Final RCRA Facility Investigation (RFI) Groundwater Work Plan Portions of Area IV under DOE Responsibility

Santa Susana Field Laboratory
Ventura County, California

Prepared for:

Department of Energy
4100 Guardian Street, Suite 160
Simi Valley, California 93063

Prepared by:

CDM Federal Programs Corporation (CDM Smith)

Prepared under:
US Department of Energy, EM Consolidated Business Center
Contract DE-EM0001128
CDM Task Order DE-DT0003515

November 9, 2015

Final RCRA Facility Investigation (RFI)
Groundwater Work Plan
Portion of Area IV under DOE Responsibility

November 9, 2015

Department of Energy
Energy Technology Engineering Center
4100 Guardian Street, Suite 160
Simi Valley, CA 93063

November 13, 2015

Mr. Mark Malinowski
California Department of Toxic Substances Control
8800 Cal Center Drive
Sacramento, CA 95826

Subject: Department of Energy (DOE) RCRA Facility Investigation Groundwater Work Plan Portions of Area IV under DOE Responsibility

Dear Mr. Malinowski:

Please find the Resource Conservation and Recovery Act (RCRA) Groundwater Facility Investigation (RFI) Work Plan for DOE's responsibilities within Area IV of the Santa Susana Field Laboratory (SSFL) describes the activities planned by DOE to collect and analyze information necessary to complete portions of the SSFL groundwater RFI necessary to revise the Site-Wide SSFL Groundwater Remedial Investigation (RI) Report. The work proposed herein is intended for partial completion of the Groundwater RFI that will be combined with efforts being implemented by Boeing and NASA to address deficiencies identified by DTSC.

This Work Plan has been developed to address in part Area IV data gaps that have been discussed with DTSC staff during technical working sessions sponsored by the DOE. This work plan presents the rationale and approach to data collection activities for portions of Area IV that are the responsibility of DOE.

I certify that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

Please find the DOE Groundwater RFI Work Plan for your review and approval. If you have any questions or concerns, please give me a call at (805) 416-0992. Best regards.

Sincerely,

John B. Jones, PMP
Director of DOE/ETEC

Cc: Stephanie Jennings, DOE/ETEC
Simon Lipstein, DOE/ETEC
Ray LeClerc, DTSC
Roger Paulson, DTSC
Tom Seckington, DTSC
Laura Rainey, DTSC
John Wondolleck, CDM-Smith

Final Work Plan

Draft RCRA Facility Investigation (RFI) Groundwater Work Plan
Portion of Area IV under DOE Responsibility
Santa Susana Field Laboratory
Ventura County, California

Contract DE-EM0001128
CDM Smith Task Order DE-DT0003515

y signed by Mike Hoffman
DN: US, E=hoffmanmj@cdmsmith.com,
M Smith, CN=Mike Hoffman
Rea n: I am the author of this document
014.05.29 14:53:42-07'00'

Reviewed by: ______________________________ ______________
Mike Hoffman, P.G. Date
CDM Smith Geologist

Reviewed by: ______________________________ 11/9/15
John Wondolleck Date
CDM Smith Project Manager

Contract DE-EM0001128
CDM Smith Task Order DE-DT0003515

Acknowledgements

Lynn France - RFI Site Evaluation

Mike Lamar – MNA Evaluation

Steve Fundingsland - FSDF Evaluation

Cherie Zakowski – Data Review

Dr. Bill Arnold, Sandia - Modeling and Sr-90 Input

Mike Hoffman – Document Review

Clint Werden - Document Review

Alletta Callaway - Document Production

Table of Contents

CDM Smith

Section 4 Area IV Groundwater Investigation Areas

Appendices

List of Tables

List of Figures

Acronyms

1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
aka	also known as
<	less than
AI	Atomic International
Am	americium
amsl	above mean sea level
AOC	Areas of Concern
ASER	Annual Site Environmental Report
AST	Above ground storage tank
Ba	barium
BEDMS	Boeing Environmental Data Management System
bgs	below ground surface
Boeing	The Boeing Company
BTV	background threshold value
C-8	Corehole-8
$CaCO_3$	calcium carbonate
CDM Smith	CDM Federal Programs Corporation
CHHSL	California Human Health Screening Levels
cis-1,2-DCE	cis-1,2-dichloroethene
Cl	chloride
Cm	curium
cm/s	centimeters per second
Co	cobalt
CO	Consent Order
COC	contaminant of concern
CO_2	carbon dioxide
Cs	cesium
CSIA	Compound Specific Isotope Analysis
CSM	conceptual site model
DCE	dichloroethene
Dhc	*Dehalococcoides spp.*
DL	detection limit
DO	dissolved oxygen
DOE	United States Department of Energy
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
ESADA	Empire State Atomic Development Authority
ETEC	Energy Technology Engineering Center
Eu	Europium
F-	Fluoride
FAL	Field Action Level
FEHM	Finite Element Heat and Mass Transfer Code
FLUTE™	Flexible Liner Underground Technologies

FSDF	Former Sodium Disposal Facility
ft	feet or foot
ft/ft	foot per foot
GETS	groundwater extraction treatment system
GIA	Groundwater Investigation Area
GIS	Geographic Information System
gpd	gallons per day
gpm	gallons per minute
GRC	Groundwater Resources Consultants
GSU	Geologic Services Unit
Guelph	University of Guelph
GWIM	groundwater interim measure
HEPA	high efficiency particulate air
HMSA	Hazardous Materials Storage Area
HWMF	Hazardous Waste Management Facility
K	potassium
K_b	bulk hydraulic conductivity
KEWB	Kinetics Experiment Water Boiler
K_m	hydraulic conductivity
LAGriT	Los Alamos Grid Tool Box
LANL	Los Alamos National Laboratory
LMEC	Liquid Metals Engineering Center
MCL	maximum contaminant level
µg/kg	microgram per kilogram
µg/L	microgram per liter
umho/cm	microhoms per centimeter
MDC	minimum detectable concentration
me/L	millimole per liter
mg/L	milligram per liter
mg/kg	milligram per kilogram
mL/g	milliliters per gram
Mn	manganese
MNA	monitored natural attenuation
MWH	MWH Americas, Inc.
NASA	National Aeronautics and Space Administration
NBZ	Northern Buffer Zone
NCY	New Conservation Yard
ND	non-detect
NO_2	nitrite
NO_3	nitrate
NORM	naturally occurring radioactive material
OCY	Old Conservation Yard
OEHHA	Office of Environmental Health Hazard Assessment
ORP	oxidation reduction potential
OS	off-site
OSWER	Office of Solid Waste and Emergency Response
%	percent

PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCR	polymerase chain reaction
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PDU	Process Development Unit
PEST	Model Independent Parameter Estimate and Uncertainty Analysis
pg/L	picogram per liter
PHG	Public Health Goal
ppb	parts per billion
Pu	plutonium
PZ	piezometer
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Groundwater Facility Investigation
RI	Remedial Investigation
RIHL	Rockwell International Hot Laboratory
RMHF	Radioactive Materials Handling Facility
RPT	reaction products tank
RTL	Reference Threshold Level
SAP	Sampling and Analysis Plan
SCTI	Sodium Component Testing Installation
SCTL	Sodium Component Testing Laboratory
Shall Drill	Shaw Portable Core Drill
Sn	tin
SNAP	Systems Nuclear Auxiliary Power
Sr-90	Strontium-90
SRE	Sodium Reactor Experiment
SSFL	Santa Susana Field Laboratory
SSME	Space Shuttle Main Engine
SVOCs	semi-volatile organic compounds
SWMU	solid waste management unit
TCA	trichloroethane
TCE	Trichloroethene
TDS	total dissolved solids
Te	tellurium
Th	thorium
TOC	total organic carbon
TPH	total petroleum hydrocarbon
U	uranium
UCL	upper confidence limit
UST	underground storage tank
VC	vinyl chloride
VOCs	volatile organic compounds
WBNS	Water Boiler Neutron Source
WQSAP	Water Quality Sampling and Analysis Plan

Section 1
Introduction

This Resource Conservation and Recovery Act (RCRA) Groundwater Facility Investigation (RFI) Work Plan for Department of Energy (DOE) responsibilities within Area IV of the Santa Susana Field Laboratory (SSFL) describes the activities planned by DOE to collect and analyze information necessary to complete portions of the SSFL Groundwater RFI necessary to revise the Site-Wide SSFL Groundwater Remedial Investigation (RI) Report (MWH, 2009; Groundwater RI (RFI) Report). The work proposed herein is intended for partial completion of the Groundwater RFI that will be combined with efforts being implemented by The Boeing Company (Boeing; Areas I, III, and IV) and the National Aeronautics and Space Administration (NASA; Areas I and II) to address deficiencies noted by the California Department of Toxic Substance Control (DTSC) on the 2009 Groundwater RI (RFI) Report. This Work Plan has been developed to address in part Area IV data gaps that have been discussed with DTSC staff during technical working sessions sponsored by the DOE. This Work Plan presents the rationale and approach to data collection activities for portions of Area IV that are the responsibility of the DOE.

