross-gradient well 27010 as summarized in Table 3.1-2 and Exhibit A-4 in Appendix A.

3.1.3 NWBCS Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) review of field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the NWBCS in FY22 is provided in Appendix I1.1.

3.1.4 NWBCS Summary and Conclusions

In FY22, the NWBCS met the compliance and performance criteria and objectives established in the LTMP. There were no CSRG-analyte exceedances in either the four-quarter moving averages or in annual ROD water quality samples in the NWBCS treatment system effluent in FY22. The reverse gradient was maintained throughout the year, which is consistent with results in previous reporting periods.

During FY22, the average flow rate was 830 gpm, pumping a total of 436,012,080 gallons, and removing a total mass of 2.9 pounds. The contaminants that were above the CSRG in influent samples were dieldrin and NDPA, both of which were successfully treated by the system. NDPA was detected for the first time in downgradient NEE well 22512, and demonstrates potentially increasing concentrations exceeding the PQL in FY22. Dieldrin was detected above the PQL in Original System downgradient performance well 37333 and NEE downgradient performance wells 22015 and 22512, however, the long-term trend is not increasing in downgradient performance wells. The dieldrin concentrations were likely above the PQL in these NWBCS downgradient performance wells during the past few years because: 1) mobilization of residual dieldrin in the aquifer sediments downgradient of the slurry wall; 2) dieldrin concentrations previously have been near or above the current PQL in the NWBCS effluent; and/or 3) possible bypass from the NEE area.

The potential for contaminated flow toward the downgradient performance wells will be further evaluated as a result of semiannual monitoring through FY23.

3.2 NORTH BOUNDARY CONTAINMENT SYSTEM

The NBCS treatment facility consists of a groundwater extraction system, monitoring wells, pre-filtration, granular activated carbon adsorption, post-filtration, ultraviolet (UV) oxidation, soil-bentonite slurry wall, and a groundwater recharge system. The NBCS was designed to intercept contaminated groundwater from the upgradient side of the slurry wall, treat it to remove the organic contaminants, and inject the treated water back into the alluvial aquifer on the downgradient side of the slurry wall. The treatment facility was originally designed as a pulse bed granular activated carbon adsorption system; however, modifications to the treatment plant in May 1995 converted the plant to a down flow carbon adsorption system.

Additional modifications to the NBCS included the addition of UV oxidation treatment in the fall of 1997 to treat NDMA, and the addition of the South Channel well system in the fall of 2002 to extract groundwater upgradient of the NBCS to optimize NBCS operations.

The treatment system is designed to provide hydraulic control and remove organic contaminants known to be present in the extracted groundwater to levels at or below the CSRGs established in the final ROD for the NBCS.

Treatment system information for the NBCS is provided for FY22 in Table 3.2-1. The results of CSRG-analyte sampling in FY22 are presented in Table 3.2-2, and in maps within Appendix B. Groundwater monitoring and water level data are included in Excel files accompanying this report.

3.2.1 NBCS Operations and Compliance

The NBCS operated at an average flow rate of 232 gpm and pumped a total volume of 121,766,632 gallons during FY22 and removed a total of 9.2 pounds of contaminant mass. The major contaminants removed via treatment included dicyclopentadiene (DCPD), DIMP, carbon tetrachloride, trichloroethylene, chloroform, tetrachloroethylene, NDPA, dieldrin, and 1,2-

dichloroethane, (Table 3.2-1). The total cost to operate the treatment plant in FY22 was $507,719 (Table 3.2-1).

Figure B-1 in Appendix B shows the locations of NBCS monitoring wells, extraction and recharge wells, the slurry wall, and the South Channel extraction wells.

Compliance for all treatment systems at RMA is based on quarterly effluent water quality monitoring. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The current CSRG list, including any revisions since the RODs were developed, is provided in the LTMP. The system effluent for the NBCS was analyzed quarterly in FY22 using the LTMP routine CSRG analyte list for the NBCS and annually using the complete CSRG list.

As presented in Table 2 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the NBCS individual effluent concentrations and associated four-quarter moving averages showed no exceedances during FY22, with the exception of 1,4-dioxane and NDMA (Navarro 2022b, 2022d, 2022f, 2022g).

The treatment plant influent and effluent concentrations for the following analytes are shown in Figures B-2 through B-9, respectively (Appendix B):

- 1,2-Dichloroethane
- 1,4-Dioxane
- Aldrin
- Carbon tetrachloride
- Chloride
- Dieldrin
- NDMA
- NDPA

Emerging contaminant 1,4-dioxane exceeded CSRGs in the plant effluent during the third quarter in FY22, and during the fourth quarter of FY22, the four-quarter moving average exceeded the CSRG for 1,4 dioxane. The NBCS does not treat for 1,4-dioxane. NDMA exceeded the CSRG in the third quarter, but the moving average did not exceed the CSRG/PQL. The graphs indicate that 1,2-dichloroethane, carbon tetrachloride, chloride, dieldrin, and NDPA exceeded CSRGs/PQLs in treatment plant influent concentrations, while concentrations in plant effluent did not exceed CSRGs/PQLs in FY22.

In FY22, the NBCS demonstrated system effectiveness for analytes addressed by treatment technologies, reducing contaminant concentrations below the CSRGs/PQL.

3.2.2 NBCS Performance Evaluation

The performance criteria for the NBCS are designed to address future monitoring needs and facilitate the system performance evaluation. The primary performance criteria for the NBCS are presented below:

- Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.
- Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance water quality wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

A secondary performance criterion was established to address system performance in the event that a reverse hydraulic gradient could not be maintained, which provides assurance that downgradient water quality is not being adversely impacted:

- If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends, based on annual evaluations, over the previous period of at least five years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

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. Figures B-23 and B-24 in Appendix B show that the reverse hydraulic gradient was maintained across the system during three quarters of FY22, with a forward gradient observed during the fourth quarter in well pair 23528/23535. A notification was made to the regulatory agencies early during the first quarter of FY23 on October 25, 2022. Plume-edge capture at the NBCS can be verified by inspection of the water-table map in Figure B-27. Water-table contours indicate that groundwater flow is being captured at the edges of the system.

Although the primary performance criterion to demonstrate a reverse gradient was not met during one quarter in FY22, evaluation relative to the secondary performance criterion was conducted. In the event that downgradient performance wells show analytes are above CSRGs/PQLs, concentration trends are evaluated by visual inspection of time versus concentration plots and are further supported by the use of Mann-Kendall statistical analysis.

Exhibit B-10, Appendix B, provides a summary table of the FY22 NBCS Performance Well Water Quality Monitoring. Figures B-11 through B-22 illustrate the distribution of contaminants in performance wells upgradient and downgradient of the NBCS for 1,4-dioxane, arsenic, carbon tetrachloride, chloride, DCPD, dieldrin, DIMP, fluoride, isodrin, NDMA, NDPA, and sulfate. Downgradient performance wells are either below detection limits or below the CSRG/PQL for most of the CSRG analytes. The only organic analytes detected in performance monitoring wells above CSRGs/PQLs were 1,4 dioxane, dieldrin, and NDMA. Anions chloride, fluoride, and sulfate were also detected above CSRGs/PQLs. The system does not treat for 1,4-dioxane or the anions.

A summary of the NBCS performance well concentration trend data is provided in Table 3.2-2 for contaminants detected above the CSRGs. In FY22 downgradient performance well 24207 could not be sampled due to insufficient water. Nearby well 24429 was monitored instead, which is reflected in the following evaluation and in relevant maps, charts, and tables in this report.

Dieldrin concentrations were above the PQL in 8 of the 11 downgradient performance wells showing decreasing, or no discernible trends using visual inspection and statistical trend analyses. The dieldrin concentrations present above the PQL in the downgradient wells are likely due to its lower solubility and affinity for soil in soil-water system. Fluctuations in groundwater levels downgradient of the NBCS slurry wall caused by variations in the recharge trench flow rates and variable recharge from First Creek likely causes desorption of dieldrin from the aquifer sediments. NDMA was only detected in well 23405 at a concentration exceeding the CSRG/PQL. 1,4-Dioxane was detected at a concentration exceeding the CSRG in downgradient performance wells 23438, 24006, 24418, 24421, and 24429.

Regarding anions, several wells had concentrations of chloride, fluoride, and/or sulfate greater than CSRGs. Although not treated at the NBCS, sulfate in plant effluent has been consistently below the CSRG and the attenuation goal is being met. Concentrations of chloride in groundwater are also eventually expected to meet the CSRG via natural attenuation processes.

Concentration versus time trend plots in NBCS wells for analytes with concentrations that exceeded CSRGs/PQLs in upgradient and downgradient performance wells are presented in Figures B-28 through B-33. In these figures, 1,4-dioxane, dieldrin, chloride, fluoride, NDMA, and sulfate are present in groundwater at levels greater than CSRGs/PQLs, but are generally not increasing in concentrations downgradient of the system. As discussed in previous ASRs, the downgradient detections of dieldrin are most likely caused by residual contamination and are not representative of system effectiveness.

The NBCS does not treat for 1,4-dioxane, but the future consolidated water treatment plant will treat for this contaminant. Although not treated by the system, the anion concentrations seem consistent with typical natural conditions; however, evaluation is necessary to assess chloride and sulfate attenuation towards meeting remediation goals.

3.2.3 NBCS Denver Formation Monitoring

3.2.3.1 Denver Formation Hydraulic Gradients

Reverse Gradients

Reverse lateral hydraulic gradients across the slurry wall and upward vertical hydraulic gradients on the upgradient (south) side of the slurry wall are desirable in the Denver unconfined wells but are not required to maintain hydraulic control. Water levels were measured quarterly at seven well pairs screened in the Denver Formation sandstone that extends under the slurry wall in the western half of the NBCS and are adjacent to the NBCS slurry wall. Reverse gradient graphs are shown in Figures B-25 and B-26 in Appendix B. The reverse gradient graphs have been consistent for the last several years.

To evaluate reverse gradients across the slurry wall, water levels for well pairs (listed from west to east) were reviewed: 23536/23537, 23538/23539, 23138/23126, 23540/23541, 23194/23195, 23542/23543, and 23242/23243. Water levels in these well pairs show that a flat to reverse hydraulic gradient was not present in well pairs 23536/23537, 23538/23539, 23540/23541, and 23542/23543. A reverse gradient was present in well pairs 23138/23126, 23194/23195 and 23542/23543 during all four quarters of FY22. The inability to maintain a constant reverse gradient is due to the semi-confined sands in the Denver Formation, which have become a significant factor in this area as water levels have decreased in the region over the past few years.

Vertical Gradients

Vertical gradients were evaluated on the upgradient (south) and downgradient (north) sides of the slurry wall to determine whether the potential exists for downward migration within the UFS of contaminants from the alluvium into the Denver Formation indicative of underflow across the slurry wall. Vertical gradients were calculated utilizing the electronic data provided in the FY22 North Boundary Containment System folder that accompanies this report.

Vertical gradients on the upgradient/south side of the slurry wall were evaluated for well pairs (listed from west to east): 23208/23537, 23207/23539, 23214/23126, 23533/23541, 23534/23195, 23535/23543, and 23212/23243. An upward vertical hydraulic gradient from the Denver Formation unconfined zone to the overlying alluvium on the upgradient side of the slurry wall indicates hydraulic containment with depth. Upward gradients were present in well pairs during all measured quarters in five of the seven well clusters on the extraction-well side of the slurry wall.

On the downgradient/north side of the slurry wall, vertical gradients were evaluated for the following well pairs (listed from west to east): 23519/23538, 23215/23138, 23510/23194, 23528/23542, and 23217/23242. In FY22, vertical hydraulic gradients were downward in well pairs 23519/23538, 23215/23138, 23510/23194, and 23217/23242, indicating hydraulic control was maintained, which is further substantiated by the presence of a reverse gradient across the slurry wall in this portion of the NBCS. In well pair 23528/23542, a downward vertical gradient was only observed during the second quarter, but hydraulic control in this area is maintained since a reverse gradient is present across the slurry wall in this area of the system.

Summary

The FY22 hydraulic gradients in the Denver unconfined wells are consistent with historical gradients. The lateral hydraulic gradients indicate that underflow of contaminants likely is not occurring as upward vertical gradients in well pairs located on the upgradient side of the slurry wall indicate hydraulic containment are being maintained.

3.2.3.2 Denver Formation Water Quality

Specific to monitoring water quality upgradient and downgradient of the slurry wall, Denver Formation UFS and CFS performance wells are sampled once every five years with sampling taking place during the five-year reporting period in FY22. The sample results for the FY22 event are presented below, with summary of the data provided in Table 3.2-3.

Unconfined Flow System

Denver UFS monitoring includes the following downgradient/upgradient well pairs:

- Wells 23194/23195
- Wells 23540/23541
- Wells 23542/23543

In addition, unpaired Denver UFS wells 23235 and 24191, located farther downgradient of the NBCS slurry wall, were also sampled in FY22.

Chloride, dieldrin, and DIMP exceeded CSRGs/PQLs in upgradient Denver UFS wells in FY22. In downgradient Denver UFS wells, carbon tetrachloride, chloride, chloroform, dieldrin, and DIMP were detected above CSRGs/PQLs (Table 3.2-3).

Well pair 23194/23195 represents the downgradient and upgradient sides of the NBCS slurry wall, respectively. Carbon tetrachloride and chloroform were detected in downgradient well 23194, but were not detected in the upgradient well, and visual review of the data indicates that concentrations are increasing. A limited reverse hydraulic gradient exists in the UFS Denver Formation in this area of the system, which may account for the higher concentrations in the downgradient well.

Well pair 23540/23541 represents the downgradient and upgradient sides of the slurry wall, respectively. Chloride, dieldrin and DIMP were detected in these two wells (Table 3.2-3). In FY22, there were higher concentrations of dieldrin and DIMP present in groundwater on the downgradient side of the slurry wall.

Well pair 23542/23543 represents the downgradient and upgradient sides of the slurry wall, respectively. Chloride, chloroform, and DIMP were detected in these two wells (Table 3.2-3). In FY22, DIMP was detected at a higher concentration in groundwater on the downgradient side of the slurry wall, while chloride was higher upgradient of the slurry wall.

In the area of well pairs 23540/23541 and 23542/23543, a slight forward gradient exists sporadically throughout the water year and is attributed to the presence of semi-confined sands in the Denver Formation, which limit the ability of the system to consistently maintain a reverse gradient. Underflow is unlikely in this area due to the competency of the bedrock in which the slurry wall was constructed on the western end of the system.

Downgradient of the NBCS, chloride and DIMP were detected in well 23235 at concentrations exceeding CSRGs in FY22 (Table 3.2-3). While concentrations of chloride have been stable in this well, 1,2-dichloroethane and DIMP indicate decreasing trends consistent with results presented in the FY19 ASR and Five-Year Summary Report (FYSR) (Navarro 2020b). In well 23191, concentrations of chloride and DIMP in FY22 were consistent with previous results indicating stable trends for both analytes downgradient of the NBCS (Navarro 2020b).

Confined Flow System

Individual downgradient wells sampled to characterize the Denver CFS include 23161, 23200, and 24171. NDMA and 1,2-dichloroethane were detected in well 23200 (Table 3.2-3). The decreasing trend of 1,2-dichloroethane is consistent with the FY19 ASR and FYSR, which concluded that contamination may have been introduced when the well was installed and has since been attenuating. 1,2-Dichloroethane and NDMA detected in well 23200 show stable trends at this time, supporting previous conclusions that contamination may have been introduced when the well was installed and has since been attenuating (Navarro 2020b).

3.2.4 NBCS Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) review of field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the NBCS in FY22 is provided in Appendix I1.2.

3.2.5 NBCS Conclusions and Recommendations

The NBCS operated at an average flow rate of 232 gpm and pumped a total volume of 121,766,632 gallons during FY22, removing a total of 9.2 pounds of contaminant mass.

In FY22, the NBCS demonstrated system effectiveness for analytes addressed by treatment technologies, reducing contaminant concentrations below the CSRGs/PQL. 1,4-Dioxane and NDMA both exceeded CSRGs in the plant effluent in FY22. NDMA did not exceed the four-quarter moving average, but during the fourth quarter of FY22, the four-quarter moving average exceeded the CSRG for 1,4 dioxane. As an emerging contaminant, 1,4-dioxane treatment was not part of the design for the NBCS and therefore is not treated by the system.

A reverse hydraulic gradient was maintained within the system during the first, second, and third quarters of FY22, with one well pair demonstrating a slight forward gradient during the fourth quarter. The concentrations in the downgradient performance wells were less than the CSRGs/PQLs, or show decreasing trends in most of the wells. Dieldrin concentrations were above the PQL in eight downgradient performance wells, but show stable, decreasing, or no discernible trends in these wells. The downgradient dieldrin concentrations above the PQL likely are caused by residual contamination that is not representative of system performance.

Based on the FY22 information, the contaminant plumes were captured at NBCS. There was no indication of underflow within the Denver Formation as vertical gradients were generally upward upgradient of the slurry wall, and contaminant levels were significantly higher upgradient of the slurry wall. Although a few analytes are above CSRGs/PQLs in downgradient wells because of residual downgradient contamination, the NBCS is functioning as intended. Continued monitoring will be conducted in downgradient performance wells where PQL exceedances occurred in FY22.

3.3 BASIN A NECK SYSTEM

The BANS was designed and constructed in 1989 to intercept contaminated alluvial groundwater originating from Basin A. Contaminated groundwater is removed from the upgradient side of a slurry wall, treated by means of air stripping and granular activated carbon adsorption to remove the organic contaminants, and injected back into the alluvial aquifer through recharge trenches on the downgradient side of the slurry wall. Since the original plant was constructed, two additional extraction systems were added in 2000, and one additional system was added in 2011. These systems include the BRES, which extracts contaminated groundwater from an area in the north-central part of Section 36, the CADT dewatering system, which pumps contaminated groundwater from the CADT area in the southeast portion of Section 36, and the Lime Basins, which pumps contaminated groundwater from the southwest corner of Section 36. All three of these extraction systems convey contaminated groundwater to the BANS for treatment. The BANS treatment system is designed to remove organic contaminants and arsenic to levels at or below the CSRGs established in the final On-Post ROD.

The contaminated groundwater from the BRES and CADT systems requires pre-treatment by air stripping for removal of VOCs. In order to accommodate the increased flows from the additional extraction systems, a shallow tray air-stripping system was installed in 2002 to replace the original packed bed air stripping system. In 2004, the air stripper was relocated to the headworks of the plant in order to process the entire plant flow. The Lime Basins Treatment Relocation Project, which directed groundwater from the Lime Basins extraction wells into the BANS treatment plant, was started in FY10 and was completed in FY11 (RVO 2013).

Treatment system information for the BANS is provided for FY22 in Table 3.3-1. Figure C-1 presents a map of the BANS, including the monitoring well network. The results of CSRG-analyte sampling and water level monitoring in BANS performance wells in FY22 are presented in Exhibit C-13 and Figure C-19, respectively, within Appendix C. Groundwater monitoring and water level data are included in electronic files accompanying this report.

3.3.1 BANS Operations and Compliance

The BANS operated at an average flow rate of 17 gpm and pumped a total volume of 9,132,842 gallons during FY22, removing a total of 59.40 pounds of contaminant mass. The major contaminants removed via treatment included the following:

- 1,2-Dichloroethylene
- 1,2-Dichloroethane
- 1,2-Dichloropropane
- Arsenic
- Chloroform
- p-Chlorophenylmethyl sulfoxide (CPMSO2)
- DCPD
- DIMP
- Dithiane
- 1,4-Oxathiane
- 1,1,2,2-Tetrachloroethane
- Trichloroethylene
- Tetrachloroethylene

Carbon usage has remained steady over the past few years (Navarro 2020b). The total cost to operate the treatment plant in FY22 was $587,993 (Table 3.3-1).

Compliance for all treatment systems at RMA is based on quarterly effluent water quality monitoring. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The current CSRG list, including any revisions since the RODs were developed, is provided in the LTMP. The system effluent for BANS was analyzed quarterly in FY22 using the complete CSRG list.

As presented in Table 4 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the BANS individual effluent concentrations and associated four-quarter moving averages showed no exceedances during FY22 (Navarro 2022b, 2022d, 2022f, 2022g).

The treatment plant influent concentrations for the following 11 analytes exceeded CSRGs/PQLs as shown in Figures C-2 through C-12 (Appendix C).

- 1,2-Dichloroethane
- 1,4-Dioxane
- Chloroform
- DIMP
- Dithiane
- Dieldrin
- NDPA
- PPDDT
- 1,1,2,2-Tetrachloroethane
- Trichloroethylene
- Tetrachloroethylene

The graphs indicate that while treatment plant influent concentrations exceeded CSRGs/PQLs, concentrations in the plant effluent did not exceed CSRGs/PQLs in FY22.