This Groundwater RFI Work Plan incorporates an evaluation of solid waste management units and areas of concern for Area IV as presented in Attachment 4 of the 2007 Consent Order (CO). Attachment 4 names the solid waste management units and leach fields (also termed Areas of Concern) and identifies either DOE, NASA, or Boeing with the lead in investigation. The Work Plan also evaluates future groundwater monitoring needs. Upon acceptance of the work concepts and data collection approaches introduced in this document by DTSC, DOE will develop a Field Sampling and Analysis Plan that will describe the details of sampling methods and analytical protocols.

The Groundwater RFI Work Plan has been developed by CDM Federal Programs Corporation (CDM Smith) under contract with DOE. The Work Plan addresses investigative work deemed necessary to complete the Groundwater RFI for Area IV of the SSFL. The Work Plan summarizes the evaluation of historic and current data and site conditions that were evaluated in support of developing the recommendations for the final investigations for Area IV.

1.1 Relationship of Area Groundwater RFI Work Plan with SSFL Groundwater Regulatory Requirements, Planning Documents, and Reports

1.1.1 Regulatory Framework – 2007 Consent Order

This Groundwater RFI Work Plan has been developed to be consistent with the following regulatory framework:

- 2007 CO for Corrective Action, Docket No. P3-07/08-003, signed by Boeing, NASA, and DOE
- California Health and Safety Code Section 25187 and Section 25356

As noted above, the Groundwater RFI Work Plan incorporates an evaluation of solid waste management units and areas of concern for Area IV as presented in Attachment 4 of the 2007 CO and the groundwater impact areas introduced in the Groundwater Water Quality Sampling and Analysis Plan (WQSAP). Upon acceptance of the work concepts and data collection approaches introduced in this document by DTSC, DOE will develop a Field Sampling and Analysis Plan that will describe the details of sampling methods and analytical protocols.

1.1.2 2008 Groundwater Characterization Work Plan

In 2008, MWH released the *Work Plan, Site-Wide Groundwater Characterization, Santa Susana Field Laboratory.* This work plan was primarily a presentation of data collected prior to work plan release, site understanding, and proposed activities to evaluate the existing data for data gaps and site characterization purposes. The work plan primarily focused on solvent contamination in vadose and saturated zones. It also addressed an ongoing, three-phased approach to assessing groundwater seeps. The first phase was initiated in late 2006 and included collection of water samples from approximately 50 seeps. The second phase goal was to sample seeps in fall 2007 and assess which of the seeps are likely receiving groundwater originating from the SSFL. The third phase of seeps work involved evaluating whether COPCs originating from the SSFL could have reached a seep but have gone undetected as a result of local attenuation via volatilization, absorption or dilution (MWH, 2008). This work was scheduled to be completed after completion of the fall 2007 seeps and analysis work (second phase). In a memorandum dated April 28, 2009 (Tom Seckington to Gerald Abrams), DTSC staff stated that "The document, however, does not meet the expectations of the GSU [Geologic Services Unit of DTSC] and only minimally meets the requirement of the Consent Order." The DTSC memorandum concluded "Characterization of the groundwater at the site will require each of the contaminant plumes, including but not limited to identified TCE, tritium, or perchlorate plumes, need to be adequately assessed through the collection of field data. The site conceptual model should be limited as a guide for the characterization activities and remedy selection." Finally the memorandum recommended "that the Respondents submit a draft Sitewide Groundwater RI (RFI) Report and SAP, due on or before September 24, 2009 that will contain an extensive evaluation of the data collected from the site and substantial recommendations to address data gaps and the issues raised in this memorandum." In a letter dated June 2, 2009 from Tom Seckington (DTSC) to Allen Elliot (NASA), Tom Gallacher (Boeing), and Thomas Johnson (DOE), DTSC provided conditional approval to the work plan based on comments summited in the April 28 Memorandum (Seckington, 2009a).

1.1.3 2009 Groundwater RI Report (RFI Report)

In 2009, MWH released the *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. The focus of the Groundwater RI (RFI) Report was on general site-wide issues with specific references to Area I and II issues; however, it contained minimal reference to Area IV groundwater issues. DTSC provided comments on the Groundwater RI (RFI) Report on December 21, 2011 (Malinowski, 2011b). The following are DTSC's general comments on the Groundwater RI (RFI) Report and DOE's explanation on how they are being addressed in this RFI Work Plan.

1. The RI (RFI) Report is incomplete and is organized in a manner difficult to review.

   DOE agrees with DTSC's assessment that the 2009 Groundwater RI (RFI) Report is incomplete. Within Section 4.0 of this Work Plan, DOE provides greater details on groundwater issues for Area IV. DOE has organized this Work Plan around the primary groundwater issues identified by DTSC in its comments. Because bedrock and release conditions vary across Area IV, DOE has developed individual site conceptual models reflecting those conditions. The fieldwork proposed in this Work Plan will be combined with prior and ongoing work in other areas of SSFL to complete the Site-Wide Groundwater RFI for DOE portions of Area IV.

2. The transport of contaminants onsite and offsite cannot be predicted.

   DOE's proposal to update the flow and transport models for Area IV conditions are described in Section 7.0 of this Work Plan.

3. The impact of numerous faults at the site on the groundwater flow and contaminant movement is not supported by site-specific field data and is oversimplified.

   Section 6.0 of this Work Plan summarizes field work completed since the 2009 Groundwater RI (RFI) Report was released to define bedrock structures in Area IV, introduces field activities to continue fault evaluation, and recognizes cooperation with Boeing and NASA will be necessary to address Site-Wide fault issues.

4. There is insufficient characterization of release locations to determine if these areas can and/or should be remediated.

   Section 4.0 of this Work Plan provides descriptions of what is known about each potential groundwater release area for Area IV. Section 2.4 relates observed groundwater contamination with potential source areas in Area IV. Section 3.0 presents the data gap process (ongoing) that addresses potential release locations, well network, and groundwater analytes. Section 4.0 relates groundwater investigation areas with prior activities that may have contributed to groundwater contamination.

1.1.4 Groundwater Remedial Investigation Data Gap Sampling and Analysis Plan

In 2010, MWH released the Groundwater Remedial Investigation Data Gap Sampling and Analysis Plan (SAP). The SAP was based on data gaps enumerated in the 2009 Groundwater RI (RFI) Report. Data Gap activities described in the 2010 Data Gap SAP for Area IV were:

- Installation of a conventional groundwater monitoring well cluster, one shallow and one deep adjacent to the former Sodium Reactor Experiment (SRE) pond. Shallow well RS-36 (20 feet deep, screen interval 3-18 feet) and deep well RD-102 (100 feet deep, screen interval 30-100 feet) were installed in November 2011.
- Assessment of the former Sodium Disposal Facility (FSDF) Structures. Trenching work of two geological structures north of the FSDF that were artificially influencing groundwater flow model results. Trenching was performed January 2012. A Technical Memorandum presenting MWH findings was issued in May 2013. MWH concluded that there were no major north-south trending, through-going faults, or open fracture zones within the area investigated. DTSC agreed with the general conclusion presented in the report.
- Additional chemical analytes for groundwater sampling. Sampling for targeted analytes and wells proposed for the second and fourth quarter 2011 monitoring events.
- Additional seep reconnaissance and sampling.

DTSC provided conditional approval of the work plan on March 9, 2011 (Malinowski 2011). In the approval letter, DTSC provided recommendations for prevention of cross-contamination during and following wells installation, but specific comments were regarding planned activities in other areas of SSFL.

1.1.5 Groundwater RI (RFI) Completion Approach

In a letter dated March 19, 2012 from Mike Bower (Boeing) to Mark Malinowski (DTSC), Boeing outlined its ongoing process for addressing DTSC comments on the 2009 Groundwater RI (RFI) Report. Activities being implemented at that time included development of data quality objectives for data gap identification, source area and plume characterization, seeps evaluation, fault studies, groundwater model revisions, and contaminant transport modeling. DTSC approved the RI (RFI) completion approach in a letter from Mark Malinowski to Mike Bower dated April 3, 2012. This Groundwater RI (RFI) Work Plan for Area IV is structured around this groundwater RFI completion approach. Section 3.0 presents the data gap process, Section 4.0 evaluates groundwater impact areas and sources, Section 5.0 addresses seeps and springs, Section 6.0 addresses faults, and Section 7.0 addresses flow and transport modeling.

1.1.6 Seeps and Springs Work Plan

Under contract to Boeing, the University of Guelph (Guelph) conducted seeps investigations for the SSFL including Area IV. In May 2012, Guelph issued a progress report of its activities during 2011 that included the installation of two seep wells at the SP-19 location in the North Buffer Zone (NBZ) to the north of Area IV (Pierce, Parker, and Cherry, 2012a). On August 31, 2012, the Guelph issued the *Work Plan for Completion of Springs Investigation at the Santa Susana Field Laboratory, Ventura County, California* (Pierce, Parker, and Cherry, 2012b). The Seeps Work Plan addressed the following issues related to seeps site-wide:

- Identification of persistent groundwater discharge features through additional seeps reconnaissance.
- Characterization of the hydrogeochemistry and isotopic signatures of discharge water.
- Determination of presence of site-related chemicals at discharges.
- Installation of seep monitoring wells.

In a letter from Roger Paulson (DTSC) to Mike Bower dated December 11 2012, DTSC approved the Seeps Work Plan. Guelph issued a progress report in October 2014 presenting results of its investigations related to Area IV (Pierce, Parker, Cherry, and Wagner, 2014). The results of implementing this work related to Area IV are described in Section 5.0 of this Work Plan along with recommended additional seeps work.

1.1.7 Groundwater Model Work Plan

In May 2013, Boeing submitted to DTSC the *Proposed Numerical Flow Modelling Work Plan in Response to DTSC Comments on the Draft SSFL Site-Wide Groundwater RI Report* (Aqua Resources, 2013). This work plan described the approach to addressing DTSC comments on the Groundwater RI (RFI), development of model criteria, strategies to reduce model simulation time, evaluation of flow sensitivity to model base, update of the structural model using recent field work results, optimization of the updated model updated flow analysis, probability-based uncertainty analysis of flow directions, evaluation of 2013 field work results for consistency with existing model, monitoring well network evaluation, and preparation of an updated Appendix 6A for the revised Groundwater RI (RFI) Report. This proposed work primarily addressed the 'mountain-scale' numerical model. DTSC provided comments on this work plan on May 21, 2013 (letter from Roger Paulson [DTSC] to Mike Bower [Boeing]). In the letter, DTSC requested that Boeing revise and finalize the work plan per comments attached to the letter.

DOE will be updating the existing model code to address groundwater contaminant issues specific to Area IV. Section 7.0 of this Work Plan describes those activities.

DTSC provided conditional approval of the groundwater modeling work plan on September 17, 2013 (R. Paulson, 2013).

1.1.8 DTSC Geologic Service Unit Comments on RFI Group Reports

Staff of DTSC's GSU provided comments on three of the four RFI Group Reports involving Area IV. These include the Group 5, Group 6, and Group 8 reports. Listed below are the reports and dates of the DTSC GSU comment documents:

- Group 5 – Central Portion of Areas III and IV RCRA Facility Investigation Report Santa Susana Field Laboratory, Ventura County, California (MWH, 2008). DTSC comments were submitted in memorandum from Tom Seckington to Gerard Abrams, January 25, 2010 (Seckington, 2010).
- Group 6 – Northeastern Portion of Area IV RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California (MWH, 2006). DTSC comments were submitted in memorandum from Tom Seckington to Gerard Abrams, January 23, 2008 (Seckington, 2008a).
- Group 8 – Western Portion of Area IV RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California (MWH, 2007). DTSC comments in memorandum from Tom Seckington to Gerard Abrams, December 10, 2008 (Seckington, 2008b).

Group 5 RFI Report

The GSU memorandum noted numerous data presentation issues relative to groundwater characterization. The majority of the comments apply to well data presentations for wells not within Area IV. However, these comments were considered during data gap evaluations that are discussed in Section 4.0 of this Work Plan.

Group 6 RFI Report

The GSU memorandum addressed several characterization issues related to the area of the former SRE. The first was shallow groundwater occurrence in the area, including the need to install shallow monitoring wells to identify the presence of groundwater that once seeped into the reactor building pits. Those wells have been installed. The second relates groundwater quality data presentation, particularly in relation to metals.

Group 8 RFI Report

The GSU memorandum commented on Chatsworth and perched groundwater flow, geologic structures potentially affecting flow, and groundwater quality results. DTSC recommended additional wells to be installed downgradient of the B4009 leachfield and between RD-57 and RD-74 to delineate TCE plumes in that area.

1.2 SSFL Facility Information

This section only addresses facility descriptive information related to Area IV of SSFL. For a description of the entirety of SSFL and its history, the reader is referred to the 2009 Groundwater RI (RFI) Report (MWH, 2009).

The SSFL is located approximately 29 miles northwest of downtown Los Angeles, California in southeastern Ventura County (**Figure 1-1**). Area IV occupies 290 acres of the western portion of SSFL, which is 2,850 acres in size (**Figure 1-2**). Boeing owns all of Area IV and leased a 90-acre section of Area IV to DOE for DOE's Energy Technology Engineering Center (ETEC) (**Figure 1-3**). During the period that Area IV was operational (1955 to 2000), DOE owned some of the buildings in Area IV, but operations and maintenance of DOE research activities was conducted under contract with Rocketdyne, a predecessor to Boeing. Boeing shares responsibilities with DOE for the investigation and cleanup of groundwater within Area IV as outlined in Attachment 4 of the 2007 CO.

SSFL was established in 1948 for the testing of rocket engine components. In 1953, the Atomics International Division of North American Aviation acquired Area IV for nuclear energy research activities. Nuclear research was conducted from 1955 to 1988. Non-nuclear and liquid metals research occurred within Area IV until about 2000. When the mission of each research activity was completed, the buildings and facilities that housed the research were subject to decommissioning, decontamination, and in many instances, demolition. At one time there were over 200 numbered structures within Area IV. In January 2015, only about 15 structures remain (11 DOE and 4 Boeing-owned structures). Section 4 of this Work Plan provides summaries of activities within Area IV that potentially led to groundwater contamination.

1.3 SSFL Land Use

Currently the area surrounding SSFL, including Area IV, is zoned by Ventura County as open space (OS-160). SSFL property has a special use permit for industrial use under its current zoning of rural agricultural (RA-5)(MWH, 2009). Prior to use for rocket component testing and energy research, SSFL was used for ranching and grazing.

Land immediately adjacent to Area IV is open space. The nearest established residential community (Bell Canyon) is located 2 miles to the southeast and it does not border Area IV (**Figure 1-1**). The Runkel Canyon residential development is located about 1.5 miles to the northwest. The adjacent property to the north of Area IV is occupied by the American Jewish University Brandeis Bardein Campus and is zoned as open space by Ventura County. Land to the west and south of Area IV is designated open space, portions of which are used for cattle grazing. SSFL Area III, once used for rocket component testing, borders Area IV to the east.

1.4 Work Plan Scope and Objectives

This Work Plan presents the results and recommendations of a groundwater data gap evaluation related to DOE 2007 CO responsibilities that was conducted to evaluate the adequacy of existing information in support of determining completeness of the Groundwater RFI and to identify where information (data gaps) was missing and necessary to complete the RFI. Based on the data evaluation, this Work Plan presents the rationale and approach for data collection to fill identified data gaps. The Work Plan also addresses the activities that DOE is implementing to answer questions raised by DTSC during review of the 2009 Groundwater RI (RFI) Report (MWH, 2009) in terms of seeps and springs, faults, and flow and transport modeling specific to Area IV. The findings from the data collection activities described in this RFI Work Plan will be presented in the Area IV section of the revised SSFL Groundwater RFI Report.

This Work Plan incorporates groundwater data collected during DOE's February 2014 groundwater sampling event.

1.5 Organization of Work Plan

The Area IV Groundwater RFI Work Plan contains nine sections:

- **Section 1 Introduction** – Provides scope and objectives of the Area IV Groundwater RFI Work Plan and summarizes historical information and adjacent land use.
- **Section 2 Area IV Geology, Hydrology, Monitoring Well Network and Groundwater Contamination Review** – Summarizes Area IV geology, hydrogeology, prior investigation results, and operational impacts to groundwater.
- **Section 3 Groundwater Data Gaps Process** – Describes the questions asked during the evaluation of groundwater sampling data, well network adequacy, and input sources used to inform the groundwater sampling program and identify additional data needs.
- **Section 4 Area IV Groundwater Investigation Areas** – Describes historical operations, potential source locations, groundwater investigations, and water quality trends for 19 investigation areas throughout Area IV (these investigation areas are introduced in Section 2.3). Section 4.0 also includes recommendations for completing groundwater characterization at each location.
- **Section 5 Seeps and Springs** – Documents Area IV-related seeps and springs surveys and sampling conducted through February 2014 and provides recommendations for additional seep and spring sampling work.
- **Section 6 Fault Studies** – Presents proposed work for investigating whether the Burro Flats Fault and the Sodium Reactor Experiment-Radioactive Materials Handling Facility (SRE-RMHF) lineament may have an influence on plume movement in Area IV.
- **Section 7 Flow and Transport Modeling** – Describes modeling updates needed to incorporate Area IV-specific parameters into the SSFL Flow and Transport models.
- **Section 8 Monitored Natural Attenuation** – Describes the approach and proposed data for monitored natural attenuation (MNA) evaluation.
- **Section 9 Area IV Groundwater Work Scope** – Provides a summary of the proposed Area IV groundwater sampling and characterization work needed to complete the Groundwater RFI.

References

Aqua Resources, 2013. *Proposed Numerical Flow Modelling Work Plan in Response to DTSC Comments on the Draft SSFL Site-Wide Groundwater RI Report*. May.