Although not a compliance requirement, reverse hydraulic gradient is monitored at the BANS as an operational consideration. As presented in the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the reverse hydraulic gradient at BANS was similar to its historical trend in previous years. Although a reverse hydraulic gradient was not present on the far western and eastern ends of the system, it was maintained in the central part of the system containing the highest concentrations of contaminants.

In FY22, the BANS demonstrated treatment system effectiveness that showed concentrations exceeding CSRGs/PQLs in treatment plant influent were less than CSRGs/PQLs in the treatment plant effluent (Figures C-2 through C-12).

3.3.2 BANS Performance Evaluation

The performance criteria for the BANS were designed to address future monitoring needs and facilitate the system performance evaluation and are presented below:

- Demonstrate effective mass removal through comparison of calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods.
- Demonstrate that concentrations in downgradient performance wells are stable or decreasing.

Performance of the BANS in FY22 relative to these two criteria is presented below.

3.3.2.1 BANS Mass Removal

A revised approach to evaluate contaminant mass removal at the BANS was proposed in 2019 consisting of a comparison of the calculated mass removed by the system to contaminant plume mass flux approaching the system. The revised technical approach serves as a prospective revision to the LTMP by focusing on measuring the effectiveness of mass removal at the point of capture (extraction) within each system, and not the mass treated at the treatment plant. The mass removal evaluation presented in this report provides a quantitative measure of extraction system performance and better quantifies contaminated groundwater not captured as an indication of potential system bypass. The potentiometric surface map of the BANS area for FY22 is consistent with previous data and indicate flow towards the system, and water levels in FY22 do not indicate any apparent gaps between either end of the slurry wall and unsaturated alluvium (Figure C-19).

Consistent with the methodology incorporated into the LTMP in 2012 (OCN-LTMP-2012-002), two methods are used in combination to estimate contaminant mass removal:

- Transect method – Used to estimate the mass flux approaching the BANS.
- Well capture method – Used to estimate the mass removal extracted within the BANS capture zone by extraction wells.

The revised mass removal performance criterion specifies removal of at least 75 percent of the contaminant plume mass migrating toward the system. As the revised approach has been implemented for only three years, an evaluation of the appropriateness of the 75 percent criterion will be conducted to support the FY23 ASR. Additional details on the technical approach and methodology for the evaluation of contaminant mass removal are presented in LTMP, OCN-LTMP-2023-005. The calculations for contaminant mass removal for the BANS are provided in the Excel file accompanying this report (FY22 BANS Mass Removal Rev0 07-19-23.xlsx).

The approximate total contaminant flow rate approaching the BANS was 12.27 gpm as shown in Table 3.3-2. The total flow rate is based on the averaged measured extraction flow rate within the capture zone of 11.64 gpm and the estimated contaminated flow outside the capture zone was approximately 0.63 gpm. Based on these flow rates, approximately 95 percent of the estimated contaminated flow was extracted and treated.

In FY22, the mass flux outside the capture zone was estimated to be 0.17 pounds per year (pounds/year) for all organic and inorganic CSRG analytes, while the mass flux within the capture zone was 13.15 pounds/year for the extraction wells. Based on these data, the total BANS mass removal is 98.7 percent, which exceeds the LTMP performance criterion of 75 percent (Table 3.3-2). Any apparent discrepancies in the quantities for mass removal can be accounted for in mathematical rounding as shown in the calculations presented in the Excel file accompanying this report.

From FY12 through FY22, mass removal has ranged from 88.5 to 99.7 percent, with an average of 97.7 percent. The lowest percentage of mass removal occurred during periods of high precipitation and an increase in the water table where flow around the northern and southern end of the slurry wall likely occurred, thus decreasing capture.

3.3.2.2 Downgradient Performance Wells

The second performance requirement is to demonstrate that concentrations in downgradient performance wells are below CSRGs/PQLs, or stable or decreasing if they are above the CSRGs/PQLs.

Table 3.3-3 presents an overview of the FY22 water quality results and concentration trends for the BANS performance wells, while Exhibit C-13, Appendix C, provides a summary of performance well analytical data. Figures C-14 through C-18 in Appendix C show the upgradient and downgradient performance well concentrations. Time versus concentration maps on Figures C-20 through C-22 show the concentration trends for analytes with concentrations that exceeded CSRGs/PQLs in downgradient wells over the past few years, including CPMSO2, dieldrin, and PPDDT.

Dieldrin concentrations were above the PQL in three of the four downgradient performance wells (26205, 35505, and 35525), but appear to be decreasing in well 26205 and show stable or no discernible trends in the other two wells. The concentrations of CSRG analyte CPMSO2 are now less than the CSRG in downgradient performance wells indicating a decrease in CSRG analyte levels downgradient of the system (Table 3.3-3). PPDDT was detected at a concentration greater than the CSRG upgradient of the BANS in FY22, and the concentration of this analyte exceeded the CSRG in downgradient well 35525 and demonstrates a decreasing long-term trend (Table 3.3-3). The data do not indicate an increasing trend for any of the contaminants as verified by Mann-Kendall trend analyses completed as part of the data quality assurance review.

3.3.3 BANS Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) reviewing field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review for BANS includes BRES, CADT, and Lime Basins data. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the BANS in FY22 is provided in Appendix I1.3.

3.3.4 BANS Conclusions and Recommendations

In FY22, the BANS met the treatment plant compliance requirements established in the LTMP. The BANS operated at an average flow rate of 17 gpm and pumped a total volume of 9,132,842 gallons during FY22, removing a total of 59.4 pounds of contaminant mass. As presented in Table 4 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the BANS individual effluent concentrations and associated four-quarter moving averages showed no exceedances during FY22. The BANS demonstrated treatment system effectiveness, specifically related to dieldrin and DIMP. Each contaminant showed concentrations exceeding CSRGs/PQLs in upgradient wells and treatment plant influent, and concentrations less than CSRGs/PQLs in treatment plant effluent. CSRG analyte concentrations detected in downgradient performance wells were less than CSRGs/PQLs.

In FY22, the BANS met the performance criteria and objectives established in the LTMP. Utilizing the revised approach to evaluate mass removal, BANS met the 75 percent goal for FY22, with mass removal estimated at 98.7 percent.

3.4 BEDROCK RIDGE EXTRACTION SYSTEM

The BRES intercepts groundwater flowing northeast out of Basin A from the CADT area. The monitoring network for the BRES is presented in Figure C-23. The potentiometric surface map (Figure C-34) indicates that the groundwater was flowing north-northwest in the vicinity of the extraction wells.

3.4.1 BRES System Operations

Extraction water from BRES is piped to and treated at BANS. The distribution of analytes exceeding CSRGs/PQLs in upgradient and/or downgradient performance wells in FY22—including 1,1-dichloroethylene, 1,2-dichloroethane, carbon tetrachloride, chloroform, DIMP, dieldrin, 1,1,2,2-tetrachloroethane, tetrachloroethylene, and trichloroethylene—are shown in Figures C-25 through C-33 (Appendix C). Concentrations of these analytes have been greater than CSRGs in upgradient wells flowing towards the extraction system (Exhibit C-24).

3.4.2 BRES Performance Evaluation

The performance criteria for the BRES are designed to evaluate the effectiveness of the extraction system in controlling downgradient contaminant migration. The system performance evaluation criteria are presented below:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.
- Demonstrate decreasing or stable concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.

The map contours illustrated in Figure C-34 in Appendix C indicate that the plume appeared to be generally captured at the western and eastern edges of the extraction system based on the potentiometric surface. There were no significant changes in the groundwater flow directions in the BRES during FY22 compared to previous years.

An overview of downgradient water quality for the BRES performance wells in FY22 is provided in Table 3.4-1. No CSRG analytes were detected at concentrations exceeding CSRGs in downgradient performance wells 36555, 36571, and 36572 in FY22. Concentrations of 1,2-dichloroethane, chloroform, DIMP, tetrachloroethylene, and trichloroethylene were above the CSRGs in well 36566. Of these contaminants, concentrations of 1,2-dichloroethane and trichloroethylene show increasing trends; while chloroform, DIMP, and tetrachloroethylene do not indicate increasing trends in downgradient water quality. Well 36566 is located downgradient of extraction well 36302, where the hydraulic gradient is much flatter than at the other downgradient performance wells. Therefore, the contamination in well 36566 would be expected to migrate much slower than in other areas of the plume.

Figures C-35 through C-39 present concentration trends in BRES performance wells where concentrations exceeded CSRGs/PQL including 1,2-dichloroethane, chloroform, DIMP, tetrachloroethylene, and trichloroethylene. These contaminants are present in groundwater at levels greater than CSRGs/PQLs in some wells, primarily upgradient of the extraction wells, but generally do not indicate increasing concentrations downgradient of the system.

Based on water quality data for well 36566, system bypass may be occurring in the vicinity of extraction wells 36302 and 36306. As a result of the supplemental monitoring program at the BRES conducted August 2019 through August 2021, elevated levels of VOCs were detected within the extraction system and in wells located downgradient of extraction wells 36302 and 36306. Increasing trends of contaminants 1,2-dichloroethane and trichloroethylene in downgradient performance wells 36566 and supplemental monitoring well 36569 indicate likely bypass between extraction wells 36302 and 36306. Lower concentrations of VOCs were detected at the far western end of the extraction system and in performance well 36571 downgradient of the eastern end of the BRES supplemental monitoring program area of interest (Navarro 2022e).

Based on the results of the BRES supplemental monitoring program, recommended actions include the following:

- Install one new extraction well between extraction wells 36302 and 36306 to improve groundwater capture.
- Enhance the BRES monitoring program by installing a downgradient monitoring well to evaluate system performance related to the enhanced extraction system.

The location of proposed wells will be determined as part of the design analysis supporting optimization of the overall system in FY24.

3.4.3 BRES Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) reviewing field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use.

Because water extracted at BRES is treated at the BANS, data review for BRES is included with the data for BANS (Section 3.3.3). Detailed information on the quality assurance evaluation for samples collected to support the BRES in FY22 is provided in Appendix I1.3.

3.4.4 BRES Conclusions and Recommendations

In FY22, the BRES did not meet the plume capture performance criteria and objectives established in the LTMP as indicated by increasing trends in one downgradient well for some contaminants. The potentiometric surface map indicates that the plume is captured at the edges of the system. In well 36566, 1,2-dichloroethane and trichloroethylene indicated increasing concentration trends through FY22. Well 36566 is located downgradient of the extraction system where the hydraulic gradient is relatively flat compared to the other downgradient performance wells. Therefore, the contamination in well 36566 is expected to decrease at a slower rate compared to other wells.

Evaluation of supplemental monitoring data collected 2019 through 2021 resulted in a recommendation to include installation of one additional extraction well and one downgradient well as part of the future optimization of the system in FY24.

This page intentionally left blank.

4.0 OTHER ON-POST SYSTEMS

4.1 COMPLEX ARMY DISPOSAL TRENCHES DEWATERING SYSTEM

The performance criteria for the CADT dewatering system are based on achieving water elevation goals (i.e., below the bottoms of the disposal trenches), rather than water quality or contaminant mass removal goals. Quarterly water level monitoring is conducted in 11 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 (see Figure D-1 for well locations). The groundwater pumped by the CADT dewatering system is treated at the BANS to meet CSRGs and reinjected in the BANS recharge trenches. Consultation trigger events for the CADT were established based on system performance criteria and non-routine operational events that might lead to performance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in the LTMP (Navarro 2021). The table also includes a list of operational trigger events that could potentially result in a performance issue.

4.1.1 CADT System Operations

Groundwater extracted from the CADT dewatering trench is piped to and treated at BANS to meet CSRGs. Extracted groundwater is also sampled and monitored to support BANS operations and treatment.

4.1.2 CADT Performance Evaluation

Evaluation of existing conditions at the CADT indicated that there is hydraulic control due to flow directed towards the extraction trench through active dewatering. Because the hydraulic gradient toward the extraction trench represents containment, the LTMP was revised in 2019 (OCN-LTMP-2019-009) to incorporate demonstration of hydraulic control as an alternate performance goal under the first performance criterion for the CADT as follows:

- Demonstrate groundwater elevations in performance monitoring wells 36216 and 36217 are below the target elevations of 5226 and 5227 feet, respectively, or demonstrate hydraulic gradient from the performance monitoring well locations is toward the extraction trench.
- Maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).

Relative to the first criterion, quarterly water levels in well 36216 were below the target elevation of 5226 feet above mean sea level (amsl) for all quarters. The water level in well 36217 remained above the target elevation for all four quarters, consistent with previous results. Water levels in wells 36216 and 36217 have been generally decreasing since October 2016, such that the water elevation in well 36217 is now only 0.03 feet above the target elevation. The hydraulic gradient from both performance monitoring wells was toward the extraction well as indicated in Figure D-1 (Appendix D), which presents the water levels from March through April 2022 and the potentiometric surface showing that hydraulic control was achieved at the CADT as groundwater flows toward the extraction trench at both wells 36216 and 36217.

Relative to the second criterion, as shown in Figure D-2, the inward gradient across the CADT slurry wall was maintained where quarterly water levels were measured in well pairs 36218/36219 and 36220/36221.

In FY22, the CADT system met the performance criteria and objectives established in the LTMP. The inward gradient was maintained across the slurry wall and, although the water levels remained above the trench-bottom elevation in well 36217, hydraulic control was maintained at both performance well locations.

4.2 SHELL DISPOSAL TRENCHES

The performance criteria for the Shell Trenches are based on achieving water elevations below the bottom of the disposal trenches (RVO 1997). In accordance with the LTMP, quarterly water level monitoring was 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 performance criteria through passive dewatering.

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 D-3 in Appendix D and Table 4.2-1. Table 4.2-1 also lists the boreholes drilled through the disposal trenches where the trench-bottom elevations were determined. The elevation of the water table at each bore location was interpolated using the quarterly groundwater elevations from monitoring wells. As shown in Table 4.2-1, the water elevations were below the bottom of the trenches at all of the borehole performance goal locations each quarter of FY22.

4.3 LIME BASINS

Baseline operational data collection and system startup of the Lime Basins Slurry Wall Dewatering System began in March 2009. Initially, groundwater was extracted and treated in a periodic "batch" mode, but it was determined that the system needed to run more continuously in order to meet dewatering goals. After notification to the regulatory agencies in September 2014, continuous operation of the system commenced.

4.3.1 Slurry Wall Dewatering System

Dewatering system performance for the Lime Basins must meet the standards established in the Amendment to the ROD (TtEC 2005) and cited in the LTMP. The performance criteria for the Lime Basins dewatering include the following:

- Maintain a positive gradient from the outside to the inside of the slurry 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 feet amsl) inside the slurry wall (for as long as the surrounding local groundwater table is in the alluvium).

Figure D-4 presents the monitoring well network for the Lime Basins.

The first performance criterion requires that positive inward hydraulic gradient be maintained across the slurry wall. Groundwater elevations inside and outside of the slurry wall have been steadily decreasing since remedy was completed, with a greater change observed in wells located within the southern slurry wall. Figure D-5 (Appendix D) shows the reverse gradient plots for the northern and southern wells measured during FY22.

During FY22, an inward gradient was present in the well pairs along the southern slurry wall segment, in contrast to an outward gradient present in the northern well pairs. Progress toward meeting the inward gradient goal is dependent on successful dewatering within the slurry wall and the groundwater trend outside the wall. Although the groundwater elevation continues to decrease inside the wall, regional drought conditions and falling water table outside the wall have resulted in slower progress toward meeting the goal and difficulty in projecting a date for achievement. In accordance with OCN-LTMP-2021-004, September 2024 is the current projected target date to re-evaluate whether the inward gradient goal has been achieved. Monitoring of the Lime Basins water levels will continue, and progress toward meeting the inward gradient goal will be reported in the ASRs.

The second performance criterion requires water levels inside the slurry wall to be below the elevation of the bottom of the waste. Figure D-5 also presents quarterly water levels for wells inside the slurry wall relative to the bottom-of-waste elevation of 5,242 feet amsl. Based on observed water levels, groundwater inside the slurry wall was below the bottom of waste during all four quarters of FY22.

4.3.2 DNAPL Remediation

In August 2009, monitoring of the Lime Basins dewatering wells indicated the potential presence of DNAPL. A Remedial Investigation/Feasibility Study (RI/FS) was conducted and three suspected DNAPL source zones were identified in the Lime Basins area as shown in Figure D-6 in Appendix D. According to the RI/FS, DNAPL at the Lime Basins primarily consists of the following five compounds: 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, chlorobenzene, and DCPD. The selected remedy consists of DNAPL source containment, removal of DNAPL to the extent practicable, and DNAPL and groundwater monitoring (TtEC and URS 2011). Extracted groundwater is treated at the BANS to meet CSRGs. In FY12, four well pairs were installed adjacent to the slurry wall, and data collection specified in the Design Analysis Report (DAR) (TtEC and URS 2012) began in FY13.

The monitoring goals for Lime Basins DNAPL Remediation include the following:

- Determine if additional DNAPL source zones exist in the Lime Basins area in addition to those previously identified.
- Determine if the extent and nature of any discovered DNAPL source zones have the potential to adversely impact the slurry wall.
- Characterize DNAPL, if present, for the purpose of correlation with groundwater characterization data as a tool in the identification of DNAPL source zones and for the purpose of waste disposal.

Lime Basins DNAPL Remediation Project monitoring consists of measuring DNAPL thickness and water levels, and sampling monitoring and dewatering wells. Figure D-4 in Appendix D presents a map of the well locations in the Lime Basins area.

Figure D-7 in Appendix D is the Lime Basins potentiometric surface map for third quarter FY22. Based on interpolated data, groundwater flows to the north-northwest inside the slurry wall area. The hydraulic gradient is relatively flat inside the slurry wall, ranging from 0.003 to 0.005 feet per foot, which is comparable to previous results. The highest water level inside the slurry wall was measured at 5239.06 feet amsl in well 36238 on the southeastern corner of the slurry wall enclosure, with the lowest water elevation, at 5237.16 feet amsl, measured in the northwest corner in well 36232. Water levels inside the slurry wall continue to decrease as dewatering continues. 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 degradation of the slurry wall.

DNAPL was measured in monitoring wells 36235 and 36248, and extraction wells 36319 and 36320, and removal is planned for FY23 where the thickness is greater than 1 foot (TtEC and URS 2012). The water level data and DNAPL measurements for FY22 indicate that the slurry wall has not been adversely impacted by DNAPL according to criteria in the DAR (TtEC and URS 2012). Consistent head differentials across the slurry wall have been maintained for all the well pairs showing that the DNAPL remediation system is functioning as intended. In addition, no DNAPL was detected outside of known source zones as presented in Appendix D, Figure D-6. The data for FY22 Lime Basins water level, DNAPL thickness, and water quality are provided in electronic files accompanying this report.

4.4 NORTH PLANTS LNAPL PILOT REMOVAL ACTION

An LNAPL pilot removal system was implemented in 2008 to evaluate and remove LNAPL due to a historical release of fuel oil in the North Plants and to gather operating data for the potential design of a full-scale LNAPL removal action. The design of the pilot removal action is presented in the North Plants LNAPL Removal System Action Plan (TtEC and URS 2009). A separate evaluation report was issued for the LNAPL Removal Action prior to FY12 (URS 2012). As discussed in the report, over two years of monitoring was conducted in the North Plants LNAPL recovery and monitoring wells without detection of sufficient quantities of LNAPL in these wells to support the removal of LNAPL. Data for the North Plants Pilot LNAPL Removal Program have been presented in ASRs and FYSRs since FY12 (URS 2012). The future of the LNAPL Removal Project was evaluated during the 2015 Five-Year Review and the monitoring frequency was reduced to an annual frequency in FY15 (Navarro 2016a).

Figure D-8 in Appendix D shows the well locations and March and April 2021 water elevations. The flow direction and hydraulic gradient in Figure D-8 are consistent with previous years. Prior to FY22, measurable LNAPL was not present in recovery wells within the North Plants area. Measurable LNAPL was detected in well 25301, and an LNAPL sheen was present in wells 25125, 25134, and 25138. It is likely that LNAPL remained within the formation due to the capillary pressure of the wells and once the water table decreased, LNAPL became mobile thus, the apparent thickness of LNAPL increased within the well. Considering 8.9 inches of LNAPL was measured in well 25301 during FY22, further evaluation will take place in FY23 to determine whether a continuing source is present within the UFS and recovery is feasible.

This page intentionally left blank.

5.0 OFF-POST EXTRACTION AND TREATMENT SYSTEMS

Off-post groundwater "pump and treat" systems consisting of extraction wells, recharge trenches, and recharge wells are in operation within both the Northern Pathway and First Creek paleochannels, and are referred to as the Northern Pathway Treatment System (NPTS) and the First Creek Treatment System (FCTS), respectively. Prior to FY22, groundwater from both the Northern Pathway and First Creek paleochannels was treated in a single plant—the Off-Post Groundwater Intercept and Treatment System (OGITS). The OGITS was shut down on May 3, 2021 in order to accommodate the construction of the FCTS and NPTS treatment plants.

The OGITS First Creek system consisted of five extraction wells and six recharge trenches. Two extraction wells—wells 37803 and 37804—were turned off in September 2003 (Navarro 2021). Recharge trenches 1 and 2 have not been in use since September 2015 and January 2009, respectively.

The OGITS Northern Pathway system originally consisted of 12 extraction wells and 24 recharge wells. Due to development in the area, three extraction wells and six recharge wells were closed, while six new extraction wells and five recharge trenches were added. Eight additional recharge wells were turned off in lieu of the operation of recharge trenches. The system operated under this configuration—15 extraction wells, 10 recharge wells and 5 recharge trenches—through May 3, 2021.

Beginning in FY21, the First Creek and Northern Pathway systems went through significant changes which resulted in the design and construction of a new treatment plant at each site.

The First Creek modifications included an upgrade of the piping and electrical systems, and removal of extraction well concrete vaults. Recharge trenches RCT-1 and RCT-2 were permanently abandoned. Extraction wells 37803 and 37804 were converted into monitoring wells. Extraction well 37800 (FE-01) was found to be severely corroded and therefore replaced by new extraction well 37830 (FE-01R) located in the same area. The FCTS began operations on October 13, 2021. Figure E-1 (Appendix E) presents the locations of the current FCTS extraction wells and recharge trenches.

The Northern Pathway modifications included the addition of seven extraction wells, three recharge trenches, one monitoring well, and nine piezometers. These additions to the Northern Pathway well field were designed and constructed to cover the "gap" area in the southern part of the system where contaminated groundwater was not being captured by the OGITS Northern Pathway system. The net result of the Northern Pathway upgrades was a more consolidated footprint of the extraction and recharge well field with no gaps in extraction. Construction of the NPTS treatment plant and additional extraction wells and recharge trenches were completed in early FY22, with system operations starting on January 31, 2022. Figure F-1 (Appendix F) presents the locations of the current NPTS extraction wells and recharge trenches.

For FY22, operations and compliance are presented separately for the FCTS and the NPTS. Operations for the FCTS covered all four quarters of FY22, while the NPTS operated January 31, 2022 through September 30, 2022.

5.1 FIRST CREEK TREATMENT SYSTEM

5.1.1 FCTS Operations and Compliance

The FCTS operated at an average flow rate of 60 gpm, pumped a total volume of 27,716,181 gallons during FY22, and removed a total of 2.8 pounds of contaminant mass. The major contaminants removed via treatment included DIMP and, to a lesser extent, DCPD, (Table 5.1-1). The total cost to operate the treatment plant in FY22 was $244,275 (Table 5.1-1). Figure E-1 in Appendix E shows the locations of FCTS monitoring wells, extraction wells and recharge trenches.

Compliance for all treatment systems at RMA is based on quarterly effluent water quality monitoring. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The current CSRG list, including any revisions since the RODs were developed, is provided in the LTMP. The system effluent for the FCTS was analyzed quarterly in FY22 using the LTMP routine CSRG analyte list for the FCTS and annually using the complete CSRG list.

As presented in Table 4 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, the FCTS individual effluent concentrations and associated four-quarter moving averages showed exceedances of chloride during the first, third and fourth quarters of FY22, with the concentration of chloride during the fourth quarter exceeding the four-quarter moving average (Navarro 2022b, 2022d, 2022f, 2022g). Chloride in groundwater is not treated at the FCTS as it will naturally attenuate as contaminant mass decreases.

The chart presented in Figure E-2 (Appendix E) shows that the four-quarter moving average for chloride in plant influent was less than the CSRG. The charts indicate that in FY22 dieldrin and DIMP exceeded their PQL and CSRG, respectively, in plant influent samples, but effluent concentrations were less than the standards (Figures E-3 and E-4). Concentrations of sulfate in plant effluent have attenuated to below the CSRG.

In FY22, the FCTS demonstrated system effectiveness for analytes addressed by treatment technologies, showing a decrease in concentrations exceeding CSRGs/PQLs in treatment plant influent compared to concentrations less than CSRGs/PQLs in the treatment plant effluent.

5.1.2 FCTS Performance Evaluation

The performance criteria for the FCTS were designed to address future monitoring needs and facilitate the system performance evaluation and are presented below:

- Demonstrate effective mass removal through comparison of total calculated mass removed by the FCTS for each of the CSRG analytes and mass flux approaching the system estimated combined well capture and transect methods.

- Demonstrate that concentrations in downgradient performance wells are stable or decreasing.

Evaluation of system effectiveness is presented in Sections 5.1.2.1 and 5.1.2.2 for each of the performance criteria.

5.1.2.1 FCTS Mass Removal

As discussed previously for the BANS, a revised approach to evaluate contaminant mass removal was proposed relative to the LTMP performance criterion by comparing the mass approaching the system to the amount of mass extracted by the system.

Consistent with the methodology incorporated into the LTMP in 2012 (OCN-LTMP-2012-002), the two methods are used in combination to estimate contaminant mass removal:

- Transect method – Used to estimate the mass flux approaching the FCTS.
- Well capture method – Used to estimate the mass removal extracted within the FCTS capture zone by extraction wells.

The mass removal performance criterion specifies removal of at least 75 percent of the contaminant plume mass migrating toward the system. Additional details on the technical approach and methodology for the evaluation of contaminant mass removal are presented in the LTMP revisions under OCN-LTMP-2023-004. The calculations for contaminant mass removal for the FCTS are provided in the Excel file accompanying this report (FY22 FCTS Mass Removal Rev0 07-19-23.xlsx).

Groundwater flows through the FCTS to the west-northwest as presented in Figure E-14. The FY22 estimated rate of contaminated groundwater flow approaching the FCTS is 63.1 gpm based on the plume transect, which is located 800–1,200 feet upgradient of the extraction system. Along this transect, the estimated flow rate of contaminated groundwater into the capture zone is 56.0 gpm, and the flow outside the capture zone is 6.1 gpm (Table 5.1-2).

In FY22, the mass flux for all CSRG analytes detected in the plume approaching the extraction system was 225,539 pounds/year, with 190,502 pounds and 35,037 pounds flowing within and outside of the capture zone, respectively (see Table 5.1-2). The majority of the plume mass flux is attributed to chloride, sulfate, and fluoride. Based on these data, 77 percent of the mass approaching the system flows into the capture zone for eventual extraction. The mass captured by the extraction system was 172,812 pounds.

The discrepancy between the plume mass flux and captured mass may be attributable to one or more of the following factors: position of plume transect located 800–1,200 feet upgradient of the extraction wells, the effect of recharged groundwater that contains a high percentage of mass attributable to anions that are not treated, the conservative assumptions made to calculate mass flux relative to the homogeneity of groundwater concentrations and flow rates, and/or attenuation processes (i.e., biodegradation, dispersion, adsorption, etc.) that may take place as contaminants migrate towards the extraction wells causing groundwater contaminant concentrations to change *in situ*.

5.1.2.2 FCTS Downgradient Performance Evaluation

The second performance criterion for FCTS is to demonstrate that concentrations of CSRG analytes are below the CSRGs/PQLs, or are stable or decreasing, in downgradient performance wells. The following sections present the results of performance water quality monitoring for the FCTS in FY22.

Table 5.1-3 presents an overview of the FY22 water quality results for the FCTS performance wells. Figures E-6 through E-13 in Appendix E show the upgradient and downgradient performance well concentrations for 1,2-dichloroethane, 1,4-dioxane, chloride, DIMP, dieldrin, fluoride, NDPA, and sulfate in FY22. Figure E-14 presents a map of the potentiometric surface in the vicinity of the FCTS, which shows that groundwater continues to flow to the west-northwest through the system area.

Time versus concentration charts depicting long-term trends presented in Figures E-15 through E-20 show the concentrations for arsenic, chloride, DIMP, dieldrin, fluoride, and sulfate. Exhibit E-5, in Appendix E, presents a summary of performance monitoring analytical results for the FCTS.

Chloride, DIMP, fluoride, and sulfate exceeded CSRGs/PQLs in both upgradient and downgradient wells in FY22. In FY22, arsenic exceeded the CSRG of 2.35 µg/L in well 37163 at a concentration of 2.45 µg/L. The concentration of arsenic in groundwater is similar to the concentration detected in nearby surface water sample SW37001 of 2.47 µg/L. Within the FCTS, First Creek overflows its banks and standing water is present across the area for much of the year, potentially impacting groundwater with respect to arsenic. Historically, the highest concentrations of arsenic in surface water, as monitored under the LTMP, occur within the First Creek location adjacent to Highway 2.

It is likely that the DIMP detected in downgradient wells 37110 and 37163 was caused by bypass of the system during the time that the system was down in FY21 during well field upgrades and plant construction. While DIMP was detected in three downgradient performance wells in FY22, dieldrin concentrations decreased to levels below the PQL in FCTS downgradient performance wells. Future monitoring of FCTS performance wells will aid in evaluating long term system effectiveness as operations continue.

Samples from the downgradient performance wells also exceeded the CSRGs for chloride, fluoride, and sulfate, but the inorganic standards for chloride and sulfate at OGITS are expected to be met by attenuation consistent with the On-Post ROD (HLA 1995).

5.1.3 FCTS Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) review of field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use.

Detailed information on the quality assurance evaluation for samples collected to support the FCTS in FY22 is provided in Appendix I1.4.

5.1.4 FCTS Conclusions and Recommendations

In FY22, the FCTS operated at an average flow rate of 60 gpm, pumped a total volume of 27,716,181 gallons, and removed a total of 2.8 pounds of contaminant mass. The major contaminants removed via treatment included DIMP and, to a lesser extent, DCPD. Only concentrations of chloride exceeded the CSRG (during the first, third and fourth quarters of FY22), and the four-quarter moving average exceeded the CSRG during the fourth quarter. Chloride is not treated at the FCTS, but is expected to attenuate to natural levels. Concentrations of sulfate in plant effluent have attenuated to below the CSRG. The FCTS system met the performance criteria and objectives established in the LTMP. Thus, the FCTS was functioning as intended.

The mass removal at the FCTS was 77 percent, meeting the performance goal of 75 percent removal in FY22. The discrepancy between the plume mass flux and captured mass at the FCTS is likely attributable to one or more of the following factors: position of plume transect located 800-1,200 feet upgradient of the extraction wells, the effect of recharged groundwater that contains a high percentage of mass attributable to anions not treated, and/or the conservative assumptions made to calculate mass removal relative to the homogeneity of groundwater concentrations and flow rates.

Detections of DIMP above the CSRG in FCTS downgradient performance wells 37110 and 37163 will continue to be monitored to determine whether continuous operation of the system results in decreases downgradient of the system. In addition, the presence of arsenic in well 37163 will continue to be monitored and evaluated with respect to the presence of arsenic in surface water adjacent to the well.

5.2 NORTHERN PATHWAY TREATMENT SYSTEM

5.2.1 NPTS Operations and Compliance

The NPTS startup began on January 31, 2022, and operated at an average flow rate of 181 gpm. The system pumped a total volume of 62,557,698 gallons during FY22, removing a total of 0.36 pounds of contaminant mass. The major contaminants removed via treatment included DIMP and, to a lesser extent, tetrachloroethylene, and chloroform (Table 5.2-1). The total cost to operate the treatment plant in FY22 was $334,127 (Table 5.2-1). Figure F-1 in Appendix F shows the locations of NPTS monitoring wells, extraction wells and recharge trenches.

Compliance for all treatment systems at RMA is based on quarterly effluent water quality monitoring. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The current CSRG list, including any revisions since the RODs were developed, is provided in the LTMP. The system effluent for the NPTS was analyzed quarterly in FY22 using the LTMP routine CSRG analyte list for the NPTS and annually using the complete CSRG list.

As presented in Table 5 in each of the quarterly *Treatment Plant Effluent Water Quality Data Reports FY22*, individual effluent concentrations and associated four-quarter moving averages did not exceed CSRGs/PQLs during FY22 (Navarro 2022b, 2022d, 2022f, 2022g). The charts presented in Figures F-2 and F-3 (Appendix F) show that the four-quarter moving average for dieldrin and NDPA, respectively, in the plant effluent was less than the CSRG. The charts indicate that in FY22 dieldrin and NDPA exceeded their PQLs in plant influent samples, but effluent concentrations were less than the standards. Concentrations of sulfate in plant effluent have attenuated to below the CSRG.

In FY22, the NPTS demonstrated system effectiveness for analytes addressed by treatment technologies, showing a decrease in concentrations exceeding CSRGs/PQLs in the treatment plant influent compared to concentrations less than CSRGs/PQLs in the treatment plant effluent.

5.2.2 NPTS Performance Evaluation

The performance criteria for the NPTS were designed to address future monitoring needs and facilitate the system performance evaluation and are presented below:

- Demonstrate effective mass removal through comparison of total calculated mass removed by the NPTS for each of the CSRG analytes and mass flux approaching the system estimated combined well capture and transect methods.
- Demonstrate that concentrations in downgradient performance wells are stable or decreasing.

Evaluation of system effectiveness is presented in Sections 5.2.2.1 and 5.2.2.2 for each of the performance criteria.

5.2.2.1 NPTS Mass Removal

As discussed previously for the BANS and FCTS, a revised approach to evaluate contaminant mass removal was proposed relative to the LTMP performance criterion by comparing the mass approaching the system to the amount of mass extracted by the system.

Consistent with the methodology incorporated into the LTMP in 2012 (OCN-LTMP-2012-002), the two methods are used in combination to estimate contaminant mass removal:

- Transect method – Used to estimate the mass flux approaching the NPTS.
- Well capture method – Used to estimate the mass removal extracted along the line of NPTS extraction wells.

The mass removal performance criterion specifies removal of at least 75 percent of the contaminant plume mass migrating toward the system. Additional details on the technical approach and methodology for the evaluation of contaminant mass removal are presented in the LTMP revisions under OCN-LTMP-2023-004. The calculations for contaminant mass removal for the NPTS are provided in the Excel file accompanying this report (FY22 NPTS Mass Removal Rev0 07-19-23.xlsx).

Groundwater flows through the NPTS to the west-northwest as presented in Figure F-11. The FY22 estimated rate of contaminated groundwater flow approaching the NPTS is 183.7 gpm based on the plume transect, which is located along the alignment of the extraction system. Along this transect, the estimated flow rate of contaminated groundwater into the capture zone is 181.3 gpm, and the flow outside the capture zone is 2.4 gpm (Table 5.2-2).

In FY22, the mass flux for all CSRG analytes detected in the plume approaching the extraction system was 346,671 pounds/year, with 342,311 pounds flowing within the capture zone, and 4,360 pounds outside of the capture zone (Table 5.2-2), with the majority of the plume mass flux is attributed to chloride, sulfate, and fluoride. Based on these data, 98.7 percent of the mass approaching the system flows into the capture zone for eventual extraction. Compared to the total mass approaching the system 345,067 pounds was extracted, equating to a mass removal of 99.5 percent (Table 5.2-2).

The discrepancy between the plume mass flux and captured mass may be attributable to one or more of the following factors: the effect of recharged groundwater that contains a high percentage of mass attributable to anions that are not treated, the conservative assumptions made to calculate mass flux relative to the homogeneity of groundwater concentrations and flow rates, and/or attenuation processes (i.e., biodegradation, dispersion, adsorption, etc.) that may take place as contaminants migrate towards the extraction wells causing groundwater contaminant concentrations to change *in situ*.

5.2.2.2 NPTS Downgradient Performance Evaluation

Table 5.2-3 presents an overview of the FY22 water quality results for the NPTS performance wells. Exhibit F-4, in Appendix F, presents a summary of performance monitoring analytical results for the NPTS. Figures F-5 through F-10 in Appendix F show the upgradient and downgradient performance well concentrations for 1,4-dioxane, carbon tetrachloride, chloride, fluoride, NDPA, and sulfate in FY22. Figure F-11 presents a map of the potentiometric surface in the vicinity of the NPTS, which shows that groundwater continues to flow to the west-northwest through the system area.

Chloride was the only contaminant detected above the CSRGs in FY22 in downgradient performance wells (well 37039). Chloride, fluoride, and sulfate were detected above CSRGs in FY22 in cross-gradient performance well 37027. Table 5.2-2 shows that concentrations of the anions do not demonstrate increasing tends, with concentrations of sulfate decreasing downgradient of the system. Long-term concentration trends for chloride, fluoride, and sulfate are presented in maps and charts for Figures F-12 through F-14.

Although elevated concentrations of chloride and sulfate are present in groundwater within the NPTS, the standards are expected to be met by attenuation consistent with the Off-Post ROD (HLA 1995). Concentrations of sulfate in plant effluent have attenuated to below the CSRG. Future evaluation will take place in order to assess chloride attenuation in groundwater towards meeting remediation goals. Anions are not treated at the NPTS, and the lack of organic contaminants detected at levels less than CSRGs/PQLs indicate the system is effective.

5.2.2.3 NPTS Well Closures

The OGITS Northern Pathway system was located on property leased by the Army (72 acres), much of which was slated for redevelopment after the Army lease expired on June 30, 2022. The new NPTS system is located within a much smaller footprint (4.5 acres) within that leased area.

As such, much of the existing well network within the previous lease area have been, or will be, removed. In September 2022, OCN-LTMP-2022-003 was signed by the regulatory agencies to approve the revised monitoring NPTS network as shown in Figure F-16. During the third quarter of FY22, OGITS Northern Pathway system wells located west of Peoria Street were formally abandoned as depicted in Figure F-15. OGITS Northern Pathway system extraneous wells located east of Peoria Street will be formally abandoned in 2023. Documentation for FY22 NPTS well closures is provided in Appendix K.

5.2.3 NPTS Quality Assurance Summary

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) review of field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the NPTS in FY22 is provided in Appendix I1.5.

5.2.4 NPTS Conclusions and Recommendations

The NPTS began operating on January 31, 2022 and met the treatment plant compliance requirements established in the LTMP. The NPTS operated at an average flow rate of 181 gpm, pumping a volume of 62,557,698 gallons, and removing 0.36 pounds of contaminant mass during FY22.

There were no CSRG-analyte exceedances of the four-quarter moving averages in the NPTS effluent in FY22. The NPTS met the compliance and performance criteria and objectives established in the LTMP. Thus, the NPTS was functioning as intended.

The mass removal at the NPTS was 99.5 percent, meeting the performance goal of 75 percent removal in FY22. The discrepancy between the plume mass flux and captured mass at the NPTS is likely attributable to one or more of the following factors: the effect of recharged groundwater that contains a high percentage of mass attributable to anions not treated, and/or the conservative assumptions made to calculate mass removal relative to the homogeneity of groundwater concentrations and flow rates.

Chloride was the only contaminant detected above the CSRGs in FY22 in downgradient performance wells (well 37039). Chloride, fluoride, and sulfate were detected above CSRGs in FY22 in cross-gradient performance well 37027. Anions are not treated by the NPTS and the lack of organic contaminants detected at levels less than CSRGs/PQLs indicate the system is effective.

6.0 SITE-WIDE ON-POST MONITORING

The site-wide on-post monitoring evaluation includes data from water level tracking, water quality tracking, and CFS monitoring. Water level monitoring for water level tracking is performed annually and a water level contour map is used to present the potentiometric surface across the on-post and off-post areas. The twice-in-five-years groundwater quality sampling of both UFS and CFS wells was conducted in FY22, along with the once-in-five-years water quality tracking. The next twice-in-five-years groundwater quality sampling will take place in FY24, with sampling of wells for both frequencies planned for FY27.

Water level and water quality monitoring are conducted in areas upgradient of 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 flow paths 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.

6.1 WATER LEVEL TRACKING

Water level tracking, which includes measuring on-post and off-post water levels and determining groundwater flow directions, is the primary means of tracking the effects of remedy activities. Water levels were measured in both on-post and off-post water-level wells in FY22. Each year, the Army collects water level data to construct a site-wide water level map of the RMA, which is used to determine groundwater flow paths and identify changes in groundwater flow directions within the UFS that could affect contaminant plume migration. The site-wide water-table contour map is provided in Figure G-1 in Appendix G.

As expected, remediation activities—such as the installation of groundwater extraction and recharge systems, engineered caps and covers, and slurry walls—have had 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. The Army collects precipitation data on-post from two locations in Section 36, one at the Shell Disposal Trenches and one at the Lime Basins.