CH2MHill, 2008. *Group 5 – Central Portion of Areas III and IV RCRA Facility Investigation Report Santa Susana Field Laboratory, Ventura County, California*. November.

Malinowski, M., 2011a. Letter from Mark Malinowski (DTSC) to Michael Bower (Boeing). *DTSC Comments and Conditional Approval to Implement Groundwater Remedial Investigation Data Gap Sampling and Analysis Plan, Santa Susana Field Laboratory, Ventura County, California.* March 9.

Malinowski, M. 2011b. Letter from Mark Malinowski (DTSC) to Tom Gallacher (Boeing). *Department of Toxic Substances Control Comments on the Sitewide Groundwater Remedial Investigation Report for Santa Susana Field Laboratory, Ventura County, California.* December 11.

MWH 2006. *Group 6 – Northeastern Portion of Area IV RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California.* September.

MWH 2007. *Group 8 – Western Portion of Area IV RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. September.

MWH 2008. *Work Plan, Site-Wide Groundwater Characterization, Santa Susana Field Laboratory, Ventura County California*. January.

MWH 2009. *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory, Ventura County, California.* December.

MWH 2010. *Groundwater Remedial Investigation Data Gap Sampling and Analysis Plan*. March

MWH 2013. *Results of Geologic Mapping and Excavations along the Western and Eastern FSDF Structures (Photolineaments) Area IV*. May.

Paulson, R., 2012. Letter from Roger Paulson (DTSC) to Mike Bower (Boeing*). Approval of Workplan for Completion of Seeps and Springs Investigation at the Santa Susana Field Laboratory, Ventura County, California*. December 11.

Paulson, R., 2013. Letter from Roger Paulson (DTSC) to Mike Bower (Boeing). *Proposed Numerical Flow Modelling Work Plan in Response to DTSC Comments on the Draft SSFL Site-Wide Groundwater RI Report Santa Susana Field Laboratory, Ventura County, California*. September.

Pierce, A., B. Parker, and J. Cherry, 2012a. Technical Memorandum, Seeps and Springs Study, Installation of Well Clusters: Overview of 2011 Field Work. May 7.

Pierce, A., B. Parker, and J. Cherry, 2012b. *Work Plan for Completion of Seeps and Springs Investigation at the Santa Susana Field Laboratory, Ventura County, California*. August 31.

Pierce, A., B. Parker, J. Cherry, and R. Wagner, 2014. *Technical Memorandum Area IV Seeps Investigation, Santa Susana Field Laboratory, Ventura County California, Summary of Work Completed in 2011 - 2014*. October 28.

Seckington, T., 2008a. Memorandum to Gerard Abrams, Group RI 6 RFI Report. January 23, 2008

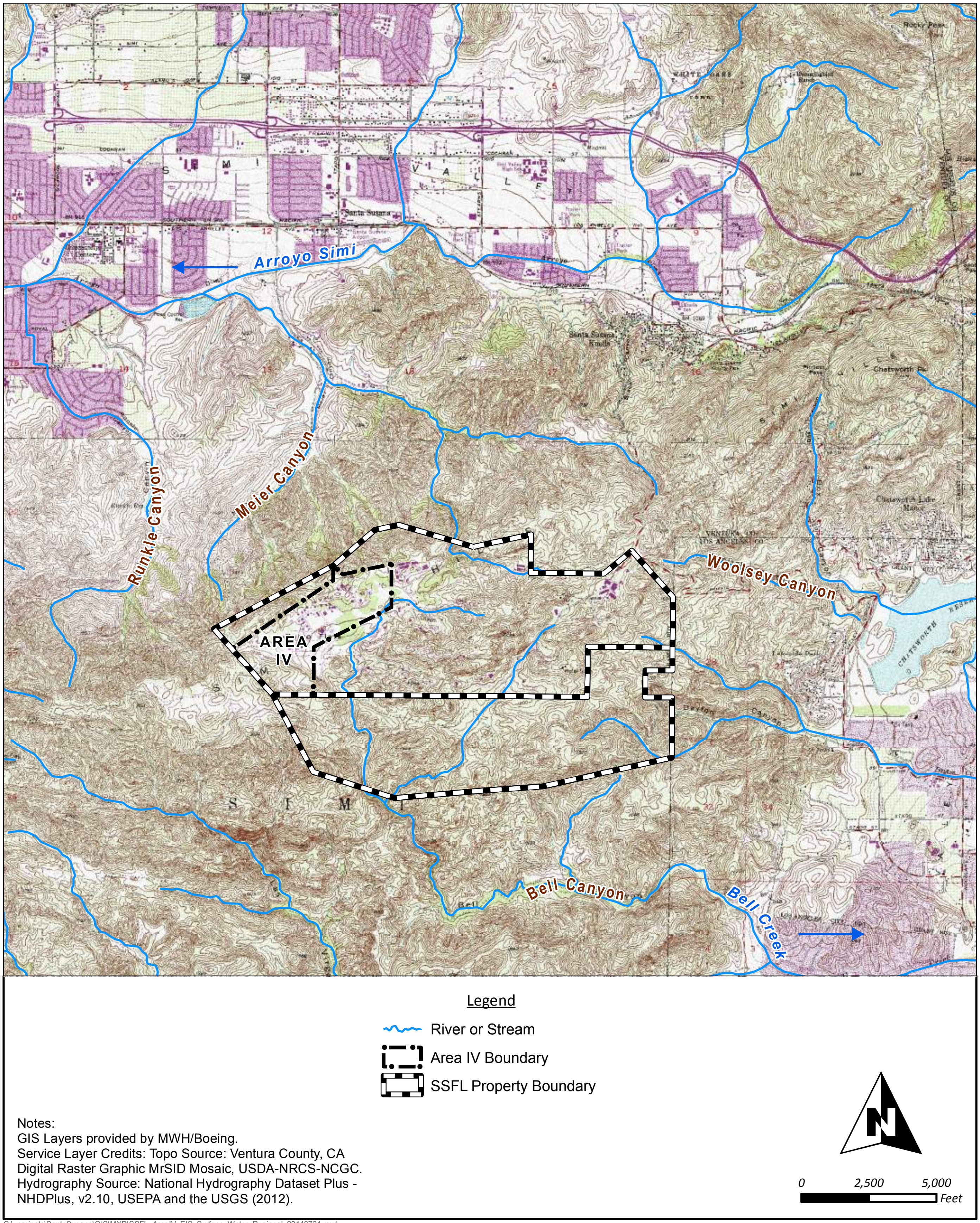
Seckington, T., 2018b. Memorandum to Gerard Abrams, Group RI 8 RFI Report. December 10, 2008.

Seckington, T. 2009a. Letter from Tom Seckington (DTSC) to Allen Elliot (NASA), Tom Gallacher (Boeing), Thomas Johnson (DOE), *Review of Work Plan, Site-Wide Groundwater Characterization, Santa Susana Field Laboratory, January 2008*. Memorandum with comments attached. April 28.

Seckington, T. 2009b. Letter from Tom Seckington (DTSC) to Allen Elliot (NASA), Tom Gallacher (Boeing), Thomas Johnson (DOE), *Conditional approval of Site-Wide Groundwater Characterization Work Plan, Santa Susana Field Laboratory, January 2008*. Memorandum with comments attached. June 2

Seckington, T., 2010. Memorandum to Gerard Abrams, Group RI 5 RFI Report. January 25, 2010.

This page intentionally left blank.