The annual precipitation at RMA, measured at the rain gauge station at the Lime Basins, was 11.13 inches in FY22, which is 0.69 inches more than what was measured in FY21. Annual precipitation data over the past five years, FY18 through FY22, showed a variable trend ranging from a low of approximately 8.35 inches in FY18 to a high of approximately 11.13 inches in FY22.

6.2 WATER QUALITY TRACKING

The water quality tracking network was sampled in FY22 in accordance with the LTMP sampling schedule. Site-wide water quality sampling was last conducted in FY19 as part of the twice-in-five-years monitoring program. The next sampling event for water quality tracking is scheduled for FY24. Figure G-2 presents a map of the water quality tracking monitoring network.

Table 6.1-6 in the LTMP 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 LTMP (Navarro 2021). The water quality tracking network established for the LTMP, is separate from system-specific performance water quality networks, and is intended to monitor changes in water quality and assess the influence of the soil remedies on groundwater contaminant levels and plume migration.

Water quality tracking, conducted in conjunction with water level tracking, is used to evaluate water quality within the identified plumes in and downgradient of contaminant source areas and upgradient of the boundary containment systems. As presented in the LTMP, water quality tracking is divided into two subgroups: source monitoring and monitoring downgradient of sources. Source monitoring is identified as a separate component of water quality tracking because of the On-Post ROD requirement for groundwater monitoring in source areas where human health exceedance soils are left in place. Monitoring downgradient of sources areas pertains to areas where contaminated soil was left in place. Data collected under this monitoring program are 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 LTMP (Navarro 2021).

As required by the LTMP, sampling was conducted in FY22. Data collected over the past 20 years, prior to and during the remedy, were also used in statistical trend analysis presented below. Data for wells within the water quality tracking network were statistically evaluated for trends utilizing the Mann-Kendall trend analysis in ChemStat software (Starpoint Software 2023). Of the data evaluated, seven analytes detected in seven wells demonstrated increasing trends, while 15 analytes in 18 wells demonstrated decreasing trends. The results of the statistical trend analyses are provided in the electronic file accompanying this report. Table 6.2-1 provides a summary of the wells and analytes where increasing statistical trends were noted based on the evaluation. Discussions in the following sections focus on those source areas where increasing concentration trends were identified in FY22.

6.2.1 Northwest Boundary Containment System

No water quality tracking indicator analytes demonstrated increasing concentration trends in wells associated with the NWBCS during FY22.

6.2.2 North Boundary Containment System

While long-term trends visually appear to be stable or potentially decreasing for contaminants upgradient of the NBCS, eight analytes—1,4-dioxane, chloride, dieldrin, isodrin, NDMA, NDPA, sulfate, and trichloroethylene—appear to be increasing upgradient of the system (Table

3.2-2). Fluoride and 1,4-dioxane were the only analytes that demonstrated increasing trends in water quality tracking wells 23096 and 24092, further upgradient of the NBCS.

6.2.3 Railyard Containment System and Motor Pool System

No water quality tracking indicator analytes demonstrated increasing concentration trends in wells associated with the RYCS and Motor Pool Systems in FY22.

6.2.4 Basin A Neck System, Basin A, and Related Section 36 Source Areas

Performance wells upgradient of the BANS indicate that concentration trends are stable or decreasing in FY22 (Table 3.3-3). Further upgradient of the BANS and downgradient of the former Basin A, arsenic, chloride, chloroform, dithiane, and trichloroethylene show increasing long-term concentration trends in wells 35065, 36630, and 36633 (Table 6.2-1). The former Basin A is the source of this contamination, which is being intercepted by the BANS downgradient of wells 35065, 36630, and 36633.

6.2.5 South Plants Source Areas

Within the South Plants source area, chloroform and chloride demonstrated statistically increasing trends in wells 01078 and 01312, respectively (Table 6.2-1). Well 01078 is located in the central portion of the former South Plants facility and well 01312 is located south and down gradient of well 01078. Although increasing trends are noted for specific analytes in these wells, trends in water quality tracking wells further downgradient do not show similar trends in FY22.

6.2.6 Summary and Conclusions

Based on the evaluation of concentration trends in water quality tracking wells, there is no indication that remedy effectiveness has been adversely impacted. Sampling within the water quality tracking network will next take place in 2024, with further evaluation and review of long-term trends to be included in the FY24 FYSR.

6.3 CONFINED FLOW SYSTEM MONITORING

Water level and water quality monitoring of the CFS was conducted within RMA sources areas including Basin A, Basin F, and South Plants. Figure G-3 presents a map of the CFS monitoring network.

The CFS was monitored for water levels in FY22, and results will be discussed within the FY24 ASR and FYSR relative to the vertical hydraulic gradients throughout the network sampled in FY22 in accordance with the LTMP sampling schedule.

Water quality sampling was conducted in FY22 as part of the twice-in-five-years monitoring program with the next CFS sampling event scheduled for FY24. Chloride and organic indicator analytes chlorobenzene and dieldrin were detected in CFS wells within the monitoring network. A comprehensive evaluation of CFS water quality trends will be presented in the FY24 ASR and FYSR. For FY22, the results for indicator analytes detected in network wells are presented in Table 6.3-1 and are summarized below.

6.3.1 Chloride

Within CFS wells, concentrations of chloride during this reporting period increased in 10 wells across the network, while decreasing in 6 wells. The highest concentrations of chloride were generally detected in the vicinity of Basin F. Elevated chloride in the CFS appears to be localized within the Denver Formation, and downgradient migration has not impacted other CFS wells on site.

6.3.2 Chlorobenzene

Chlorobenzene has been detected in former South Plants area well 02057 since 1989. Concentrations detected in this well demonstrate a decreasing trend over the past 20 years. The integrity of the aquitard is questionable in well 02057 and well construction and screen placement likely explain the presence of contamination that likely migrated vertically into the well when a downward gradient was present between the UFS and CFS in this area.

6.3.3 Dieldrin

Dieldrin was detected for the third time in Basin F CFS well 26150, after being previously detected in 1988 and 1990. Dieldrin was also detected in Basin F wells 23187, 23193, 26147, and 26153. Downward gradients exist between these wells and paired UFS wells, which could account for vertical migration downgradient of former Basin F. Based on the presence of dieldrin in groundwater within CFS groundwater associated with Basin F, monitoring data and well integrity will be evaluated under a future program to determine the nature of CFS contamination.

7.0 SITE-WIDE OFF-POST MONITORING

7.1 OFF-POST EXCEEDANCE MONITORING

The Off-Post Exceedance Monitoring Program takes place twice every five years in accordance with Section 6.2.1 of the LTMP, and sampling was conducted in FY22. Figure G-4 in Appendix G presents a map of the Exceedance Monitoring network. In FY22, the network was expanded downgradient of the NWBCS to include 10 additional wells to monitor for dieldrin after this contaminant was detected at concentrations exceeding the PQL in the off-post area.

A summary of the results, shown as concentrations exceeding CSRGs, are provided in Table 7.1-1. The following analytes were detected in off-post groundwater at concentrations exceeding CSRGs in FY22, and represent the same analytes depicted in the FY19 ASR and FYSR (Army 2021):

- 1,2-Dichloroethane
- 1,4-Dioxane
- Arsenic
- Carbon tetrachloride
- Chloride
- DIMP
- Dieldrin
- Fluoride
- NDPA
- Sulfate

A map of the FY22 results, depicted as groundwater plumes, will be published in 2023 in the Off-Post CSRG Exceedance Map. Off-post Exceedance Monitoring will next take place in FY24.

Based on the data collected to date under this program, the well-specific analyte lists for off-post exceedance monitoring should be evaluated and updated, as needed, to support sampling in FY24. Consideration should be given to well locations where CSRG analytes have not been detected and plumes currently do not exist in the off-post area.

7.2 OFF-POST SURFACE WATER MONITORING

In order to evaluate the effect of groundwater treatment on surface water quality off-post of RMA, sampling is conducted during low-flow or base-flow conditions when groundwater is most likely to be discharging into First Creek. 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 for comparison to the two downstream sites. Figure G-5 (Appendix G) presents the locations of LTMP off-post surface water sample locations.

Annual surface water quality samples are collected at these sites when there is low flow in First Creek. Typically, this sampling occurs during the spring or summer. The target analyte list includes aldrin, arsenic, chloride, dieldrin, DIMP, NDMA, and sulfate. The requirements for sampling are provided in the LTMP, Section 6.3.

7.2.1 Results of FY22 Off-Post Surface Water Monitoring

Sites SW08003, SW24004, and SW37001 were sampled once in FY22, on June 16, 2022. Only arsenic, chloride, dieldrin, and sulfate were detected in surface water samples. Only arsenic was detected at concentrations greater than the CSRG (Table 7.2-1), but the concentration of 2.47 ug/L is less than the Basic Standards Applicable to Surface Waters of the State (Colorado WQCC 2023).

In FY22, the concentrations of arsenic, chloride, dieldrin, and sulfate were higher in First Creek downgradient of RMA at SW37001 than at SW24004. Historically, arsenic in the First Creek sample collected at Hwy. 2 (SW37001) has been detected higher concentrations compared to samples collected at the RMA boundary at 96th Avenue (SW24004), which is consistent with the historical trends in arsenic detected within First Creek. Therefore, it is likely that the presence of arsenic in surface water at SW37001 is naturally occurring and not attributable to RMA activities.

Similar to arsenic, the highest concentrations of chloride and sulfate were detected in the First Creek sample SW37001 in FY22. Based on Mann-Kendall analyses, arsenic concentrations demonstrate a stable trend since August 2013, while chloride and sulfate concentrations show decreasing trends during the same time period.

In FY22, dieldrin was detected in First Creek at locations SW37001 and SW24004 at concentrations less than the PQL. Dieldrin has previously been detected at concentrations less than the PQL at SW37001 in 2018 and 2019 and at SW24004 in 2019. Shallow groundwater is often in contact with surface water within the First Creek area, which may account for the occurrence of dieldrin in off-post surface water downgradient of RMA.

7.2.2 Quality Assurance Review for Off-Post Surface Water Monitoring

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) reviewing field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the off-post surface water sampling program in FY22 is provided in Appendix I1.6.

7.3 TRI-COUNTY HEALTH DEPARTMENT OFF-POST GROUNDWATER MONITORING

In FY22, the Private Well Monitoring Program was administered by TCHD per a 1997 Memorandum of Agreement with the Army and summarized in the 2005 Five-Year Review Report (Army 2007). Under this program, TCHD samples private wells and surface water sources in the off-post study area. The program is separate and independent from the off-post monitoring program administered and conducted by the Army. Private well monitoring provides water quality data to address community health concerns and communicate the effectiveness of the remedy to the public related to off-post groundwater contamination. Data from the TCHD private well monitoring program is used to help delineate the CSRG exceedance area. In addition, TCHD collects samples from newly installed private wells within the CSRG exceedance area and from off-post CFS wells that may function as conduits for contaminants to migrate from the shallower UFS to the CFS.

Eight off-post private wells were sampled for DIMP, dieldrin, and 1,4-dioxane by TCHD in FY22 (TCHD 2022). In FY22, well 359D had a DIMP detection of 15.3 µg/L, which exceeds the CSRG of 8 µg/L. No other analyte concentrations exceeded CSRGs/PQLs in off-post private wells in FY22.

Well 359D was installed by the Army in November of 2016 to replace well 359A. In July 2021, a field investigation took place to evaluate the integrity of the well and determine whether DIMP in groundwater could be isolated to a specific zone within the Arapahoe aquifer. The DIMP concentration within the upper and lower screened zones exceeded the CBSG for DIMP (Navarro 2022a). As a result of the field investigation, it was recommended that a small-scale "point of entry" carbon filtration system be installed at the wellhead in order to provide uncontaminated water to the residents on the property. Bottled water is currently being provided to the residents and installation of the treatment system is anticipated to take place pending homeowner approval.

Table 7.3-1 presents a summary of the analytical results for off-post private well sampling. The *Private Well Monitoring Program Annual Summary for Fiscal Year 2022* (TCHD 2022) is presented in Appendix J.

Beginning January 1, 2023, the ACHD assumed responsibility for private well sampling with the dissolution of TCHD. Future sampling of off-post private wells will be conducted by the ACHD under a Memorandum of Understanding with the Army.

This page intentionally left blank.

8.0 POST-SHUT-OFF AND SHUT-OFF MONITORING

8.1 RAILYARD CONTAINMENT SYSTEM

8.1.1 RYCS Shut-Off Monitoring

The RYCS was designed to capture the Railyard dibromochloropropane (DBCP) plume. When the MPS/ICS extraction systems were shut down, 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 RYCS. DBCP was the major contaminant removed via treatment.

The RYCS was shut down on May 25, 2016 because the system met ROD and LTMP shut-off requirements, and pre-shut-off monitoring was successfully completed. ROD- and LTMP-required shut-off monitoring commenced thereafter. Concentrations of the CSRG analytes DBCP and trichloroethylene were below the CSRGs in the shut-off wells sampled in June and August 2016.

The *Railyard Containment System Shut-Off Sampling and Analysis Plan* (RYCS Shut-off SAP), and associated Decision Document DD-34, were prepared for review and approval by the regulatory agencies in 2016 (Navarro 2016b). The shut-off water quality monitoring network consisted of eight wells, which are shown on Figure H-1 in Appendix H:

03501	03503	03529	03534
03502	03528	03530	03538

The wells are sampled for the ICS CSRG analytes DBCP and trichloroethylene. The RYCS met shut-off criteria and was shut down in the third quarter of FY16, at which time quarterly shut-off monitoring was required for one year. During the first quarter of FY17, the DBCP concentration in one well exceeded the CSRG, and quarterly sampling took place beginning in the second quarter of FY17 through the first quarter of FY18, with detections at or below the CSRGs for DBCP (0.2 µg/L) and trichloroethylene (5 µg/L) (Navarro 2020b). Because the results for quarterly monitoring indicated that there were no CSRG exceedances, annual shut-off monitoring began in FY18 and continued through FY20. There were no DBCP or trichloroethylene detections above the CSRG.

During FY22, quarterly monitoring took place during the first quarter in accordance with the RYCS Shut-off SAP (Navarro 2016b) with results indicating that DBCP and trichloroethylene were not detected in any wells (Table 8.1-1). Based on the results of monitoring, the first quarter of FY22 represented the last sampling event under the RYCS Shut-off SAP, and the *Railyard Containment System Post-Shut-Off Monitoring Sampling and Analysis Plan* was issued in March 2022 (Navarro 2022c). RYCS post-shut-off monitoring will take place twice every five years and will be included as part of the water quality tracking network with sampling to begin in 2024. Upgradient wells 03523 and 03534 and downgradient well 03509 will be sampled under this program (Figure F-2). The RYCS was decommissioned and demolished during the fourth quarter of FY22, where the treatment plant was removed from the site and wells were abandoned—including extraction, recharge, and monitoring wells.

8.1.2 RYCS Quality Assurance Review

The purpose of the data review is to evaluate data quality with respect to the established DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) review of field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the RYCS shut-off monitoring program in FY22 is provided in Appendix I1.7.

8.2 MOTOR POOL SYSTEM/IRONDALE CONTAINMENT SYSTEM

8.2.1 MPS/ICS Post-Shut-Off Monitoring

The goal of the MPS/ICS post shut-off monitoring is to monitor groundwater levels, flow directions, and contaminant trends relative to CSRGs to evaluate potential changes after successful shutdown of the system (URS 2011).

In FY22, wells 04021, 04535, and 33081 were sampled under *Motor Pool System/Irondale Containment System Post-Shut-Off Monitoring Sampling and Analysis Plan* (URS 2011). Figure H-2 in Appendix H shows the well locations within the MPS/ICS area. Wells 04021 and 04535 are downgradient of the MPS and were sampled for trichloroethylene. Well 33081 is located between the RYCS and former ICS and was sampled for DBCP. DBCP was not detected in well 33081. While trichloroethylene was detected in well 04535 at a concentration of 0.622 µg/L, below the CSRG of 5 µg/L, it was not detected further downgradient in well 04021 (Table 8.2-1).

Review of water level data presented in the FY22 regional water level map (Figure G-1) and similar maps over the previous five years indicates that the groundwater flow direction in the area appears unchanged.

The water level and water quality data for the MPS/ICS are included in electronic files accompanying this report. Since the SAP criteria were met in FY22, post-shut-off monitoring will continue in accordance with the MPS/ICS SAP (URS 2011) (Figure G-2).

8.2.2 MPS/ICS Quality Assurance Review

The purpose of the data review is to evaluate data quality with respect to the DQOs. Components of the data review process include: 1) evaluating the data against the data quality indicators precision, bias, representativeness, completeness, sensitivity, and comparability; 2) reviewing field and laboratory QC results; and 3) evaluating the data for suitability based on the intended use. The data review has determined that the data quality meets or exceeds the established DQOs and is of the correct type, quality, and quantity to support the intended use. Detailed information on the quality assurance evaluation for samples collected to support the MPS/ICS shut-off monitoring program in FY22 is provided in Appendix I1.7.

9.0 PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that include many compounds. The following PFAS are monitored at RMA:

- Perfluorobutanesulfonic acid (PFBS)
- Perfluorohexane sulfonic acid (PFHxS)
- Perfluorononanoic acid (PFNA)
- Perfluorooctanoic acid (PFOA)
- Perfluorooctanesulfonic acid (PFOS)
- Hexafluoropropylene oxide dimer acid (HFPODA), commonly referred to as GenX chemicals

PFAS have been classified as emerging contaminants by the EPA and the DoD. Although there are no current federal regulatory standards, the EPA updated interim health advisory levels for PFOA and PFOS in drinking water in 2022. The EPA also issued new final drinking water health advisories for PFBS and GenX chemicals (e.g., HFPODA) (EPA 2022a).

The Army issued guidance for evaluating restoration sites for potential PFAS contamination in 2016. The Army conducted an investigation from July 2017 to August 2018 to assess the potential for PFAS groundwater contamination at the RMA (Navarro 2017b). The results of the investigation indicated detectable levels of PFOA and PFAS in RMA groundwater, although only one location near the South Plants spill area was above the 2016 EPA health advisory level (0.07 µg/L). The initial investigation concluded that further characterization of PFAS contamination was necessary (Navarro 2019b).

In FY19, PFOA and PFOS were analyzed in samples from a select group of wells and the treatment plant influents/effluents to verify the results from 2017 and 2018 and determine the extent of potential releases at RMA. PFOA and/or PFOS were detected above the 2016 health advisory level (0.07 µg/L) in one South Plants well, which is located in the area of the single documented use on site, and in four wells located immediately downgradient of the use area. PFOA and PFOS were not present at concentrations above the 2016 health advisory level in the remaining wells sampled or in the treatment plants influent/effluent (Navarro 2020a).

Subsequently, the LTMP was revised to include PFAS for select water quality tracking wells, which are sampled once every five years, within and downgradient of the South Plants source area. PFAS were also added to annual treatment plant influent and effluent sampling to provide continued monitoring of these emerging contaminants (OCN-LTMP-2020-004). Treatment plant monitoring frequency was subsequently revised to quarterly, beginning in the first quarter of FY23.

In 2018, EPA began including regional screening levels (RSL) for PFAS on their default screening level tables for ingestion of drinking water. Subsequently, in June of 2022, EPA published revised lifetime drinking water health advisories for four perfluoroalkyl substances, including updated health advisories for PFOA and PFOS and new final health advisories for PFBS and HFPODA (EPA 2022a). Consistent with the latest DoD guidance, issued in July

2022, RMA expanded its PFAS analytical list to also include PFBS, PFHxS, PFNA, and HFPODA (DoD 2022). In FY22, PFAS were analyzed under EPA Drinking Water Method 537. However, beginning in FY23, groundwater samples will be analyzed using EPA Method 1633 for non-drinking water samples.

9.1 TREATMENT PLANT SAMPLING

Influent and effluent samples were collected in July 2022 and analyzed for the expanded list of PFAS. PFAS were detected in the influent samples collected at all five treatment plants. Influent at NWBCS, BANS and NPTS exceeded the respective health advisory levels for PFOA and PFOS. Analytical results for PFAS treatment plant monitoring in FY22 are provided in Table 9.0-1.

Only PFBS was detected in NPTS plant effluent during FY22. The PFBS effluent concentration of 0.0046 µg/L was less than the health advisory level (2 µg/L).

9.2 GROUNDWATER MONITORING

Water Quality Tracking wells 01525, 36181, 36210, 36627, and 36631 were sampled in FY22 in accordance with the LTMP. The results of PFAS monitoring are summarized below:

- Concentrations of PFOA and PFAS exceeded their respective EPA health advisory levels in source area well 01525, located within the former South Plants area, and the four downgradient wells. Concentrations of PFHxS and PFNA exceed the current RSL for drinking water ingestion.
- PFBS was detected in each of the five wells at concentrations less than the health advisory level. PFBS concentrations are also below the RSL.
- PFHxS was detected in each of the five wells at concentrations above the RSL. PFNA was detected at concentrations below the RSL in source area well 01525 and downgradient wells 36181 and 36210, but not detected in the other two downgradient wells. There are no health advisory levels for PFHxS and PFNA.
- HFPODA was not detected in any of the five wells.

Analytical results for PFAS groundwater monitoring in FY22 are provided in Table 9.0-2.

Considering the existing data, conceptual site model, and relevant guidance it is recommended that the Army consult the regulatory agencies to determine whether additional PFAS investigation is warranted for RMA.

10.0 SUMMARY AND CONCLUSIONS

The ASR includes an evaluation of the data collected to evaluate the compliance and performance criteria related to the operating systems, groundwater and surface water quality and hydrology, as well as other supplemental monitoring in FY22. In addition, the ASR includes data reporting for the FY22 site-wide monitoring programs, project-specific monitoring, and Consultative Process notifications.

Sections 10.1 through 10.5 summarize the results supporting the FY22 ASR reporting period as presented in greater detail within Sections 3 through 9 of this report.

10.1 ON-POST AND OFF-POST TREATMENT SYSTEMS

In general, the groundwater containment and mass removal systems met the treatment plant compliance monitoring criteria, and the performance criteria presented in the LTMP (Navarro 2021), as well as the objectives identified in the On-Post ROD (Foster Wheeler 1996) and Off-Post ROD (HLA 1995).

Performance criteria were not met in some portions of the NWBCS, BRES, and Lime Basins systems. Table 10.0-1 presents a summary of the compliance criteria and the system- and project-specific performance criteria and whether these criteria were met in FY22. In instances where compliance or performance criteria were not met, or data suggest that performance criteria are at risk of not being met, proposed or current actions are indicated and will be followed up in the FY23 ASR. Recommendations presented in previous sections of the report are also presented below, which will result in OCNs to the LTMP.

Summarized below are the results and conclusions for system-specific operational compliance monitoring and performance monitoring relative to the performance criteria and goals as stated in the LTMP.

10.1.1 On-Post Extraction and Treatment Systems

Northwest Boundary Containment System

- In FY22, the NWBCS operated at an average flow rate of 830 gpm, pumping a total volume of 436,012,080 gallons and removing a total of 2.9 pounds of contaminant mass.
- The NWBCS met the compliance and the primary performance criteria for the Original System and objectives established in the LTMP. The NWBCS had no CSRG/PQL analyte exceedances for quarterly samples or the four-quarter moving averages in the treatment system effluent in FY22. A reverse hydraulic gradient was maintained within the system and plume capture was evident based on visual observation of the potentiometric surface within the original system as well as within the NEE and SWE. Thus, the NWBCS was functioning as intended.
- Dieldrin and NDPA were detected above the PQL in Original System and NEE downgradient performance wells during the reporting period:

  - Original System downgradient well 37333 contained dieldrin above the PQL in FY22. However, the secondary performance criterion was met during the reporting period because the long-term trend was not increasing in downgradient performance wells.
  - NEE downgradient well 22512 and 22015 contained dieldrin and NDPA above the PQLs in FY22. Isodrin was also detected above the CSRG in well 22015. However, the secondary performance criterion was met for dieldrin because the long-term trend was not increasing in downgradient performance wells. NDPA exceeded the PQL in downgradient NEE well 22512, and concentrations indicate an increasing trend in FY22.

- Dieldrin and NDPA above their respective PQLs in downgradient performance wells may be attributed to a variety of factors including contamination due to mobilization of residual contamination or possible system bypass around the north end of the NEE slurry wall. An investigation of potential bypass of the NEE slurry wall was conducted in FY21. While monitoring is ongoing within the NEE, preliminary data demonstrate that the water table is very low in the area north of the slurry wall, indicating limited groundwater flow in this area.

<u>Recommended Additional Action</u>: Complete the evaluation of NWBCS NEE system bypass based on the results of 2021 investigation and monitoring conducted through FY22.

North Boundary Containment System

- In FY22, the NBCS operated at an average flow rate of 232 gpm and pumped a total volume of 121,766,632 gallons and removed a total of 9.2 pounds of contaminant mass.
- NDMA exceeded CSRG/PQL in the plant effluent—during the third quarter of FY22—although the moving average did not exceed the standard. 1,4-Dioxane also exceeded CSRGs in the plant effluent during the first, third, and fourth quarters, while the PQL was exceeded during the fourth quarter. As an emerging contaminant, 1,4-dioxane treatment was not part of the design for the NBCS and therefore is not treated by the system.
- Dieldrin, NDMA, and 1,4-dioxane concentrations are above their respective CSRGs/PQLs in downgradient performance wells but show non-discernible, stable, or decreasing trends in wells. Concentrations of anions chloride, fluoride, and sulfate exceeded CSRGs. Chloride and sulfate are expected to naturally attenuate to background levels. Based on the FY22 information, the contaminant plumes continue to be captured by the NBCS system.
- A reverse hydraulic gradient was maintained within the system during the first, second, and third quarters of FY22, with one well pair demonstrating a slight forward gradient during the fourth quarter. Although the reverse gradient was not maintained across the system during the fourth quarter of FY22, plume capture is evident as indicated the potentiometric surface map and the evaluation of downgradient water quality data. Thus, the NBCS functioned as intended in FY22.

Basin A Neck System

- In FY22, the BANS operated at an average flow rate of 17 gpm and pumped a total volume of 9,132,842 gallons during FY22, removing a total of 59.4 pounds of contaminant mass. The BANS had no CSRG/PQL analyte exceedances for quarterly samples or the four-quarter moving averages in the treatment system effluent in FY22.
- The BANS met both performance criteria and objectives established in the LTMP. The 75 percent mass removal criterion was met in FY22, with mass removal estimated at 98.7 percent. Concentrations of analytes that remain above CSRGs/PQLs indicate stable or decreasing trends. Thus, the BANS was functioning as intended.

Recommended Additional Action: Maintain the current performance goal of 75 percent for the BANS until mass removal can be evaluated aligning with system-specific goals to be recommended in the FY23 ASR.

Bedrock Ridge Extraction System

- In FY22, the BRES did not meet the plume capture performance criteria and objectives established in the LTMP. Analytes 1,2-dichloroethane and trichloroethylene in well 36566 show increasing concentration trends. Although the plume appears captured at both edges of the system, bypass may be occurring within the west-central portion of the extraction system.
- Evaluation of supplemental monitoring data collected from 2019 through 2021 resulted in a recommendation to include installation of one additional extraction well and one downgradient well as part of the future optimization of the system.

10.1.2 Other On-Post Systems

Complex Army Disposal Trenches

- In FY22, the CADT system met the performance criteria and objectives established in the LTMP. The inward gradient was maintained across the slurry wall and hydraulic control was maintained in the vicinity of performance wells 36216 and 36217.

Shell Disposal Trenches

- In FY22, the Shell Disposal Trenches met the performance criteria and objectives established in the LTMP. All groundwater elevations were below the bottom of the trenches at all of the borehole performance goal locations.

Lime Basins Slurry Wall Dewatering System

- The first performance criterion requires that a positive inward hydraulic gradient be maintained across the slurry wall. In FY22, an inward gradient was present in all well pairs on the southern side while an outward gradient was still present for all the well pairs on the northern side, consistent with results obtained since FY14. Groundwater elevations inside of the slurry wall have been steadily decreasing; however, progress toward meeting the goal is dependent on water level fluctuations outside the slurry wall.
- The second performance criterion requires that water levels inside the slurry wall are below the elevation of the bottom of the waste (5,242 feet amsl). During all four quarters

of FY22, the water elevation in each well inside the slurry wall was below the bottom of waste elevation. Therefore, this dewatering performance criterion was met during FY22.

Lime Basins DNAPL Remediation Monitoring

- The water level data and DNAPL measurements for FY22 indicated that DNAPL was detected in well 36235 outside and/or adjacent to the slurry wall. DNAPL was detected within the slurry wall in extraction wells 36319 and 36320 and monitoring well 36248. The data indicate that the slurry wall has not been adversely impacted by historical DNAPL contamination. Consistent head differentials across the slurry wall have been maintained for all the well pairs showing that the DNAPL remediation system is functioning as intended.
- The observed presence of DNAPL has been consistent since FY13. No additional areas of DNAPL were identified in the vicinity of the Lime Basins slurry wall in FY22. Current data indicate that no additional DNAPL sources zones appear to exist within the Lime Basins slurry wall and that the extent of DNAPL is decreasing. Removal of recoverable DNAPL will take place in FY23.

North Plants LNAPL Pilot Removal Action

- Measurable LNAPL was detected in well 25301, and an LNAPL sheen was present in wells 25125, 25134, and 25138. Prior to FY22, measurable LNAPL was not present in wells within the North Plants area. It is likely that LNAPL remained within the formation due to the capillary pressure of the wells and once the water table decreased, LNAPL became mobile thus, the apparent thickness of LNAPL increased within the well.
- Considering 8.9 inches of LNAPL was measured in well 25301 during FY22, further evaluation will take place in FY23 to determine whether a continuing source is present within the UFS and recovery is feasible.

Recommended Additional Action: Determine whether a continuing source of LNAPL is present within the UFS and whether recovery is feasible. The evaluation should consider the use of bail-down and/or pumping tests to determine the mobility and recoverability of LNAPL within the UFS.

10.1.3 Off-Post Extraction and Treatment Systems

First Creek Treatment System

- The FCTS operated at an average flow rate of 60 gpm, pumping a volume of 27,716,181 gallons, and removing a total of 2.8 pounds of contaminant mass.
- Concentrations of chloride exceeded the CSRG during the third and fourth quarters of FY22, and the four-quarter moving average exceeded the CSRG during the fourth quarter. Chloride is not treated at the FCTS.
- Mass removal at the FCTS was 77 percent, meeting the performance goal of 75 percent removal in FY22.
- Detections DIMP above the CSRG in FCTS downgradient performance wells 37110 and 37163 will continue to be monitored to determine whether continuous operations of the system results in decreasing concentrations downgradient of the system. In addition, the

presence of arsenic in well 37163 will continue to be monitored and evaluated with respect to the presence of arsenic in surface water adjacent to the well.

- The FCTS met the performance criteria and objectives established in the LTMP. Thus, the FCTS was functioning as intended.

Recommended Additional Action: Maintain the current performance goal of 75 percent for the until the future optimization of the FCTS is completed. Mass removal can then be evaluated aligning with recommended system-specific goals based on an optimized monitoring network.

Northern Pathway Treatment System

- The NPTS began operating on January 31, 2022 and met the treatment plant compliance requirements established in the LTMP. The NPTS operated at an average flow rate of 181 gpm, pumping a volume of 62,557,698 gallons, and removing 0.36 pounds of contaminant mass during FY22.
- There were no CSRG-analyte exceedances of the four-quarter moving averages in the NPTS effluent in FY22.
- The mass removal at the NPTS was 99.5 percent, meeting the performance goal of 75 percent removal in FY22.
- Chloride was the only contaminant detected above the CSRGs in FY22 in downgradient performance wells (well 37039). Chloride, fluoride, and sulfate were detected above CSRGs in FY22 in cross-gradient performance well 37027. Anions are not treated at NPTS, and the lack of organic contaminants detected at levels less than CSRGs/PQLs indicate the system is effective.
- The NPTS met the performance criteria and objectives established in the LTMP. Thus, the NPTS was functioning as intended.

Recommended Additional Action: Maintain the current performance goal of 75 percent for the NPTS until mass removal can be evaluated aligning with system-specific goals to be recommended in the FY23 ASR.

10.2 SITE-WIDE MONITORING

A summary of the results of site-wide monitoring for the on-post and off-post programs is presented below for the reporting period. Based on the evaluation of data collected during the reporting period, additional actions have been recommended for some monitoring programs as indicated.

10.2.1 Site-Wide On-Post Monitoring

Water Level Tracking

- Overall, groundwater flow directions and associated migration of contaminant plumes have not changed significantly during the FY22 reporting period. In some areas of the RMA, water levels continue to decrease due to lack of regional precipitation.

Water Quality Tracking

- Based on the evaluation of concentration trends in water quality tracking wells, there is no indication that remedy effectiveness has been adversely impacted. Sampling within the water quality tracking network will next take place in 2024, with further evaluation and review of long-term trends included in the FY24 FYSR.

Confined Flow System Monitoring

- CFS water quality sampling took place in FY22 as part of the twice-in-five-years monitoring program. The next CFS sampling event is scheduled for FY24.
- Based on the FY22 data, and noting the first-time presence of dieldrin in groundwater in CFS well 26150 associated with Basin F, monitoring data and well integrity will be evaluated under a future program to investigate the CFS contamination.
- Considering the known presence of elevated levels of chloride in well 35083, a future evaluation is planned to evaluate whether the chloride is the result of anthropogenic sources or can be attributed to natural background.

10.2.2 Site-Wide Off-Post Monitoring

Off-Post Exceedance Monitoring

- In FY22, ten analytes were detected in off-post groundwater at concentrations exceeding CSRGs in FY22, and represent the same analytes depicted in the FY19 ASR and FYSR. Six organic analytes were detected at concentrations exceeding CSRGs/PQLs including: 1,2-dichloroethane, 1,4-dioxane, carbon tetrachloride, DIMP, dieldrin, and NDPA. Arsenic and three anions—chloride, fluoride, and sulfate—were also detected at concentrations exceeding CSRGs.

<u>Recommended Additional Action</u>: Evaluate and update, as needed, the well-specific analyte lists for off-post exceedance monitoring to support sampling in FY24. Consideration should be given to well locations where CSRG analytes have not been detected and plumes currently do not exist in the off-post area.

Off-Post Surface Water

- In FY22, only arsenic was detected in off-post surface water samples at concentrations greater than the off-post CSRG. The concentration of arsenic has been generally higher in First Creek at SW37001, furthest downstream of RMA and is consistent with the historical trends detected within First Creek. Based on statistical trend analyses, arsenic concentrations demonstrate a stable trend since August 2013, Therefore, it is likely that the presence of this constituent in surface water at SW37001 is naturally occurring and not attributable to RMA activities.
- Dieldrin was detected in First Creek at locations SW37001 and SW24004 at concentrations less than the off-post CSRGs. Dieldrin has previously been detected at concentrations less than the off-post CSRGs at SW37001 in 2018 and 2019 and at SW24004 in 2019. Shallow groundwater is often in contact with surface water within the First Creek area, which may account for the occurrence of dieldrin in off-post surface water downgradient of RMA.

- Chloride and sulfate were detected at levels less than CSRGs, and concentrations continue to show stable and decreasing trends, respectively, since 2004.

Tri-County Health Department Off-Post Groundwater Monitoring

- Eight off-post private wells were sampled for DIMP, dieldrin, and 1,4-dioxane by TCHD in FY22. In FY22, well 359D had a DIMP detection of 15.3 µg/L, which exceeding the CSRG of 8 µg/L. No other analyte concentrations exceeded CSRGs/PQLs in off-post private wells in FY22.
- Well 359D was installed in November 2016, and is screened in two separate zones in the Lower Arapahoe aquifer, similar to the well it replaced, 359A. In July 2021, a field investigation took place to evaluate the integrity of the well and whether DIMP in groundwater could be isolated to a specific zone within the Arapahoe aquifer. The result of the field investigation was a recommendation that a small-scale “point of entry” carbon filtration system be installed at the wellhead in order to provide uncontaminated water to the residents on the property. Bottled water is currently being provided to the residents and installation of the treatment system is anticipated to take place pending homeowner approval.

10.3 POST-SHUT-OFF AND SHUT-OFF MONITORING

Railyard Containment System Shut-Off Monitoring

- During FY22, quarterly monitoring took place in accordance with the RYCS Shut-Off SAP, and the results indicate that there were no contaminants that exceeded CSRGs. The two primary contaminants of concern, DBCP and trichloroethylene, were not detected in any wells. Based on the monitoring to date, the first quarter of FY22 served as the last sampling event under the RYCS Shut-Off SAP.
- The RYCS was demolished during the fourth quarter of FY22, where the treatment plant was removed from the site and wells were abandoned—including extraction, recharge, and monitoring wells. Decommissioning and demolition of the RYCS was completed in FY22. Post-shut-off monitoring will be conducted twice every five years as part of the water quality tracking network beginning in 2024.

Motor Pool/Irondale Containment Post-Shut-Off Monitoring

- Review of water level data presented in the FY22 regional water level map and similar maps over the previous five years indicates that the groundwater flow direction in the area appears unchanged. Since the SAP criteria were met in FY22, post-shut-off monitoring will continue in accordance with the MPS/ICS SAP.

10.4 PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES

- PFAS have been detected above health advisory levels or regional screening levels in groundwater at RMA. PFAS sample analysis in annual treatment plant influent and effluent samples and for select wells in the LTMP once-in-five-years sitewide water quality tracking network has been implemented to continue to evaluate site conditions.
- Influent and effluent samples were collected in July 2022 and analyzed for the expanded list of PFAS. PFAS were detected in the influent samples collected at all five treatment

plants. Influent at NWBCS, BANS and NPTS exceeded the respective health advisory levels for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) published in June 2022. No effluent samples exceeded the respective health advisory levels or RSL. Perfluorobutanesulfonic acid (PFBS) was the only PFAS-related contaminant detected in effluent samples, which were collected at the NPTS plant, and the levels were below the health advisory level.

- Groundwater was sampled in Water Quality Tracking wells 01525, 36181, 36210, 36627, and 36631 in accordance with the LTMP. Concentrations of PFOA and PFAS exceeded their respective EPA health advisory levels in source area well 01525, located within the former South Plants area, and the four wells that are located downgradient of the source area. PFHxS was detected in each of the five wells; however, there is no published health advisory. Concentrations of PFOA, PFAS, and PFHxS exceed their respective RSL for drinking water exposure. PFBS was also detected in each of the five wells at concentrations below the health advisory and RSL. PFNA was detected at concentrations below the RSL in source area well 01525 and downgradient in wells 36181 and 36210. HFPODA was not detected in any of the five wells.

Recommended Additional Action: Consult the regulatory agencies to determine whether additional PFAS investigation is warranted for RMA considering the existing data, conceptual site model, and relevant guidance.

11.0 REFERENCES

U.S. Department of the Army (Army)

2021 Estimated Areas Exceeding Containment System Remediation Goals for Fiscal Year 2019 Map, Revision 0, March 1, 2021.

2007 Final 2005 Five-Year Review Report for Rocky Mountain Arsenal Commerce City Adams County, Colorado, November 2007.

Colorado Water Quality Control Commission (Colorado WQCC)

2023 Rule 5 Colorado Code of Regulations 1002-31, Regulation No. 31 – The Basic Standards and Methodologies for Surface Water. June 14, 2023.

U.S. Department of Defense (DoD)

2022 Investigating Per- and Polyfluoroalkyl Substances within the Department of Defense Cleanup Program, July 6, 2022.

U.S. Environmental protection Agency (EPA)

2022a EPA Drinking Water Health Advisories for PFOA and PFOS 2022, Interim Updated PFOA and PFOS Health Advisories. https://www.epa.gov/sdwa/drinking-water-health-advisories-pfoa-and-pfos, June 15, 2022.

2022b ProUCL: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. Version 5.2. https://www.epa.gov/land-research/proucl-software, June 14, 2022.

Foster Wheeler Environmental Corporation (Foster Wheeler)

1996 Record of Decision for the On-Post Operable Unit, Final, June 1996.

Harding Lawson Associates (HLA)

1996 Remediation Scope and Schedule for the Offpost Operable Unit, Rocky Mountain Arsenal, Commerce City, Colorado, September 25, 1996.

1995 Rocky Mountain Arsenal Offpost Operable Unit Final Record of Decision Rocky Mountain Arsenal Commerce City, Colorado, December 19, 1995.

Navarro Research and Engineering, Inc. (Navarro)

2022a Field Investigation Report for Off-Post Private Well 359D, Revision 0, January 25, 2022.

2022b Treatment Plant Effluent Water Quality Data Report, First Quarter, Fiscal Year 2022, Revision 0, April 26, 2022.

2022c Railyard Containment System Demolition Project Work Plan, Revision 0, July 27, 2022.

2022d Treatment Plant Effluent Water Quality Data Report, Second Quarter, Fiscal Year 2022, Revision 0, August 5, 2022.

2022e Bedrock Ridge Extraction System Data Summary and system Evaluation Report, Revision 0, August 31, 2022.

2022f Treatment Plant Effluent Water Quality Data Report, Third Quarter, Fiscal Year 2022, Revision 0, October 11, 2022.