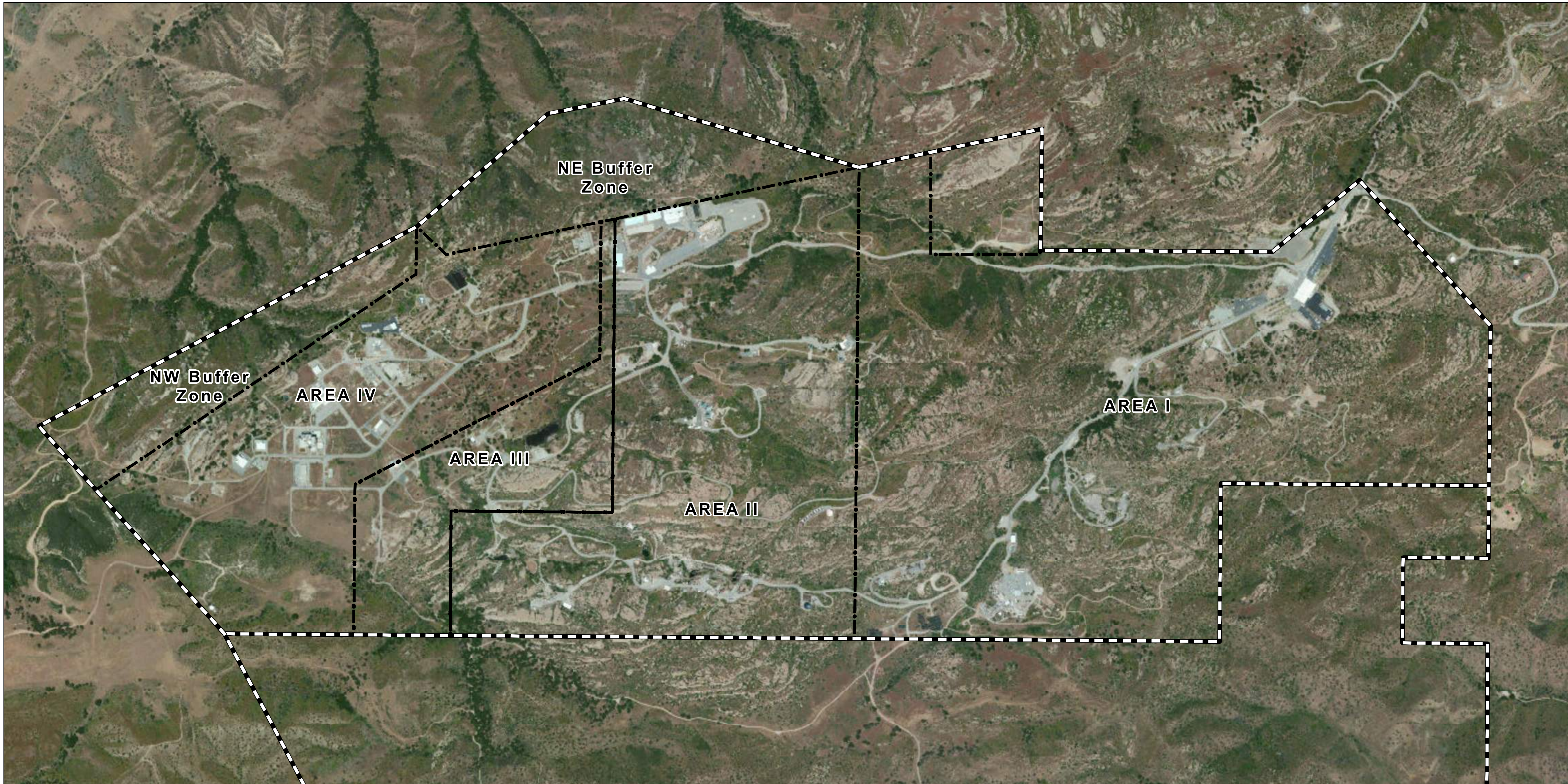


Notes:
GIS Layers provided by MWH/Boeing.
Service Layer Credits: Topo Source: Ventura County, CA
Digital Raster Graphic MrSID Mosaic, USDA-NRCS-NCGC.
Hydrography Source: National Hydrography Dataset Plus - NHDPlus, v2.10, USEPA and the USGS (2012).

C:_projects\SantaSusana\GIS\MXD\SSFL_AreaIV_EIS_Surface_Water_Regional_20140731.mxd

CDM Smith

FIGURE 1-1
SSFL Regional Setting



LEGEND

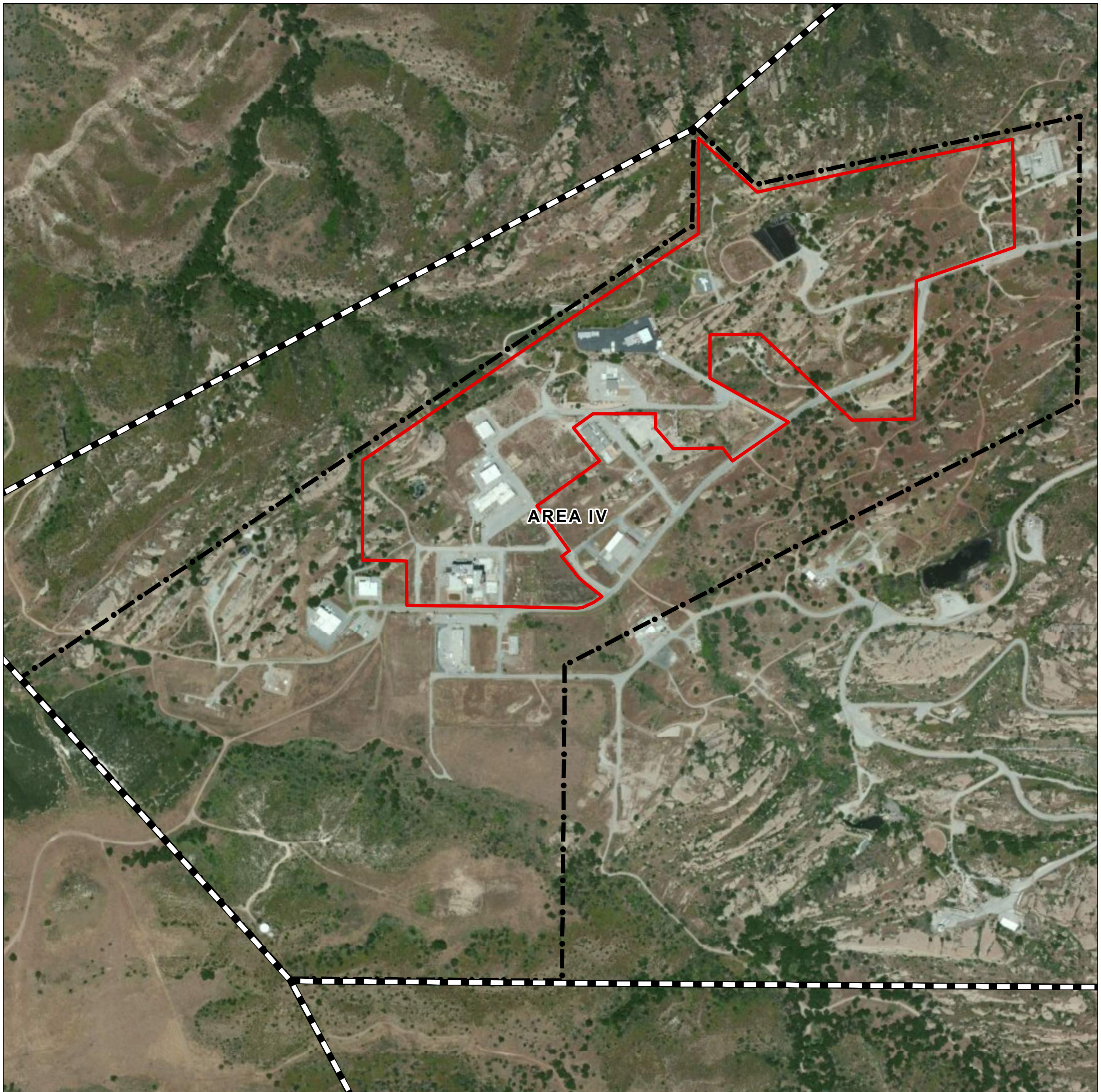
Site Area Boundary   SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

0 600 1,200 Feet

C:_projects\SantaSusana\GIS\MXD\EIS\SSFL_Site_Areas_20150108.mxd 1/8/2015

FIGURE 1-2
SSFL Site Area Designations



Notes:
- GIS Layers provided by MWH/Boeing.
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

C:_projects\SantaSusana\GIS\MXD\EIS\SSFL_AreaIV_ETEC_Boundary_20141024.mxd

CDM Smith

FIGURE 1-3
ETEC Boundary

Section 2

Area IV Geology, Hydrogeology, Monitoring Well Network, and Groundwater Contaminant Review

2.1 Area IV Geology and Hydrogeology

2.1.1 Area IV Topography

Area IV of the Santa Susana Field Laboratory (SSFL) is located in the Simi Hills, a northeast/southwest trending sub-range of the Santa Monica Mountains, located in the Transverse Ranges physiographic province of California. The topography of Area IV (**Figure 2-1**), including the Northern Buffer Zone (NBZ), ranges between 1,300 feet above mean sea level (amsl) within the NBZ and 2,150 feet amsl along the southwestern boundary of Area IV. Along the northwestern boundary of Area IV, the land slopes steeply towards Simi Valley. The central portion of Area IV, where the majority of development occurred, is relatively flat and is named Burro Flats.

2.1.2 Area IV Geology

There are two geologic formations that underlie Area IV: the Chatsworth Formation and Santa Susana Formation.

The Cretaceous Period (65 to 140 million years ago) Chatsworth Formation underlies about 80 percent of Area IV and consists primarily of over 6,000 feet of massive thickly-bedded sandstone with lesser amounts of interbedded shale, siltstone, and conglomerate (**Figure 2-2**). The Chatsworth Formation is divided into an upper and lower unit. The Lower Chatsworth Formation is exposed (or outcrops) only in the southeastern portion of SSFL. The Upper Chatsworth Formation is subdivided into upper and lower stratigraphic "packages" referred to as Sandstone 1 and Sandstone 2, respectively. Area IV is primarily underlain by Sandstone 2, which comprises three coarser-grained members separated by two finer-grained members. These members from oldest to youngest are: Silvernale, SPA, Lower Burro Flats, ELV, and Upper Burro Flats. The finer-grained members (the SPA and ELV members) contain at least 50 percent siltstone or shale interbedded with sandstone. A third thinner and less continuous fine-grained unit, the Lot Bed, is found in the lower section of the Upper Burro Flats member in the northwest part of Area IV.