2022g Treatment Plant Effluent Water Quality Data Report, Fourth Quarter, Fiscal Year 2022, Revision 0, December 21, 2022.

2021 Rocky Mountain Arsenal Long-Term Monitoring Plan for Groundwater and Surface Water, Revision 1, May 27, 2021.

2020a Fiscal Year 2019 Perfluorinated Compounds Data Summary Report, Revision 0, March 25, 2020.

2020b Rocky Mountain Arsenal Fiscal Year 2019 Annual Summary and Five-Year Summary Report for Groundwater and Surface Water, Review Period: April 1, 2015 – March 31, 2020, Revision 0, November 6, 2020.

2019a Rocky Mountain Arsenal Sampling Quality Assurance Project Plan, Revision 2, January 30, 2019.

2019b Rocky Mountain Arsenal Emerging Contaminants Data Summary Report, January 8, 2019.

2017a Rocky Mountain Arsenal Annual Summary Report for Groundwater and Surface Water, FY16, Revision 0, September 27, 2017.

2017b Emerging Contaminants Sampling and Analysis Plan, FY16, Revision 0, April 2017.

2016a Final 2015 Five-Year Review Report for Rocky Mountain Arsenal Commerce City Adams County, Colorado, Volumes I and II, September 2016.

2016b Railyard Containment System Shut-Off Sampling and Analysis Plan, Revision 0, May 2016.

Program Manager Rocky Mountain Arsenal (PMRMA)

1997 Memorandum of Agreement between Tri-County Health Department and Program Manager for Rocky Mountain Arsenal.

Remediation Venture Office (RVO)

2013 Rocky Mountain Arsenal Annual Summary Report for Groundwater and Surface Water, FY11, Revised, March 2013.

1997 Complex Trenches and Shell Trenches Groundwater Barrier Project, 100 Percent Design Package, Revision 1, November 1997.

Starpoint Software, Inc. (Starpoint Software)

2023 ChemStat Statistical Analysis Software for Environmental Data, Version 6.5, January 2023.

Tetra Tech EC, Inc. (TtEC)

2012 Rocky Mountain Arsenal Practical Quantitation Limit Study Report for Aldrin, Dieldrin, and n-Nitrosodimethylamine, Final, February 2012.

2005 Amendment to the Record of Decision for the On-Post Operable Unit, Rocky Mountain Arsenal Federal Facility Site, Section 36 Lime Basins Remediation, Basin F Principal Threat Soil Remediation, Revision 0, October 2005.

Tetra Tech EC, Inc. and URS Corporation (TtEC and URS)

2012 Rocky Mountain Arsenal Lime Basins Dense Non-Aqueous Phase Liquid Remediation Project, Design Analysis Report, Final, April 9, 2012.

2011 Lime Basins Dense Non-Aqueous Phase Liquid Feasibility Study Report, Final, June 2011.

2009 North Plants Light Non-Aqueous Phase Liquid Removal System Action Plan, Revision 1, February 2009.

Tri-County Health Department

2022 Private Well Monitoring Program Annual Summary for Fiscal Year 2022. November 28, 2022.

URS Corporation (URS)

2012 Rocky Mountain Arsenal North Plants Pilot Non-Aqueous Phase Liquid Removal Action 2010- 2011 Evaluation Report, Final, March 30, 2012.

2011 Motor Pool System/Irondale Containment System Post-Shut-Off Monitoring Sampling and Analysis Plan, Revision 0, September 28, 2011.

This page intentionally left blank.

TABLES

This page intentionally left blank.

LIST OF TABLES

LIST OF TABLES

Table 1.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
FY22 Trigger Events and Agency Notifications			
12/15/2021	Failure to collect water quality tracking data in well 01044	Well 01044 was not sampled because it was dry. Several attempts were made to collect a sample; however, the well remained dry.	No corrective action is necessary. Nearby wells 01101, 01047, 01582, 01669 and 01670 were sampled in FY22. Future sampling will be conducted in FY27 in accordance with the LTMP schedule.
5/12/2022	NBCS—Individual effluent sample above the CSRG	Quarter three sampling was performed at the NBCS on April 11, 2022. The NDMA concentration in the plant effluent sample was 0.00972 ug/L, which exceeded the current PQL of 0.009 ug/L. The four-quarter moving average remained below the PQL at 0.0049 ug/L.	No operational changes are proposed at this time. Based on operational plant data, it appears that the UV treatment unit is functioning properly, and review of the operational data suggests analytical variability in data across the plant since the plant effluent was reported higher than the UV unit effluent. NDMA was not detected in the NBCS effluent during the subsequent quarter.
6/30/2022	Failure to collect CSRG exceedance monitoring data in well 37108	Off-post well 37108 was buried when Havana Street north of 104th Avenue was widened. No sample was able to be collected.	Well 37108 was identified as an unsafe well for continued monitoring due to proximity to the road and likelihood of road widening. The most recent off-post monitoring network evaluation provided to Water Team on 23 September 2021 recommended abandoning well 37108 and instead using well 37097 for future monitoring since it is located nearby in the same flow path. Refer to approved OCN-LTMP-2022-004 below.
7/20/2022	FCTS—Failure to collect performance monitoring data in well 37084 Failure to collect CSRG exceedance monitoring data in well 37084	Off-post well 37084 was damaged during Commerce City mowing operations along Highway 2. The well is no longer viable and could not be sampled during scheduled FY22 field sampling activities.	Well 37084 was identified as an unsafe well for continued monitoring due to proximity to the road and construction related to road widening. The most recent off-post monitoring network evaluation provided to Water Team on 23 September 2021 recommended abandoning well 37084 and instead using well 37116 for future performance monitoring. Well 37116 is located on the east side of Highway 2 and is similarly screened. With the destruction of well 37084, well 37116 will be sampled as an alternate performance well for FY22. Well 37084 was also part of the CSRG exceedance monitoring network. New well 37162 is nearby and has already been incorporated into the CSRG exceedance network providing adequate coverage north of the extraction and recharge area. Refer to approved OCN-LTMP-2022-005 below.

Table 1.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
FY22 Operational Change Notices			
Approved 12/13/2021	Lime Basins calculation of PRAS for DNAPL	Monitoring since 2012 has shown that the PRAS calculations have not been a reliable indicator of DNAPL presence.	OCN-LTMP-2021-005 – The LTMP was revised to remove Decision Rule 1b requiring the calculation of PRAS as an indicator of a DMAPL source zone. Quarterly and semiannual monitoring will be conducted to evaluate the presence of DNAPL.
Approved 12/15/2021	FCTS extraction well 37800 was damaged	During construction of the new FCTS, extraction well FE-1 (well 37800), was determined to be corroded and damaged beyond repair.	OCN-LTMP-2021-006 –A new extraction well (FE-1R) was constructed to replace the damaged well. The new well was assigned ID 37830. The LTMP was revised to replace well 37800 with new well 37830. In addition, extraction wells 37803 and 37804 were converted from extraction wells to monitoring wells since they were not useful in capturing the plume and are not included as extraction wells for the new system.
Approved 5/16/2022	New treatment plants and system well networks	The OGITS plant has been replaced by two new treatment buildings, the FCTS and the NPTS.	OCN-LTMP-2022-001 –The LTMP was revised to reflect the two new treatment systems. Recharge trenches 1 and 2 were abandoned during FCTS construction activities. Operational wells 37042 and 37044, located within recharge trench 1, were also removed during construction. Performance well 37127 (used for water level monitoring), located immediately adjacent to extraction well FE-1, was observed to be damaged. It was determined that replacement of well 37127 was not necessary as there are sufficient water level monitoring wells in the area. Construction of the NPTS included installation of seven new extraction wells, one new monitoring well, three new recharge trenches, and nine new piezometers. Performance well 37080 was added to the performance water quality network
Approved 4/6/2022	RYCS Permanent Shut-Off	The RYCS met shut-off criteria and five years of shut-off monitoring have been completed to demonstrate concentrations of CSRG analytes have remained below ARARs.	OCN-LTMP-2022-002 – Per approved Decision Document DD-40, LTMP text and figures were revised to reflect permanent system shut-off and identity post-shut off monitoring wells.

Table 1.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
Approved 9/6/2022	NPTS monitoring network modification	Construction of the NPTS is complete and replaces the NPS portion of the OGITS. Because alignment of the NPTS differed from that of the Original System, modification of the monitoring network was warranted. In addition, most of the Original System wells are located on private property where the existing lease expired and most of the wells will be abandoned.	OCN-LTMP-2022-003 – The LTMP text, tables and NPTS figure are being revised to remove unnecessary wells associated with the Original System from the NPTS monitoring network and to revise the location descriptions for retained wells to reflect the NPTS alignment. Original System downgradient performance wells were retained for continued monitoring, except for wells 37012 and 37013, which have been closed due to development in the former lease area. These wells will be replaced by existing or new wells for FY23 and future monitoring. Original system cross-gradient well 37039 was retained; however, it is downgradient of the NPTS and has been revised to a downgradient performance well. Original system cross-gradient well 37027 was retained pending further evaluation of other existing cross-gradient wells.
Approved 9/6/2022	Off-post well 37108 lost	Off-post well 37108 was buried when Havana Street north of 104th Avenue was widened. Well 37108 was included in the CSRG exceedance network for DIMP monitoring; however, DIMP has been below the CSRG since 2004 with only one detection during that time.	OCN-LTMP-2022-004 – The LTMP was revised to reflect the closure of well 37108. Nearby LTMP wells 37097 and 37499 are also included in the CSRG monitoring network, are similarly screened and are in the same flow path. Continued monitoring of wells 37097 and 37499 satisfies the monitoring requirement in this area.
Approved 10/12/2022	Off-post well 37084 lost	FCTS performance well 37084 was damaged during Commerce City mowing operations along Highway 2 and is no longer viable. This OCN also corrects an error on LTMP Table 6.3-1 for well 03512	OCN-LTMP-2022-005 – The LTMP was revised to reflect the closure of well 37084. Well 37116 is located across Highway 2 from well 37084 and is similarly screened. The location and screen intervals are suitable and well 37116 replaced 37084 as a FCTS performance well. Well 37084 was also included in the CSRG exceedance network. Well 37162 was installed in 2020 as a new CSRG well (OCN-LTMP-2020-003) and provides adequate coverage north of the extraction and recharge area. The analyte list for 37162 was revised to include all analytes previously included for well 37084. LTMP Table 6.3.1 was revised to indicate well 03512 as a water level tracking well, consistent with Table 6.1-2.

Table 1.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
Approved 11/4/2022	CSRG exceedance network modification	Recent monitoring of wells downgradient of the NWBCS identified a dieldrin plume with some concentrations exceeding the dieldrin PQL.	OCN-LTMP-2022-006 – The LTMP was revised to include a network of wells downgradient of the NWBCS to monitor the existing dieldrin plume. The network includes five existing wells and four newly installed wells. One additional well is planned to replace well 37336 after a property access agreement is completed. These wells were added as part of the overall CSRG exceedance monitoring network for the off-post Operable Unit. Monitoring and will include twice-in-5-year sampling with analysis for dieldrin. The new wells are also included in the water level tracking network, replacing wells 37334, 37335 and 37385, which have become unsafe to monitor due to roadway widening and development.

Table 3.1-1. NWBCS Treatment System Statistics for FY22

Dates of operation [1]	10/1/2021 through 10/1/2022
Total downtime	23 hours
Downtime attributable to maintenance, equipment failure, or other events	1.5 hours
Downtime attributable to power failure	21.75 hours
Average flow rate and total volume treated [2]	830 gpm 436,012,080 gallons
Total mass of contaminants removed [3]	2.9 pounds
Contaminants contributing to majority of mass removed (pounds) [4]	Chloroform – 1.57 Dieldrin – 1.07 Endrin ketone – 0.12 NDPA – 0.06 PPDDT – 0.03
Carbon usage	58,000 pounds
Cost of operations	$598,401

Notes:

[1] FY22 data covers the time period October 1, 2021 through October 1, 2022 based on weekly treatment system meter readings.

[2] Average flow rate and total volume treated are based on metered readings for the three adsorbers within the NWBCS plant. See NWBCS Water Management Report_FY22.pdf included in data accompanying the report.

[3] See NWBCS Contaminant Removal Report_FY22.pdf included in the electronic file accompanying the report.

[4] Refer to Appendix I2 for listing of contaminant names.

gpm – gallons per minute

Table 3.1-2. NWBCS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient							Cross-gradient			Downgradient							
		SWE	Original System					NEE	SWE		Original	SWE	Original System					NEE	
		27517	22008	22043	22053	22081	27500	22505	27516	28521	27010	27522	37330	37331	37332	37333	37600	22015	22512
1,4-Dioxane	0.35	NA	●			●		●	NA	NA									
Arsenic	2.35	NA				●		●	NA	NA									
Chloroform	6	NA		▼					NA	NA									
Dieldrin[1a]	0.002/0.013	▼	▼	●	▼	▼	▼	●	▼	▼	●	▼	▼	▼	▼	▼	▼	▼	●
Endrin	2																		
Isodrin	0.06	○	●	●	●	▼	○	●	○	○	○	○	○	○	○	▼	▼	●	●
NDMA[1b]	0.00069/0.009	NA							NA	NA									
NDPA	0.005	○	▲	○	▼	●	○	●	NA	NA	○	○	○	○	○	○	○	○	▲
Trichloroethylene	3	NA							NA	NA									

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NA – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit A-4, Appendix A, for a summary of FY22 water quality data.

Bold indicates analytes in which trend information are graphically presented in maps in Appendix A, Figures A-14 through A-16.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

Table 3.2-1. NBCS Treatment System Statistics for FY22

Dates of operation [1]	10/1/2021 through 10/1/2022
Total downtime	4.5 hours
Downtime attributable to maintenance, equipment failure, or other events	0.5 hours
Downtime attributable to power failure	4 hours
Average flow rate and total volume treated [2]	232 gpm 121,766,632 gallons
Total mass of contaminants removed [3]	9.2 pounds
Contaminants contributing to majority of mass removed (pounds) [4]	DCPD – 4.14 DIMP – 1.78 Carbon tetrachloride – 0.63 Trichloroethylene – 0.55 Chloroform – 0.48 Tetrachloroethylene – 0.36 NDPA – 0.38 Dieldrin – 0.23 1,2-Dichloroethane – 0.21
Carbon usage	40,000 pounds
Cost of operations	$507,719

Notes:

[1] FY22 data covers the time period October 1, 2021 through October 1, 2022 based on weekly treatment system meter readings.

[2] Average flow rate and total volume treated are based on metered readings for the three adsorbers within the NBCS plant. See NBCS Water Management Report_FY22.pdf included in data accompanying the report.

[3] See NBCS Contaminant Removal Report_FY22.pdf included in data accompanying the report.

[4] Refer to Appendix I2 for listing of contaminant names.

gpm – gallons per minute

Table 3.2-2. NBCS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells											Downgradient Wells											
		23119	23160	23211	24101	24105	24106	24114	24117	24185	24199	24201	23405	23434	23436	23438	24004	24006	24415	24418	24421	24424	24207 [2]	24429 [2]
1,2-Dichloroethane	0.4		●		●							●											NA	
1,2-Dichloroethylene	70																						NA	
1,4-Dioxane	0.35	●	●	○	▲	○	○	▼	○	○	○	●	▼	●	●	●	●	●	●	●	●	▲	NA	▲
1,4-Oxathiane	160												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aldrin [1a]	0.002/0.014																						NA	
Arsenic	2.35																						NA	
Atrazine	3												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	3																						NA	
Carbon tetrachloride	0.3									●													NA	
Chloride	250,000	●	●	●	●	●	▲	▼	▲	●	▲	▲	▼	●	●	●	●	▼	▲	●	●	●	NA	●
Chloroform	6																						NA	
CPMS	30												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CPMSO	36												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CPMSO2	36												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DBCP	0.20																						NA	
DCPD	46				●																		NA	
Dieldrin [1a]	0.002/0.013	●	●	●	●	●	●	●	●	●	●	▲	▼	●	●	●	●	▼	●	●	●	●	NA	▼
DIMP	8			▼	▼							●											NA	
Dithiane	18												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin	2																						NA	
Fluoride	2,000	●	●	●	●	●	●	●	●	●	●	▼	●	▼	●	●	●	●	●	●	●	●	NA	●
Isodrin	0.06	▲	●	●	●	●	●																NA	
Malathion	100												NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	5																						NA	

Table 3.2-2. NBCS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells											Downgradient Wells											
		23119	23160	23211	24101	24105	24106	24114	24117	24185	24199	24201	23405	23434	23436	23438	24004	24006	24415	24418	24421	24424	24207 [2]	24429 [2]
NDMA [1b]	0.00069/0.009	●	●	●	●	○	●	●	●	●	●	▲	●	●	●	●	○	●	●	●	●	●	NA	○
NDPA	0.005	▼	●		▲							▲											NA	
Sulfate	540,000	●	●	●	●	●	●	▼	▲	●	●	●	●	●	●	●	●	●	▲	●	●	▼	NA	●
Tetrachloroethylene	5											●											NA	
Toluene	1000																						NA	
Trichloroethylene	3				●							▲											NA	
Xylenes	1000																						NA	

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NA – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit B-10, Appendix B, for a summary of FY22 water quality data.

Bold indicates analytes in which trend **data** are graphically presented in maps in Appendix B, Figures B-28 through B-33.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

Table 3.2-3. Summary of FY22 North Boundary Containment System Denver Formation Water Quality

Well ID	Sample Date	Analyte Concentrations with CSRGs/PQLs noted in italics (µg/L)						
		1,2-Dichloroethane	Carbon tetrachloride	Chloroform	Chloride	DIMP	Dieldrin	NDMA
		0.4	*0.3*	*6*	*250,000*	*8*	*0.013*	*0.009*
UFS Upgradient Wells								
23195	7/25/2022	—	LT 0.2	1.43	**313,000**	LT 0.5	—	—
23541	7/25/2022	—	—	—	**595,000**	**15.7**	**0.0867**	—
23543	7/21/2022	—	—	2.12	**290,000**	0.818	—	—
UFS Downgradient Wells								
23194	7/25/2022	—	**0.648**	**7.13**	**440,000**	LT 0.5	—	—
23235	8/10/2022	0.355	—	—	**521,000**	**71.7**	—	—
23540	7/25/2022	—	—	—	**533,000**	**637**	**0.132**	—
23542	7/21/2022	—	—	0.487	215,000	1.86	—	—
24191	8/15/2022	—	—	—	184,000	6.52	—	—
CFS Downgradient Wells								
23161	7/21/2022	—	—	—	42,000	LT 0.5	—	—
23200	7/18/2022	**0.673**	—	—	124,000	LT 0.5	—	**0.0481**
24171	8/1/2022	—	—	—	36,300	LT 0.5	—	—

Note:

Results are presented for the well-specific analytical requirements presented in the LTMP Table 4.4-4 (Navarro 2021). Concentrations greater than CSRGs/PQLs are in **bold** and shaded.

Table 3.3-1. BANS Treatment System Statistics for FY22

Dates of operation [1]	10/1/2021 through 10/1/2022
Total downtime	0.5 hours
Downtime attributable to maintenance, equipment failure, or other events	0 hours
Downtime attributable to power failure	0.5 hours
Average flow rate and total volume treated [2]	17 gpm 9,132,842 gallons
Total mass of contaminants removed [3]	59.40 pounds
Contaminants contributing to majority of mass removed (pounds) [4]	Chloroform – 16.1 Trichloroethylene – 14.46 DIMP – 9.27 Dithiane – 7.9 Tetrachloroethylene – 3.8 CPMSO2 – 2.1 1,2-Dichloroethylene – 1.0 1,1,2,2-Tetrachloroethane – 1.5 1,4-Oxathiane – 0.83 Arsenic – 0.65 1,2-Dichloroethane – 0.56 1,2-Dichloropropane – 0.39 DCPD – 0.30
Carbon usage	11,500 pounds
Cost of operations	$587,993

Notes:

[1] FY22 data covers the time period October 1, 2021 through October 1, 2022 based on weekly treatment system meter readings. BANS treatment supports groundwater extracted at BANS, BRES, CADT, and Lime Basins.

[2] Average flow rate and total volume treated are based on metered readings for the effluent tank within the BANS plant. See BANS Water Management Report_FY22.pdf included in data accompanying the report.

[3] See BANS Contaminant Removal Report_FY22.pdf included in data accompanying the report.

[4] Refer to Appendix I2 for listing of contaminant names.

gpm – gallons per minute

Table 3.3-2. FY22 BANS Estimated Mass Removal

Contaminant Flow Rate [1]	Total – 12.27 gpm Into Capture Zone – 11.64 gpm North of Capture Zone – 0.63 gpm South of Capture Zone – 0.00164 gpm
Plume Mass Flux [1]	Total – 13.32 pounds Into Capture Zone – 13.15 pounds North of Capture Zone – 0.17 pounds South of Capture Zone – 0.00044 pounds
Extracted Mass	13.15 pounds
Percent Mass Removed	**98.7% – Meets current performance criterion of 75%**

Notes:

[1] Any apparent discrepancies in the quantities for mass removal can be accounted for in mathematical rounding as shown in the calculations presented in the Excel file FY22 BANS Mass Removal Rev0 07-19-23 accompanying this report.

gpm – gallons per minute

Table 3.3-3. BANS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient				Downgradient			
		26507	35512	35514	35516	26501	26505	35505	35525
1,1,1-Trichloroethane	200								
1,1-Dichloroethylene	7								
1,2-Dichlorobenzene	600								
1,2-Dichloroethane	0.4			●	●				
1,3-Dichlorobenzene	94								
1,4-Dichlorobenzene	75								
1,4-Oxathiane	160								
Arsenic	50								
Atrazine	3								
Benzene	5								
Carbon tetrachloride	0.3								
Chlorobenzene	100								
Chloroform	6								
CPMS	30								
CPMSO	36								
CPMSO2	36	●	●	●	●	○	●	▼	●
Dicyclopentadiene	46								
Dieldrin [1a]	0.002/0.013	●	●	●	●	●	▼	●	●
Dithiane	18			●					
Endrin	2								
Hexachlorocyclopentadiene	50								
Mercury	2								
PPDDT	0.10	●	▼	▼	●	●	▼	▼	▼
1,1,2,2-Tetrachloroethane	0.18								
Tetrachloroethylene	5								
Trichloroethylene	5								

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NS – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit C-13, Appendix C, for a summary of FY22 water quality data.

Bold indicates analytes in which trend **data** are graphically
presented in maps in Appendix C, Figures C-20 through C-22.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

Table 3.4-1. BRES Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient				Downgradient			
		36565	36567	36575	36250	36555	36566	36571	36572
1,1,1-Trichloroethane	200								
1,1-Dichloroethylene	7		●		●				
1,2-Dichlorobenzene	600								
1,2-Dichloroethane	0.4	○	▼	○	▼	○	▲	●	○
1,3-Dichlorobenzene	94								
1,4-Dichlorobenzene	75								
1,4-Oxathiane	160								
Arsenic	50	NA	NA	NA	NA	NA	NA	NA	NA
Atrazine	3								
Benzene	5								
Carbon tetrachloride	0.3		▼		●				
Chlorobenzene	100								
Chloroform	6	○	●	○	●	○	▼	●	●
CPMS	30								
CPMSO	36								
CPMSO2	36								
Dicyclopentadiene	46								
Dieldrin [1a]	0.002/0.013		●						
DIMP	8	●	▼	●	●	●	●	●	●
Dithiane	18								
Endrin	2								
Hexachlorocyclopentadiene	50								
Mercury	2	NA	NA	NA	NA	NA	NA	NA	NA
PPDDT	0.10								
1,1,2,2-Tetrachloroethane	0.18				▲				
Tetrachloroethylene	5	●	▼	●	●	●	●	●	●
Trichloroethylene	5	○	●	○	●	○	▲	●	●

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NA – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit C-24, Appendix C, for a summary of FY22 water quality data.

Bold indicates analytes in which trend **data** are graphically presented in maps in Appendix C, Figures C-35 through C-39.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

Table 4.2-1. Shell Disposal Trenches FY21 Performance Groundwater and Trench Bottom Elevations

Borehole ID	Trench Bottom Elevation (feet amsl)	Groundwater Elevation (feet amsl)			
		Quarter 1 12/3/2020	Quarter 2 2/25/2021	Quarter 3 5/27/2021	Quarter 4 7/28/2021
3178	5242.0	5236.4	5236.1	5238.1	5238.2
3444	5244.1	5236.8	5236.5	5236.9	5236.9
3445	5240.5	5236.0	5235.8	5237.2	5236.7
3446	5240.6	5235.7	5235.4	5236.7	5236.5
3457	5240.8	5236.5	5236.1	5237.7	5237.8
SDT-02	5238.4	5237.0	5236.8	5237.1	5237.2

Note:

Groundwater elevations for each quarter at each bore location are presented quarterly in Treatment Plant Effluent Water Quality Data Reports FY21 (Navarro 2022b, 2021a, 2021c, 2021d). Trench bottom elevations were higher than groundwater elevations for all four quarters of FY21.

Table 5.1-1. FCTS Treatment System Statistics for FY22

Dates of operation [1]	10/1/2021 through 10/1/2022
Total downtime	19.75 hours
Downtime attributable to maintenance, equipment failure, or other events	16.25 hours
Downtime attributable to power failure	3.5 hours
Average flow rate and total volume treated [2]	60 gpm 27,716,181 gallons
Total mass of contaminants removed [3]	2.8 pounds
Contaminants contributing to majority of mass removed (pounds) [4]	DIMP – 2.8 DCPD – 0.01
Carbon usage	7,500 pounds
Cost of operations	$244,275

Notes:

[1] FY22 data covers the time period October 1, 2021 through October 2, 2022 based on treatment plant meter readings.

[2] Average flow rate and total volume treated are based on metered readings for the effluent tank at the FCTS plant.

[3] See FCTS Contaminant Removal Report_FY22.pdf included in data accompanying the report.

[4] Refer to Appendix I2 for listing of contaminant names.

gpm – gallons per minute

Table 5.1-2. FY22 FCTS Estimated Contaminant Mass Removal

Contaminant Flow Rate [1]	Plume Approaching System – 63.1 gpm Plume Entering Capture Zone – 56.0 gpm Plume Outside Capture Zone – 7.1 gpm Extraction System – 53.4 gpm
Plume Mass Flux [1]	Total – 225,539 pounds Inside Capture Zone – 190,502 pounds Outside Capture Zone – 35,037 pounds
Extracted Mass	172,812 pounds
Percent Mass Removed	**77% – Meets current performance criterion of 75%**

Note:

[1] Any apparent discrepancies in the quantities for mass removal can be accounted for in mathematical rounding as shown in the calculations presented in the Excel file FY22 FCTS Mass Removal Rev0 07-19-23.xlsx accompanying this report.

gpm – gallons per minute

Table 5.1-3. FCTS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells						Downgradient Wells		
		37074	37075	37076	37083	37370	37373	37110	37116	37163
1,2-Dichloroethane	0.4			●	●					
1,3-Dichlorobenzene	6.5									
1,4-Oxathiane	160									
Aldrin [1a]	0.002/0.014									
Arsenic	2.35	○	●	○	○	●	○	○	○	●
Atrazine	3	NA	NA	NA	NA		NA			
Benzene	3									
Carbon tetrachloride	0.3									
Chlordane [2]	0.03									
Chloride	250,000	▼	▼	●	▼	●	●	●	●	●
Chlorobenzene	25									
Chloroform	6									
CPMS	30	NA	NA	NA	NA		NA			
CPMSO	36	NA	NA	NA	NA		NA			
CPMSO2	36	NA	NA	NA	NA		NA			
DBCP	0.2									
DCPD	46									
Dieldrin [1a]	0.002/0.013	▼	●	●	●	●	●	○	●	●
DIMP	8	▼	●	●	●	●	●	▼	●	●
Dithiane	18	NA	NA	NA	NA		NA			
Endrin	2									
Ethylbenzene	200									
Fluoride	2,000	▲	▲	●	●	●	●	●	●	●
Hexachlorocyclopentadiene	0.23									
Isodrin	0.06									
Malathion	100	NA	NA	NA	NA		NA			
NDMA [1b]	0.00069/0.009									
NDPA	0.005			●	●					
PPDDE	0.1									
PPDDT	0.1									
Sulfate	540,000	▼	▼	▲	▼	▲	▼	●	●	●
Tetrachloroethylene	5									
Toluene	1000									
Trichloroethylene	3									

Table 5.1-3. FCTS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells						Downgradient Wells		
		37074	37075	37076	37083	37370	37373	37110	37116	37163
Xylenes	1000									

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NA – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit E-5, Appendix E, for a summary of FY22 water quality data.

Bold indicates analytes in which trend **data** are graphically presented in maps in Appendix E, Figures E-15 through E-20.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

Table 5.2-1. NPTS Treatment System Statistics for FY22

Dates of operation [1]	1/31/2022 through 10/1/2022
Total downtime	0 hours
Downtime attributable to maintenance, equipment failure, or other events	0 hours
Downtime attributable to power failure	0 hours
Average flow rate and total volume treated [2]	181 gpm 62,557,698 gallons
Total mass of contaminants removed [3]	0.36 pounds
Contaminants contributing to majority of mass removed (pounds) [4]	DIMP – 0.18 Tetrachloroethylene – 0.08 Chloroform – 0.03
Carbon usage	0 pounds
Cost of operations	$334,127

Notes:

[1] FY22 data covers the time period January 31 through October 1, 2022 based on weekly treatment plant meter readings.

[2] Average flow rate and total volume treated are based on metered readings for the effluent tank at the NPTS plant.

[3] See NPTS Contaminant Removal Report_FY22.pdf included in data accompanying the report.

[4] Refer to Appendix I2 for listing of contaminant names.

gpm – gallons per minute

Table 5.2-2. FY22 NPTS Estimated Contaminant Mass Removal

Contaminant Flow Rate [1]	Plume Approaching System – 183.7 gpm Plume Entering Capture Zone – 181.3 gpm Plume Outside Capture Zone – 2.4 gpm Extraction System – 180.4 gpm
Plume Mass Flux [1]	Total – 346,671 pounds Inside Capture Zone – 342,311 pounds Outside of Capture Zone – 4,360 pounds
Extracted Mass	345,067 pounds
Percent Mass Removed	**99.5% – Meets current performance criterion of 75%**

Note:

[1] Any apparent discrepancies in the quantities for mass removal can be accounted for in mathematical rounding as shown in the calculations presented in the Excel file FY22 NPTS Mass Removal Rev0 07-19-23.xlsx accompanying this report.

gpm – gallons per minute

Table 5.2-3. NPTS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells												Cross-gradient Wells		Downgradient Wells [2]						
		37080	37157	37158	37159	37160	37457	37458	37469	37471	37473	37474	EPA-4	37027	37452	37008	37009	37010	37011	37012	37013	37039
1,2-Dichloroethane	0.4																					
1,3-Dichlorobenzene	6.5																					
1,4-Oxathiane	160						NA	NA	NA	NA	NA	NA	NA	NA								
Aldrin [1a]	0.002/0.014																					
Arsenic	2.35																					
Atrazine	3						NA	NA	NA	NA	NA	NA	NA	NA								
Benzene	3																					
Carbon tetrachloride	0.3			●																		
Chlordane	0.03																					
Chloride	250,000	▼	●	●	●	●	●	●	●	●	●	●	●	▲	●	●	●	●	●	●	●	●
Chlorobenzene	25																					
Chloroform	6																					
CPMS	30						NA	NA	NA	NA	NA	NA	NA	NA								
CPMSO	36						NA	NA	NA	NA	NA	NA	NA	NA								
CPMSO2	36						NA	NA	NA	NA	NA	NA	NA	NA								
DBCP	0.2																					
DCPD	46																					
Dieldrin [1a]	0.002/0.013	▲			●					●	●	▼										
DIMP	8																					
Dithiane	18						NA	NA	NA	NA	NA	NA	NA	NA								
Endrin	2																					
Ethylbenzene	200																					
Fluoride	2,000	●	●	●	●	●	●	●	●	●	●	●	▼	●	●	●	●	●	●	●	●	●
Hexachlorocyclopentadiene	0.23																					

Table 5.2-3. NPTS Performance Well Concentration Trends for CSRG Analyte Exceedances

CSRG Analyte	CSRG/PQL (µg/L)	Upgradient Wells												Cross-gradient Wells		Downgradient Wells [2]						
		37080	37157	37158	37159	37160	37457	37458	37469	37471	37473	37474	EPA-4	37027	37452	37008	37009	37010	37011	37012	37013	37039
Isodrin	0.06																					
Malathion	100						NA	NA	NA	NA	NA	NA	NA	NA								
NDMA [1b]	0.00069/0.009																					
NDPA	0.005					●	▼	▼														
PPDDE	0.1																					
PPDDT	0.1																					
Sulfate	540,000	●	●	●	●	●	●	●	▼	●	▼	●	▼	●	▼	●	▼	●	●	●	●	▼
Tetrachloroethylene	5																					
Toluene	1000																					
Trichloroethylene	3																					
Xylenes	1000																					

Notes:

● – Concentrations demonstrate a stable trend or no discernible trend over the past 20 years.

○ – Analyte was not detected during the past 20-year period to support the trend evaluation.

▼ – Concentrations demonstrate a decreasing trend over the past 20 years.

▲ – Concentrations demonstrate an increasing trend over the past 20 years.

NA – Indicates that the respective well was not sampled for the indicated analyte in FY22.

Refer to Exhibit F-4, Appendix F, for a summary of FY22 water quality data.

Bold indicates analytes in which trend **data** are graphically presented in maps in Appendix F, Figures F-12 through F-14.

Blank cells indicate that reported concentrations were lower than the CSRG or PQL for the respective analyte.

Shading indicates that the analyte concentration exceeded the CSRG/PQL in FY22.

[1] The ROD indicates PQLs for the following analytes:

[a] Dieldrin – Effective April 2012 [b] NDMA – Effective September 2016

[2] In October 2020, Wells 37094, 37095, 37395 and 37404 were replaced by wells 37157, 37160, 37159 and 37158, respectively.

Table 6.2-1. Water Quality Tracking Wells and Analytes Demonstrating Increasing Statistical Trends

Well	Indicator Analyte and Concentration Trend[1]	Location and Monitoring Justification	Number of Detections/ Number of Samples	Historical Range of Detections (µg/L)	Comments
Northwest Boundary Containment System					
No Water Quality Tracking indicator analytes demonstrated increasing concentration trends in wells associated with the Northwest Boundary Containment System in FY22.					
North Boundary Containment System and North Plants					
23096	1,4-Dioxane Increasing trend	Upgradient of NBCS and downgradient from Basins C and F sources	4/4	0.21–0.57	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
	Fluoride Increasing trend		7/7	93,000-179,000	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
24092	Fluoride Increasing trend	Upgradient of NBCS and downgradient from North Plants source	7/7	1020–3240	Highest concentration detected in FY19 with a decrease in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
Railyard Containment System and Motor Pool System					
No Water Quality Tracking indicator analytes demonstrated increasing concentration trends in wells associated with the Railyard Containment and Motor Pool Systems in FY22.					
Basin A Neck System, Basin A, and Related Section 36 Source Areas					
35065	Chloride Increasing trend	Upgradient of BANS and downgradient of Basin A source	4/4	2,040,000-4,840,000	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
	Chloroform Increasing trend		7/9	0.382–1.04	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
	Dithiane Increasing trend		5/5	45.5–228	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
	Trichloroethylene Increasing trend		8/9	0.574–2.4	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.

Table 6.2-1. Water Quality Tracking Wells and Analytes Demonstrating Increasing Statistical Trends

Well	Indicator Analyte and Concentration Trend[1]	Location and Monitoring Justification	Number of Detections/ Number of Samples	Historical Range of Detections (µg/L)	Comments
36630	Dithiane Increasing trend	Downgradient from Basin A source, 36630 replaced well 36108	6/6	245–710	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
36633	Arsenic Increasing trend	Basin A source,36633 replaced well 36599	6/6	18.2–35.2	Highest concentration detected in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
South Plants Source Areas					
01078	Chloroform Increasing trend	South Plants source	8/8	14,600–39,800	Highest concentration detected in FY19 with a decrease in FY22. Long-term concentrations appear to be increasing based on statistical evaluation.
01312	Chloride Increasing trend	STF benzene plume, 01312 replaced well 01534	4/4	51,300–64,900	Long-term concentrations appear to be increasing based on statistical evaluation.

Note:

[1] Trends were evaluated statistically using the Mann-Kendall test for trends unless otherwise noted.

Table 6.3-1. Summary of FY22 Detections in the Confined Flow System Monitoring Network

Well ID	Analyte	Sample Date	Concentration (ug/L)	Comments [1]
Basin A				
35063	Chloride	12/8/2021	81,000	Stable trend over past 20 years, but increased in FY22.
35067	Chloride	12/7/2021	567,000	Increasing trend over the past 20 years.
35068	Chloride	12/7/2021	50,800	Decreasing concentrations since 2009.
35083	Chloride	12/8/2021	1,650,000	Stable trend since 2009, with increase in FY22.
36113	Chloride	12/9/2021	16,800	Stable trend over past 20 years, but increased in FY22.
36114	Chloride	12/9/2021	199,000	Stable trend over past 20 years, but increased in FY22.
36159	Chloride	12/9/2021	586,000	Stable trend over past 20 years, but increased in FY22.
36171	Chloride	9/12/2022	22,200	Stable trend over past 20 years, but decreasing since 2009.
36183	Chloride	12/8/2021	53,400	Stable trend over past 20 years, but anomalously high detection in 2007.
Basin F				
23187	Chloride	12/2/2021	418,000	Stable trend over past 20 years, but increased in FY22.
	Dieldrin		0.0077	Variable detections since 2016, but decreased in FY22.
23193	Chloride	9/20/2022	415,000	Stable trend over past 20 years, but decreased in FY22.
	Dieldrin		0.0234	Increasing trend since 2016, and increased in FY22.
26147	Chloride	12/2/2021	189,000	Stable trend over past 20 years, but increased in FY22.
	Dieldrin		0.00425	Decreased since first time detected in 2018.
26150	Chloride	12/7/2021	160,000	Stable trend over past 20 years, but increased in FY22.
	Dieldrin		0.00275	Detected in FY22 for first time since 1992.
26152	Chloride	12/8/2021	69,800	Stable trend over past 20 years, but increased in FY22.
26153	Chloride	12/2/2021	230,000	Stable trend over past 20 years, but anomalously low detection in 2016.
	Dieldrin		0.00464	Variable concentrations since 2012 and decreasing since 2016.
South Plants				
01067	Chloride	12/16/2021	33,100	Stable trend over past 20 years, but increased in FY22.
01102	Chloride	12/16/2021	51,600	Stable trend over past 20 years, but increased in FY22.
01109	Chloride	9/20/2022	84,300	Stable trend over past 20 years, but decreased in FY22.

Table 6.3-1. Summary of FY22 Detections in the Confined Flow System Monitoring Network

Well ID	Analyte	Sample Date	Concentration (ug/L)	Comments [1]
01300	Chloride	12/13/2021	30,200	Increased in FY22.
02047	Chloride	12/13/2021	36,600	Increased in FY22.
02048	Chloride	9/21/2022	61,300	Increased in FY22.
02057	Chloride	12/16/2021	43,300	Increased in FY22.
	Chlorobenzene		0.375	Concentrations have been decreasing.

Note:
[1] Trends indicated in comments are based on visual evaluation of time versus concentration charts provided in RMA Water.