At SSFL, the Santa Susana Formation is only found in the southern portions of Area IV and southwestern-most Area III (**Figure 2-2**). The Santa Susana Formation is separated from the Chatsworth Formation by the Burro Flats Fault. The formation is lower Eocene and Paleocene in age and according to *Geologic Map of the Calabasas Quadrangle* (Dibblee, 1992), comprises four mappable units. The uppermost (youngest) outcrops in Area IV and consists of gray micaceous claystone and siltstone with few minor thin sandstone beds.

2.1.3 Area IV Geologic Structure

SSFL is located on the south flank of an approximately east-west striking, westward plunging syncline. Beds of the Chatsworth Formation in Area IV strike approximately N70°E and dip 25 to 30 degrees to the northwest. There are three categories of geologic structures present at SSFL: faults/fault zones, deformation bands, and lineaments. Lineaments are features that have been identified from aerial photographs that are not definable as faults or deformation bands due to the lack of exposure on the surface (MWH, 2009). The Burro Flats fault, the dominant structural feature in Area IV, places the Chatsworth Formation in structural contact with the Santa Susana Formation in the southwest portion of Area IV. Two parallel north-south trending lineaments (**Figure 2-2**) have also been identified in the western portion of Area IV at the Former Sodium Disposal Facility (FSDF). These lineaments were investigated by MWH (2013a) and determined not to be fault structures. A third lineament, called the Sodium Reactor Experiment-Radioactive Materials Handling Facility (SRE-RMHF) lineament in this Work Plan, is an east-west lineament that roughly follows the drainage from the RMHF and the drainage from the SRE.

Fractures and joints are prevalent throughout the Chatsworth Formation and may be important conduits for groundwater and contaminant movement. A study of approximately 1,000 joints found in the Chatsworth Formation at SSFL (Wagner and Perkins, 2009) found that about 70 percent of the joints belonged to one of two "sets"; one set trends to the northwest and the other to the northeast. Both joint sets dip steeply (greater than 60 degrees). Less than 2 percent of the joints observed in outcrops dipped at less than 30 degrees. However, water-producing open fractures along bedding planes have also been observed in geophysical borehole logs.

2.1.4 Area IV Soils

Bedrock is exposed at the ground surface over a significant portion (about 40 percent) of Area IV and the NBZ; i.e., there is no soil in these areas. The parent material of the soil that covers the remainder of Area IV is the weathered bedrock, colluvium, and alluvium derived from both the Chatsworth and Santa Susana Formations. Although a thin veneer (5 to 10 feet thick) covers much of Burro Flats, soil in Area IV can be up to 20 feet thick. Alluvial soil is also found at the base of hill slopes, topographic lows, and along stream drainages.

2.1.5 Area IV Hydrogeology

Groundwater beneath Area IV occurs as:

- Near-surface perched groundwater in the alluvial soil and/or weathered bedrock that is not in direct connection with bedrock groundwater,
- Near-surface groundwater in the alluvial soil and/or weathered Chatsworth Formation bedrock that has connection with bedrock groundwater, and
- Chatsworth Formation groundwater in the unweathered Chatsworth Formation bedrock.

All groundwater units are directly or indirectly recharged by precipitation; typical rainfall at SSFL is 18.6 inches per year. The rate of groundwater recharge by rainfall is dependent on surface geology, local topography, and vegetation. It is estimated that average recharge is less than 2 inches per year (MWH, 2009); therefore, the majority of precipitation evaporates, is taken up by plants, or is lost as runoff. The near-surface groundwater zone is replenished by infiltration from rain and this water eventually passes through the shallow groundwater zone to replenish the Chatsworth Formation groundwater (MWH, 2009). However, the winters of 2013, 2014, and 2015 have been dryer than normal resulting in less recharge and the reduced presence of the near surface groundwater within Area IV.

The topographic setting of SSFL, on a ridge, creates a "groundwater ridge;" i.e., a ridge of near surface groundwater that mimics the terrain topography (compare **Figure 2-1** Topographic Map with **Figure**

2-3 Groundwater Elevation Map). As rainwater recharges both hydrologic units, it flows downward through the vadose zone until it encounters groundwater or an impermeable layer. Infiltrated groundwater then moves outward from the ridge. Groundwater is removed from the hydrogeologic system through discharge via groundwater seeps and springs, and uptake by plants. Area IV groundwater discharges from seeps that are found on the slopes northwest of the NBZ.

The groundwater elevation contour map for first quarter 2014 (**Figure 2-3**), shows the "ridge" of groundwater in the Burro Flats of Area IV. A northeast/southwest trending groundwater divide is evident on this figure: groundwater on the northwestern side of the divide moves vertically downward and laterally to the northwest while groundwater on the southeastern side of the divide migrates vertically downward and then laterally to the southeast.

There are two areas of perched groundwater of significance in Area IV; one occurring below the FSDF site and the other in the vicinity of the Hazardous Materials Storage Area (HMSA). The significance of these two perched areas is described in Section 4.0.

Near-surface groundwater beneath portions of Area IV can exist in the alluvium and weathered bedrock that sits on the bedrock. Generally the near-surface groundwater in Area IV is found along drainage features and near the outcrop of the fine-grained members of the Chatsworth Formation. The fine-grained shale members (i.e., SPA and ELV members) are less permeable than the sandstone members and, therefore, are more likely to develop a shallow water table.

The extent of near-surface groundwater varies considerably depending on the amount of precipitation. A comparison of water levels in near-surface groundwater wells in April 2011, a "wet" period, to those in February 2014, a "dry" period, is shown on **Figures 2-4 and 2-5**, respectively. During the wet period there is a larger area of near-surface groundwater occurring in Burro Flats.

Groundwater enters the Chatsworth Formation (sandstone bedrock) through infiltration from the near-surface groundwater. Chatsworth Formation groundwater is found within pore spaces between grains of rock (primary porosity) and in the open fractures (secondary porosity). The effective porosity of the rock matrix, the interconnected pore spaces, is about 14 percent of the rock. By comparison, the secondary porosity (space in the interconnected fractures) is much smaller; about 0.01 percent (MWH, 2009). Groundwater storage in the Chatsworth Formation primarily occurs within the sandstone matrix porosity (about 14 percent) while groundwater flow occurs primarily through fractures (0.01 percent).

Hydraulic conductivity is the proportionality constant that describes the ease with which water can move through pore spaces and/or fractures. Hydraulic conductivity depends on the permeability of the rock and on the degree of saturation. Both matrix and bulk hydraulic conductivity measurements for the Chatsworth Formation have been made across SSFL.

Matrix hydraulic conductivity is a measurement of the unfractured rock including the interconnected open pore spaces between the grains of rock. The matrix hydraulic conductivity for the Burro Flats Member of the Upper Chatsworth Formation has been estimated from measurements of unfractured core samples to range between 1×10^{-7} and slightly less than 1×10^{-6} centimeters per second (cm/s) (MWH, 2009).

Bulk hydraulic conductivity is a measure of the matrix hydraulic conductivity plus the influence of other lithologic features, primarily of fractures. Bulk hydraulic conductivity for the Sandstone 2 members (Burro Flats, ELV, Spa, and Silvernale) has been estimated between 8.3×10^{-8} cm/s and 8.1 x

10^{-5} cm/s. DOE will use data for Corehole 8 (see Subsection 4.1, FSDF) for discussion of work related to Corehole 8.

The bedrock overall provides for low bulk hydraulic conductivities that would be resistive to groundwater movement. However, the bedrock fractures appear to be interconnected horizontally and vertically. The bedding parallel fractures and joints are hydraulically active with evidence of fracture interconnectivity.

Where multiple wells are located close together but are open at different depths, the change in vertical gradients, with depth, can be observed. Cluster-well hydrographs are used to illustrate the vertical hydraulic gradient at each location within Area IV. **Table 2-1** provides the average, minimum, and maximum vertical gradients for each cluster calculated as the difference in head divided by the vertical distance between open-interval (i.e., screened or uncased) mid-points (MWH, 2009).

Cluster wells RD-33ABC, RD-34ABC, and RD-54ABC monitor the Upper Burro Flats Member hydrogeologic unit (**Figure 2-2 and 2-6**). These three-well clusters are located at the top of the northwest-sloping escarpment that forms the border of the Burro Flats plateau. Recharge occurring on the plateau results in fairly strong downward hydraulic gradients in the shallower part of the flow system from the A to B zones, with head drops of up to 100 feet and gradients ranging from -0.1 to -0.8 foot per foot (ft/ft). The A and B zones of these cluster wells are generally located in the stratigraphically higher part of the Upper Burro Flats Member hydrogeologic unit. The C zones of these well clusters generally have higher heads related to recharge in the updip outcrops of the statigraphically lower parts of the flow system, resulting in upward gradients ranging up to +0.3 ft/ft (MWH, 2009). Vertical anisotropy and intervening fine-grained beds, such as the Lot Bed, result in semi-confined conditions in the lower part of the Upper Burro Flats Member hydrogeologic unit at deeper locations downdip of the recharge location.

Cluster well RD-59ABC monitors the Shale 3 hydrogeologic unit. The cluster is located below the escarpment with groundwater flow from the mountain resulting in a generally upward gradient (MWH, 2009). Upward gradients range from 0.2 to 0.5 ft/ft in the A zone. The heads of B and C are above the ground surface and result in flowing artesian conditions (MWH, 2009).

Vertical gradients observed in Area IV Flexible Liner Underground Technologies (FLUTe™) multilevel system wells are shown Table 2-2. RD-21, RD-33A, RD-50, and RD-57 exhibited little head change over the Upper Burro Flats Member monitored. Wells RD-23, RD-54A, RD-65 had head declines ranging from 25 to 50 feet and a fairly gradual downward gradient of -0.3 ft/ft (MWH, 2009).

The conceptual model describing how contaminants move in Area IV groundwater from releases at the surface is summarized. Trichloroethene (TCE) that was once present in ponds (e.g., at the FSDF) from chemical releases, leach fields, or in soil from leaks or spills would dissolve into precipitation infiltrating through the soil, and migrate to the near-surface groundwater. Once in the groundwater, dissolved TCE will migrate with groundwater flow, which is initially downward into the bedrock. TCE-contaminated near surface groundwater would migrate into the low-permeability zone of the underlying weathered and competent rock and into the Chatsworth Formation through fractures in the competent rock. Contaminated groundwater within fractures would move laterally and vertically depending on the orientation of the fractures. Within the fractures, some TCE molecules could then diffuse into the bedrock matrix and once in equilibrium with the fractures, diffuse out from the matrix. Groundwater data collected for RD-63 near the RMHF indicate that diffusion from the matrix has been occurring since cessation of groundwater pumping 20 years ago (see Subsection 4.7).

Table 2-1. Vertical Hydraulic Gradients

Well ID	Monitored Hydro-geologic Unit	Approx GSE (ft amsl)	Open Interval (ft bgs)			Period of Record	Mid-Point of Open Interval Below Water Table (ft)*			Inter-val	Difference in Hydraulic Head (ft)			Vertical Hydraulic Gradient (ft/ft)			Dates	
			Top	Bot	Mid-Pt		Avg	Min	Max		Avg	Min	Max	Avg	Min	Max	Min	Max
RD-33A	Upper Burro Flats Member	1,793	100	320	210	12/91-01/09	263	260	266	A - B	-84	-96	-71	-0.7	-0.8	-0.6	05/98	12/91
RD-33B			360	415	388	12/91-07/09				B - C	0.2	-2.3	2.5	0.002	-0.02	0.02	08/07	08/97
RD-33C			480	520	500	12/91-07/09												
RD-34A	Upper Burro Flats Member	1,762	16	60	38	09/91-07/09	48	57	37	A - B	-8	-22	4.8	-0.05	-0.1	0.03	02/04	08/93
RD-34B			180	240	210	09/91-07/09				B - C	35	0.1	56	0.2	0.0004	0.3	03/93	02/04
RD-34C			380	450	415	09/91-07/09												
RD-54A	Upper Burro Flats Member	1,842	119	278	199	11/93-01/09	220	215	224	A - B	-93	-112	-68	-0.5	-0.6	-0.4	05/95	11/93
RD-54B			379	437	408	11/93-07/09				B - C	23	10	32	0.1	0.05	0.2	07/08	05/94
RD-54C			558	638	598	09/93-07/09												
RD-59A	Shale 3	1,341	21	58	40	11/94-08/09	43	42	42	A - B	61	28	81	0.4	0.2	0.5	12/03	11/02
RD-59B	Upper Burro Flats Member		178	209	194	11/94-08/09				B - C	2.4	-1.7	8.7	0.01	-0.01	0.05	02/02	08/95
RD-59C			346	397	371	02/95-08/09												

* Corresponds to time of minimum and maximum vertical hydraulic gradient measurements; some anomalous head spikes omitted from vertical gradient calculations.
ft = feet/foot
ft bgs = feet below ground surface
amsl = above mean sea level
GSE = ground surface elevation

Source: Table 6-5 (MWH, 2009)

0.4	Upward (positive value)
0.002	Small to neutral (<0.01 ft/ft)
-0.7	Downward (negative value)

Table 2-2. FLUTe Well Gradient Data

Well ID	Dates Measured	Observed Vertical Gradients [a]		
		Direction	Characteristics	Approx. Magnitude (ft/ft)
RD-07			No data loggers installed.	
RD-21 [b]	02/5/03 - 12/19/08	~ None	Little head change in Upper Burro Flats Member (if data from faulty transducer are not considered).	
RD-23	03/19/03 - 01/13/09	Down	~ 25 feet head decline over ~ 80 feet of Upper Burro Flats Member.	-0.3
RD-33A [b]	03/25/03 - 01/13/09	~ None	Little head change over ~ 110-foot interval in Upper Burro Flats Member.	
RD-50 [b]	02/5/03 - 01/13/09	~ None	Little head change over ~ 60-foot interval in Lower Burro Flats Member.	
RD-54A	03/19/03 - 01/13/09	Down	~ 30 feet head decline over ~ 100 feet of Upper Burro Flats Member.	-0.3
RD-57	12/19/02 - 01/13/09	Down (net)	Overall 5 to 15 feet head decline in Upper Burro Flats Member.	
RD-65	12/18/02 - 01/13/09	Down	~ 50 feet head decline over ~ 160 feet of Upper Burro Flats Member.	-0.3

Footnotes:

Data source: SCM Element 5-2 (Cherry et al., 2009)
[a] Excluding perched zones, except where noted
[b] Questionable FLUTe seal and/or transducer malfunction or error
FLUTe™ – flexible liner underground technologies
ft/ft – foot per foot

Source: Table 6-6 (MWH, 2009)

Groundwater monitoring data indicate that the movement of contaminants generally follows gradients moving away from the shallow groundwater mound, although it is recognized that fracture orientation can locally redirect contaminant movement differently. TCE diffusing from the groundwater in the fractures into the rock matrix decreases the concentration of TCE in fractures, generally slowing the migration of the plume front.

2.2 Monitoring Well Network

2.2.1 Bedrock Well Network

The groundwater monitoring well network within Area IV is comprised of two types of wells. The first type reflects bedrock coreholes, typically cased-off (meaning a conductor casing has been installed to prevent borehole collapse) through the unconsolidated surficial material interval, and the second type are open corehole to total depth. The majority of the Chatsworth Formation wells installed in Area IV are "open hole," meaning no well casing exists within the bedrock zone, rather than being screened over a discrete interval. Some of these wells have conductor casings installed into the bedrock; some as deep as 557 feet (ft) below ground surface (bgs). Some of these wells are open over hundreds of feet.

The Chatsworth Formation bedrock well network in Area IV is shown on **Figure 2-6**. **Table 2-3** lists the wells, depth, and open borehole intervals. With a few exceptions, well depths range between

60 bgs to 400 feet bgs. Some of the deep wells have had FLUTe™ liner systems installed for some sampling periods. **Table 2-4** provides information for wells that had FLUTe™ systems installed. Installation of the FLUTe™ systems started in 2002 and use of the systems to sample groundwater continued until the systems failed (meaning they no longer could be used for water level gauging or selective interval sampling). Some of the systems were removed in 2013. When in place, selective intervals within the bedrock wells were sampled for groundwater contaminants. The history of usage of the FLUTe™ systems resulted in wide variations in contaminant concentration results between pre-, during-, and post-FLUTe™ system sampling. As a result, inconsistent sampling of the deep wells has provided limited characterization data, mostly identifying what well depth interval lacks contamination. This issue is addressed in Section 4. Liner removal and packer testing of selected deep wells is proposed for future monitoring events to address the uncertainty of the depth of contamination.