Table 7.1-1. Summary of FY22 Off-Post CSRG Exceedances

Well	Sample Date	Analyte Concentration (µg/L, CSRG/PQL shown in italics)									
		1,2-Dichloroethane	1,4-Dioxane	Arsenic	Carbon tetrachloride	Chloride	DIMP	Dieldrin	Fluoride	NDPA	Sulfate
		0.4	*0.35*	*2.35*	*0.3*	*250,000*	*8*	*0.013*	*2,000*	*0.005*	*540,000*
North Boundary											
23198	8/15/22	—	**0.539**	—	—	**265,000**	<CSRG	**0.0484**	**3,180**	—	<CSRG
24162	8/10/22	—	<CSRG	—	—	<CSRG	<CSRG	**0.0371**	**2,280**	—	<CSRG
24166	8/10/22	—	**0.481**	—	—	<CSRG	<CSRG	**0.0277**	<CSRG	—	<CSRG
37338	8/15/22	—		—	—	**445,000**	<CSRG	**0.0341**	<CSRG	—	—
37339	8/15/22	—	<CSRG	—	—	**1,240,000**	<CSRG	—	**2,560**	—	**2,010,000**
Northwest Boundary											
37125	9/28/22	—	—	—	—	—	—	<CSRG	—	—	—
37177	9/29/22	—	—	—	—	—	—	<CSRG	—	—	—
37178	9/29/22	—	—	—	—	—	—	<CSRG	—	—	—
37179	9/29/22	—	—	—	—	—	—	<CSRG	—	—	—
37180	9/29/22	—	—	—	—	—	—	<CSRG	—	—	—
37181 [1]	4/23/23	—	—	—	—	—	—	<CSRG	—	—	—
37430	9/28/22	—	—	—	—	—	—	<CSRG	—	—	—
37440	9/28/22	—	—	—	—	—	—	<CSRG	—	—	—
37441	9/28/22	—	—	—	—	—	—	<CSRG	—	—	—
37442	9/28/22	—	—	—	—	—	—	<CSRG	—	—	—
First Creek Pathway											
37041	6/22/22	—	—	—	—	**285,000**	<CSRG	—	—	—	—
37065	6/28/22	**0.527**	<CSRG	<CSRG	<CSRG	**295,000**	**117**	<CSRG	<CSRG	**0.0109**	**705,000**
37070	6/22/22	—	—	—	—	—	<CSRG	—	<CSRG	—	—
37074	6/27/22	—	—	—	—	<CSRG	<CSRG	—	**2,860**	—	<CSRG
37076	6/28/22	**0.773**	**0.39**	—	—	**418,000**	**121**	—	**2,340**	**0.025**	**790,000**
37081	6/28/22	<CSRG	**0.427**	—	<CSRG	**308,000**	<CSRG	**0.0828**	**2,180**	<CSRG	<CSRG
37083	6/27/22	**0.527**	**0.446**	—	—	<CSRG	**83.5**	—	**2,400**	**0.0132**	<CSRG
37110	7/13/22	<CSRG	<CSRG	<CSRG	<CSRG	**1,010,000**	<CSRG	<CSRG	**2,940**	<CSRG	**1,380,000**
37161	6/15/22	<CSRG	—	—	<CSRG	**273,000**	<CSRG	—	—	—	<CSRG
37162	6/15/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG

Table 7.1-1. Summary of FY22 Off-Post CSRG Exceedances

Well	Sample Date	Analyte Concentration (µg/L, CSRG/PQL shown in italics)									
		1,2-Dichloroethane	1,4-Dioxane	Arsenic	Carbon tetrachloride	Chloride	DIMP	Dieldrin	Fluoride	NDPA	Sulfate
		0.4	*0.35*	*2.35*	*0.3*	*250,000*	*8*	*0.013*	*2,000*	*0.005*	*540,000*
37163	6/15/22	<CSRG	<CSRG	**2.45**	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37369	6/27/22	<CSRG	**0.468**	—	<CSRG	**263,000**	<CSRG	**0.0842**	<CSRG	—	—
37370	6/23/22	<CSRG	—	<CSRG	<CSRG	**417,000**	<CSRG	**0.0617**	**2,700**	<CSRG	**913,000**
37396	9/27/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
Northern Pathway											
37008	3/3/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37009	2/15/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37010	2/15/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37011	3/3/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37012	3/3/22	<CSRG	<CSRG	<CSRG	<CSRG	**273,000**	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37013	3/3/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37027	2/15/22	—	<CSRG	—	—	**460,000**	<CSRG	—	**4,120**	<CSRG	**750,000**
37039	2/14/22	—	<CSRG	—	<CSRG	—	<CSRG	—	—	—	—
37080	7/12/22	—	<CSRG	—	—	—	<CSRG	**0.0329**	—	—	—
37157	6/15/22	<CSRG	**0.468**	—	<CSRG	**408,000**	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG
37158	3/2/22	<CSRG	<CSRG	<CSRG	**0.371**	—	—	—	—	—	—
37159	3/2/22	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	<CSRG	**0.0854**	<CSRG	<CSRG	<CSRG
37160	3/2/22	<CSRG	<CSRG	<CSRG	<CSRG	**330,000**	<CSRG	<CSRG	**3,200**	**0.0354**	<CSRG
37368	3/1/22	—	<CSRG	—	—	**360,000**	<CSRG	—	—	**0.0524**	<CSRG
37452	3/14/22	—	—	—	<CSRG	<CSRG	<CSRG	—	—	—	—
Off-post Plume											
37097	7/14/22	—	<CSRG	—	—	—	<CSRG	—	—	—	—
37126	6/29/22	<CSRG	<CSRG	—		<CSRG	<CSRG	**0.0306**	—	—	—
37150	6/30/22	—	<CSRG	—	<CSRG	<CSRG	—	—	—	—	—
37151	6/30/22	—	<CSRG	—	<CSRG	<CSRG	<CSRG	**0.0574**	—	—	—
37164	6/30/22	—		—	—	<CSRG	<CSRG	<CSRG	**2,020**	<CSRG	
37165	6/30/22	—	<CSRG	—	—	<CSRG	<CSRG	**0.0389**	<CSRG	—	—
37166	6/22/22	<CSRG		—	—	—	<CSRG	—	—	—	—

Table 7.1-1. Summary of FY22 Off-Post CSRG Exceedances

Well	Sample Date	Analyte Concentration (µg/L, CSRG/PQL shown in italics)									
		1,2-Dichloroethane	1,4-Dioxane	Arsenic	Carbon tetrachloride	Chloride	DIMP	Dieldrin	Fluoride	NDPA	Sulfate
		0.4	*0.35*	*2.35*	*0.3*	*250,000*	*8*	*0.013*	*2,000*	*0.005*	*540,000*
37328	6/27/22	<CSRG	**0.397**	—	<CSRG	**328,000**	**22.8**	**0.024**	**2,460**	<CSRG	<CSRG
37353	7/14/22	—	—	—	—	—	<CSRG	—	—	—	—
37374	7/12/22	—	—	—	—	**410,000**	<CSRG	<CSRG	<CSRG	—	**1,270,000**
37377	6/29/22	—	<CSRG	—	—	<CSRG	<CSRG	—	**2,400**	—	<CSRG
37378	6/29/22	—	<CSRG	—	<CSRG	<CSRG	<CSRG	**0.054**4	—	—	<CSRG
37379	7/12/22	—	—	—	—	**548,000**	**20**	—	—	—	**1,340,000**
37389	6/28/22	—	**0.376**	—	—	**275,000**	<CSRG	**0.234**	—	**0.0164**	—
37391	6/29/22	—	**0.366**	—	—	**529,000**	<CSRG	**0.0344**	—	**0.0626**	**1,0200,00**
37392	6/29/22	—	<CSRG	—	—	<CSRG	<CSRG	**0.0309**	—	—	—
37405	9/27/22	—	<CSRG	—	—	—	—	—	—	—	—
37428	6/22/22	—	—	—	—	—	<CSRG	—	—	—	—
37498	7/13/22	—	—	—	—	—	<CSRG	—	—	—	—
37499	7/13/22	—	—	—	—	—	<CSRG	—	—	—	—

Note:

Concentrations that exceed their respective CSRG/PQL are indicated in **bold**.

[1] Wells 37177, 37178, 37179, and 37180 were installed to monitor dieldrin in groundwater downgradient of the NWBCS in September 2022. Well 37181 was to be installed at the same time as the other four, but installation was delayed until March 2023 with sampling conducted on April 23, 2023. The results for dieldrin in well 37181 are included in order to provide a complete summary of CSRG exceedance monitoring within these five wells intended for FY22.

Table 7.2-1. Analytical Results of the FY22 Off-Post Surface Water Monitoring Program

Analyte	CSRG/PQL (µg/L)	Analyte Concentrations (µg/L) – Sampled 6/16/2022 [1]		
		SW08003 First Creek Near Buckley Road	SW24004 First Creek Near 96th Avenue	SW37001 First Creek Near Hwy 2
Aldrin	0.014	LT 0.00605	LT 0.00605	LT 0.00605
Arsenic [2]	2.35	LT 1	1.92	**2.47**
Chloride	250,000	142,000	167,000	193,000
Dieldrin	0.013	LT 0.00252	0.00396	0.00576
DIMP	8	LT 0.5	LT 0.5	LT 0.5
NDMA	0.009	LT 0.003	LT 0.003	LT 0.003
Sulfate	540,000	184,000	220,000	263,000

Note:
[1] Concentrations greater than CSRG/PQL are presented in **bold**.
[2] All arsenic concentrations represent filtered samples.

Table 7.3-1. FY22 Water Quality Data for the Off-Post Private Well Network

Private Well ID	Sample Date	Analyte Concentrations (µg/L) [1]		
		DIMP (CBSG – 8 µg/L)	1,4-Dioxane (CBSG – 0.35 µg/L)	Dieldrin (PQL – 0.013 µg/L)
Alluvial Aquifer				
359C	9/13/2022	1.4	NA	NA
621B	9/12/2022	LT 0.50	0.112	LT 0.00252
632A	9/20/2022	LT 0.50	0.203	LT 0.00252
989A	9/20/2022	LT 0.50	LT 0.075	0.00846
1402B	9/19/2022	LT 0.50	0.141	0.00873
Arapahoe Aquifer				
359D	9/13/2022	**15.3**	NA	NA
621A	9/12/2022	LT 0.50	NA	LT 0.00252
644C	9/19/2022	LT 0.50	NA	NA

Additional Analyses

Private Well ID	Sample Date	Analyte Concentrations (µg/L)			
		HPCLE	AENSLF	NDMA	NDPA
621B	9/12/2022	0.0225	LT 0.00181	NA	NA
1402B	9/19/2022	0.0335	0.00621	LT 0.003	LT 0.003

Notes:

[1] Concentrations greater than CSRG/PQL are presented in **bold**.

LT – Analyte not detected and reported as a value less than the reporting limit.

NA – Not analyzed

HPCLE – Heptachlor epoxide

AENSLF – alpha-Endosulfan

Table 8.1-1. Railyard Containment System Shut-Off Monitoring Results for FY22

Well	Sample Date	Analyte Concentration (µg/L)	
		DBCP (CSRG – 0.2 µg/L)	Trichloroethylene (CSRG – 5 µg/L)
Upgradient Wells			
03501	12/7/20	LT 0.0192	LT 0.2
	3/9/21	LT 0.0192	LT 0.2
	5/12/21	LT 0.0194	LT 0.2
	7/19/21	LT 0.0192	LT 0.2
	10/18/21	LT 0.0194	LT 0.2
03502	Not sampled in FY22	—	—
03503	12/7/20	LT 0.0188	LT 0.2
	3/9/21	LT 0.019	LT 0.2
	5/12/21	LT 0.0194	LT 0.2
	7/19/21	LT 0.0194	LT 0.2
	10/19/21	LT 0.0196	LT 0.2
03534	12/7/20	LT 0.019	LT 0.2
	3/9/21	LT 0.019	LT 0.2
	5/13/21	LT 0.0192	LT 0.2
	7/20/21	LT 0.0194	LT 0.2
	10/18/21	LT 0.0194	LT 0.2
03538	12/7/20	LT 0.019	LT 0.2
	3/9/21	LT 0.0192	LT 0.2
	5/12/21	LT 0.0194	LT 0.2
	7/19/21	LT 0.0194	LT 0.2
	10/18/21	LT 0.0192	LT 0.2
Downgradient Wells			
03528	12/8/20	LT 0.019	LT 0.2
	3/8/21	LT 0.0192	LT 0.2
	5/13/21	LT 0.0194	LT 0.2
	7/19/21	LT 0.0194	LT 0.2
	10/19/21	LT 0.0192	LT 0.2
03529	12/8/20	LT 0.019	LT 0.2
	3/8/21	LT 0.0192	LT 0.2
	5/13/21	LT 0.0192	LT 0.2
	7/20/21	LT 0.0194	LT 0.2
	10/19/21	LT 0.0194	LT 0.2

Table 8.1-1. Railyard Containment System Shut-Off Monitoring Results for FY22

Well	Sample Date	Analyte Concentration (µg/L)	
		DBCP (CSRG – 0.2 µg/L)	Trichloroethylene (CSRG – 5 µg/L)
03530	12/8/20	LT 0.0194	LT 0.2
	3/8/21	LT 0.019	LT 0.2
	5/13/21	LT 0.0192	LT 0.2
	7/20/21	LT 0.0192	LT 0.2
	10/19/21	LT 0.0194	LT 0.2

Note:
LT – Analyte not detected and reported as less than the reporting limit.

Table 8.2-1. Motor Pool System/Irondale Containment System Post-Shut-Off Monitoring Results for FY22

Well and Sample Date [1]	Analyte Concentrations (µg/L)	
	DBCP (CSRG – 0.2 µg/L)	Trichloroethylene (CSRG – 5 µg/L)
Motor Pool System		
04021 (9/8/2022)	NA	LT 0.2
04535 (9/7/2022)	NA	0.622
Irondale Containment System		
33081 (9/9/2022)	LT 0.0194	NA

Notes:

[1] No concentrations of detected analytes exceeded CSRGs in FY22. Annual sampling for wells 04535 and 33081 will next take place in the first quarter of FY23.

[2] Well 04021 is sampled twice every five years. This well will be sampled next in FY24.

NA – Not analyzed

Table 9.0-1. Perfluoroalkyl Substances Results for FY22 Treatment Plant Samples

Treatment Plant	Sample Date	Sample Location	Analyte Concentrations and *Health Advisory Levels* (µg/L)				
			PFBS *2*	PFHxS *NA*	PFNA *NA*	PFOA *0.000004*	PFOS *0.00002*
On-Post Systems							
NWBCS	7/19/2022	Influent	0.0035	0.0039	LT 0.002	**0.002**	**0.0027**
		Effluent	LT 0.002	LT 0.002	LT 0.002	LT 0.002	LT 0.002
NBCS	7/19/2022	Influent	0.0022	0.0032	LT 0.002	LT 0.002	LT 0.002
		Effluent	LT 0.002	LT 0.002	LT 0.002	LT 0.002	LT 0.002
BANS	7/19/2022	Influent	LT 0.002	LT 0.002	LT 0.002	**0.0061**	**0.0079**
		Effluent	LT 0.002	LT 0.002	LT 0.002	LT 0.002	LT 0.002
Off-Post Systems							
FCTS	7/19/2022	Influent	0.006	LT 0.002	LT 0.002	LT 0.002	LT 0.002
		Effluent	LT 0.002	LT 0.002	LT 0.002	LT 0.002	LT 0.002
NPTS	7/19/2022	Influent	0.0065	0.0032	LT 0.002	**0.0022**	**0.003**
		Effluent	0.0046	LT 0.002	LT 0.002	LT 0.002	LT 0.002

Notes:

None of the effluent results exceeded the EPA health advisory levels.

Bold values indicate an individual concentration exceeds the EPA health advisory level.

LT – Analyte was not detected and reported as less than the method reporting limit.

NA – Not applicable

Table 9.0-2. Perfluoroalkyl Substances Results for FY22 Groundwater Samples

Well ID	Sample Date	Analyte Concentrations and *Health Advisory Levels* (µg/L)					
		HFPO-DA *NA*	PFBS *2*	PFHxS *NA*	PFNA *NA*	PFOA *0.000004*	PFOS *0.00002*
Source Area Well							
01525	9/20/2022	LT 0.08	0.22	5.1	0.027	**0 .19**	**6.9**
Downgradient Wells							
36181	9/20/2022	LT 0.004	0.45	2.8	0.004	**0.14**	**0.41**
36210	9/20/2022	LT 0.004	0.039	0.54	0.0012 @	**0.025**	**0.032**
36627	9/20/2022	LT 0.04	0.042	0.5	LT 0.02	**0.036**	**0.18**
36631	9/20/2022	LT 0.04	0.041	0.48	LT 0.02	**0.044**	**0.17**

Notes:
Bold values indicate an individual concentration exceeds the EPA health advisory level.
LT – Analyte was not detected and reported as less than the method reporting limit.
NA – Not applicable
@ – Value is estimated

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Northwest Boundary Containment System – Treatment System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Primary Performance Criteria [2] – Original System	
Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Secondary Performance Criterion [2] – Original System	
If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends, based on annual evaluations, over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Secondary performance criterion is not applicable since primary performance criteria were achieved. Continued monitoring will be conducted to evaluate performance wells where CSRG/PQL exceedances occurred.
Northwest Boundary Containment System – Northeast Extension	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	No. Dieldrin and NDPA were detected above CSRGs/PQLs in downgradient performance wells 22015 and 22512, however, the long-term trends for dieldrin are not increasing in downgradient performance wells while NDPA, first detected in FY22 in well 22512, indicates an increasing trend. The potential for contaminated flow toward the downgradient performance wells will be further evaluated based on semiannual monitoring continuing through FY23.

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells.	No. NDPA was detected three times in well 22512 in FY22, all at concentrations exceeding the PQL. Concentrations indicate an increasing trend through FY22.
Northwest Boundary Containment System – Southwest Extension	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes
Demonstrate decreasing concentration trends or that concentrations are at or below the CSRGs/PQLs in downgradient performance wells.	Yes
North Boundary Containment System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	No. 1,4-dioxane concentrations exceeded the CSRG/PQL in plant effluent during the first, third, and fourth quarters of FY22, with the fourth quarter moving average exceeding the CSRG/PQL.
Primary Performance Criteria [2]	
Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	No. Well pair 23528/23535 showed a slight forward gradient during the fourth quarter FY22.
Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps, and evaluation of water quality data from performance water quality wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes. The potentiometric surface map and the evaluation of water quality data indicate plume edge capture at both ends of the system.

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Secondary Performance Criterion [2]	
If unable to maintain reverse hydraulic gradient due to factors beyond Army control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.	Yes. Analytes treated by the system, including dieldrin and NDMA, exceed CSRGs/PQLs and do not exhibit increasing trends.
Basin A Neck System	
Compliance Criterion	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the BANS (OCN-LTMP-2023-005).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes
Bedrock Ridge Extraction System Performance Criteria	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	Yes
Demonstrate decreasing or stable concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.	No. Concentrations of 12DCLE and trichloroethylene are above CSRGs in well 36566 and exhibit increasing trends. Evaluation of supplemental monitoring data resulted in a recommendation to include installation of one additional extraction well and one downgradient well as part of the future optimization of the system.

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Complex Army Disposal Trenches Performance Criteria	
Demonstrate groundwater elevations in performance monitoring wells 36216 and 36217 are below the target elevations of 5226 and 5227 ft, respectively, or Demonstrate hydraulic gradient from the performance monitoring wells locations is toward the extraction trench.	Yes. The CADT system met the performance criteria and objectives established in the LTMP. Although the water levels remained above the trench-bottom elevation in well 36217, hydraulic control was maintained at both performance well locations.
Maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).	Yes
Shell Disposal Trenches Performance Criterion	
Demonstrate groundwater elevations are below the disposal trench bottom elevations within the slurry wall enclosure listed in the 2021 LTMP, Table 5.2-2.	Yes. Groundwater elevation is below the bottom of trenches at all borehole locations.
Lime Basins Slurry Wall Dewatering System Performance Criteria	
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).	No. Outward gradient is present in wells on the north side of the slurry wall.
Maintain a groundwater level below the elevation of the Lime Basins waste (5242 feet) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).	Yes
Lime Basins DNAPL Remediation Monitoring Performance Criteria	
Primary Goals [3]	
To determine if additional DNAPL source zones exist in the Lime Basins area in addition to those previously identified.	Yes. No additional DNAPL source zones were identified based on measured DNAPL in wells.
To determine if the extent and nature of any discovered DNAPL source zones have the potential to adversely impact the slurry wall.	Yes. No adverse impacts to the slurry wall due to the presence of DNAPL have been observed.
To characterize DNAPL, if present, for the purpose of correlation with groundwater characterization data as a tool in the identification of DNAPL source zones and for the purpose of waste disposal.	Yes. DNAPL continues to be characterized.

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
First Creek Treatment System	
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the FCTS (OCN-LTMP-2023-004).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes
Northern Pathway Treatment System	
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Yes
Performance Criteria	
Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by combined well capture and transect methods for the NPTS (OCN-LTMP-2023-004).	Yes
Demonstrate that concentrations in downgradient performance wells are stable or decreasing.	Yes
Railyard Containment System	

Table 10-1. Summary of FY22 Compliance and Performance Criteria and Goals Achievement

LTMP Performance Criterion or Primary Goal [1]	Criterion or Goal Achievement
Compliance Criteria	
Demonstrate system compliance through effluent water quality monitoring to confirm that CSRGs are met. Compliance is based on running averages for the last four quarters, or one annual sample for those analytes that are not sampled quarterly.	Not Applicable. Annual shut-off monitoring concluded in FY22. The RYCS was shut off and demolished. Post-shut-off monitoring will commence in FY24.
Performance Criteria	
Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.	Not Applicable. Annual shut-off monitoring concluded in FY22. The RYCS was shut off and demolished. Post-shut-off monitoring will commence in FY24.
Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.	

Notes:

[1] Criteria and goals are listed as presented in the LTMP and reflect any changes in accordance with OCNs as indicated. Primary criteria are provided unless otherwise noted. For systems without primary/secondary criteria, all criteria must be met.

[2] Only the NWBCS and NBCS are bound to secondary performance criteria, and only if primary performance criteria are not met.

[3] There are no performance criteria for the Lime Basins DNAPL Remediation Monitoring program, but goals are specified in the LTMP.