Table 2-3. Area IV Well Completion Details

Shallow Well Network				Bedrock Well Network			
Well ID	Well Depth (ft)	Screen/Open Borehole (ft)	Installation	Well ID	Well Depth (ft)	Screen/Open Borehole (ft)	Installation
ES-31	25	11.6-25	Jan-87	RD-07	300	25-300	Jan-86
PZ-05	45	25-45	Nov-00	RD-13	160	30-160	Jul-89
PZ-41	29.6	19-29	Jan-01	RD-14	125	30-125	Jul-89
PZ-51	27	5-15	Dec-00	RD-15	152	30-152	Jul-89
PZ-52	30	18.9-28.9	Dec-00	RD-16	220	30-220	Aug-89
PZ-55	29.5	19-29	Jan-01	RD-17	125	30-125	Aug-89
PZ-97	44.5	33-43	Oct-01	RD-18	240	30-240	Jul-89
PZ-98	37.5	24-34	Oct-01	RD-19	135	30-135	Jul-89
PZ-99	ABD	ABD	ABD	RD-20	127	30-127	Jul-89
PZ-100	16.5	5.7-15.7	Oct-01	RD-21	175	30-175	Aug-89
PZ-101	27	10-20	Oct-01	RD-22	440	30-440	Aug-89
PZ-102	59.2	48.5-59.2	Oct-01	RD-23	440	30-440	Aug-89
PZ-103	39	26-39	Oct-01	RD-24	150	30-150	Aug-89
PZ-104	38.5	18-28	Oct-01	~~RD-25~~	~~175~~	~~30-175~~	~~Aug-89~~
PZ-105	28	17-27	Oct-01	RD-27	150	30-150	Aug-89
PZ-106	35	18-28	Oct-01	~~RD-28~~	~~150~~	~~30-150~~	~~Aug-89~~
PZ-107	11	5-10	Oct-01	RD-29	100	30-100	Aug-89
PZ-108	30	26-30	Oct-01	RD-30	75	30-75	Aug-89
PZ-109	36.5	25-35	Oct-01	RD-33A	320	100-320	Sep-91
PZ-110	17.5	7-17	Oct-01	RD-33B	415	360-415	Sep-91
PZ-111	20	7.5-17.5	Oct-01	RD-33C	520	480-520	Sep-91
PZ-112	35	24-34	Oct-01	RD-34A	320	11-320	Sep-91
PZ-113	15	7-15	Oct-01	RD-34B	415	360-415	Sep-91
PZ-114	48.2	37-47	Oct-01	RD-34C	520	480-520	Sep-91
PZ-115	40	25-40	Oct-01	RD-50	195	18-195	May-93
PZ-116	34	22-32	Oct-01	RD-54A	278	119-278	Aug-93
PZ-120	26	15-25	Mar-03	RD-54B	437	379-437	Aug-93
PZ-121	33	15-25	Mar-03	RD-54C	638	557-638	Jul-93
PZ-122	27.5	15.5-25.5	Mar-03	RD-57	419	19.5-419	Feb-94
PZ-124	31	11.3-31	Mar-03	RD-59A	58	21-58	May-94
PZ-150	27.5	17.5-27.5	Aug-08	RD-59B	214	178-214	May-94
PZ-151	82	69.5-79.5	Aug-08	RD-59C	398	345-397	May-94
PZ-160	27	17-27	Aug-08	RD-63	230	20-230	Oct-94
PZ-161	28	18-28	Aug-08	RD-64	398	19-398	May-94
RS-11	17.5	10-18.5	Jun-85	RD-65	397	19-397	Aug-94
RS-16	20.5	16.5-20.5	Jun-85	RD-74	101	30-101	Jan-99
RS-18	13	7.5-13	Jun-85	RD-85	90	20-90	Aug-04

Table 2-3. Area IV Well Completion Details

Shallow Well Network				Bedrock Well Network			
Well ID	Well Depth (ft)	Screen/Open Borehole (ft)	Installation	Well ID	Well Depth (ft)	Screen/Open Borehole (ft)	Installation
RS-23	13	8-13	Aug-88	RD-86	80	20-80	Aug-04
RS-24	8.5	4-8.5	Aug-88	RD-87	60	20-60	Aug-04
RS-25	13.5	8.5-13.5	Aug-88	RD-88	30	20-30	Aug-04
RS-27	9	5-9	Aug-88	RD-89	50	30-50	May-05
RS-28	19	14-19	Aug-89	RD-90	125	20-125	Mar-04
RS-36	20	3-18	Nov-11	RD-91	140	20-140	Mar-04
RS-54	38	7-38	Aug-93	RD-92	105	20-105	Mar-04
				RD-93	60	20-60	May-05
				RD-94	35	20.5-35	May-05
				RD-95	80	50-80	May-05
				RD-96	90	20-90	Mar-06
				RD-97	74.5	20-74.5	Apr-06
				RD-98	65	20-65	Jun-08
				RD-102	100	30-100	Nov-11
				WS-07	700	216 to 400	Circa 1954

Notes:
ft-feet, ID-identification, Jan-January, Nov-November, Dec-December, Oct-October, Mar-March, Aug-August, Jun-June, Apr-April, Jul-July, ABD-abandoned, ~~strikeout~~ –well has been removed
RD-25 and RD-28 were abandoned in 2004 during the demolition of Building 4059
PZ-99 was abandoned in 2006 as a part of installation of Outfall 005

Table 2-4. FLUTe System Installation Data

Well ID	Date of Well Installation	Date of FLUTe™ Installation	Date of FLUTe™ Removal
RD-07	Jan-86	Apr-02	Jan-13
RD-21	Aug-89	Jan-03	Jan-13
RD-22	Aug -89	Feb-03	--
RD-23	Aug-89	Jan-03	--
RD-33A	Sep-91	Jan-03	--
RD-50	May-93	Jan-03	--
RD-54A	Aug-93	Jan-03	Jan-13
RD-57	Feb-94	Sep-03	--
RD-64	May-94	Apr-02	--
RD-65	Aug-94	Oct-02	Feb-13

Notes:
FLUTe – Flexible Liner Underground Technologies
The functional versus non-functional status of the FLUTe systems could not be determined accurately

Investigation of the bedrock groundwater quality was initiated in 1986 with the installation of well RD-07 at the Building 56 landfill site. Since then, 49 additional bedrock wells (designated RD) have been installed throughout Area IV; one water supply well (WS-07) is also used for monitoring bedrock water quality. The last well to be installed was RD-102 at the SRE pond, installed in November 2011. Two bedrock wells, RD-25 and RD-28, have been removed. Pumping of these wells as part of the dewatering of the Building 4059 basement excavation has provided some aquifer characteristic information for the northwest section of Area IV.

Former water supply well WS-07, located near the eastern boundary of Area IV, is used by NASA to monitor groundwater. In 1954 WS-07 was drilled 700 feet into bedrock, has a metal casing to 400 feet bgs that is perforated between 216 ft bgs to 400 ft bgs, and is assumed to be an open bedrock borehole below 400 ft bgs. As a water supply well, it was pumped between 1955 and 1959.

2.2.2 Shallow Well Network

The shallow well network reflects wells installed in the alluvium above the bedrock, or just into the weathered bedrock (based on refusal while drilling using a hollow stem auger, for example). These wells range in depth between 8.5 and 82 ft bgs, with most shallow wells less than 40 ft deep. Several were installed dry (never encountered groundwater) and most are dry (fall 2014) due to the ongoing drought. Most of the shallow monitoring wells, designated RS, were installed coincidentally with RD wells, while the piezometers (PZ) were installed as a separate effort to identify and monitor shallow groundwater across Area IV. One shallow well, ES-31, was installed as an extraction well, but at a depth of 31 ft bgs and has been mostly dry.

Figure 2-6 illustrates the locations of the shallow wells within Area IV. There is one ES well, 10 RS wells, and 32 PZs in Area IV. One piezometer, PZ-99, has been abandoned. **Table 2-3** also lists the completion details for the shallow wells.

Also included as part of the shallow well network are seep wells installed in the NBZ. Section 5 of this Work Plan describes the seep investigation and sampling program. **Table 2-5** provides details for the seep well network for Area IV groundwater characterization.

Table 2-5. Seep Cluster Installation Details

Well ID	Elevation (ft above MSL)	Well Depth (ft bgs)	Screen Interval (ft bgs)	Installation Date
SP-T02A	1,721 *	9.4	7.4 - 9.4	Jan-13
SP-T02B	1,725 *	12.42	9.4 - 12.9	Jan-13
SP-T02C	1,728 *	24.3	18.3 - 24.3	Jan-13
SP-T02D	1,716 *	35.1	30.1 - 35.1	Jan-13
SP-900A	1,467	10	6.2 - 10	Oct-13
SP-900B	1,389.15	18.4	15.9 - 18.4	Oct-13
SP-900C	1,388.46	30.1	26.6 - 30.1	Oct-13

Notes:
ft bgs – feet below ground surface
ft above MSL – feet above mean sea level
* estimated elevation

2.2.3 Off-site Wells

There are two clusters of wells to the northwest of Area IV classified as off-site (OS). Three of the wells in the OS cluster – OS-04, OS-05, and OS-05A – have no completion information, and are therefore not reliable monitoring points. Well OS-03 was drilled to 100 ft bgs but has conflicting data on its completed depth.

Co-located with the OS well cluster is the RD-59 well cluster that has installation information. This information is provided in **Table 2-6**.

Table 2-6. RD-59 Well Cluster Installation Details

Well ID	Ground Elevation (ft above MSL)	Well Depth (ft bgs)	Open Borehole Interval (ft bgs / ft above MSL)	Installation Date
RD-59A	1,340.59	58	21 – 58 / 1,319.59 – 1,282.59	May-94
RD-59B	1,342.49	214	178 – 209 / 1,164.49 – 1,133.49	Jul-94
RD-59C	1,345.41	398	345.5 – 397 / 999.91 – 948.41	Jul-94

Notes:
ft bgs – feet below ground surface
ft above MSL – feet above mean sea level

2.3 Operational Aspects of Area IV in Relation to Groundwater Impacts

For planning purposes, Area IV has been divided into 19 groundwater investigation areas. These have been derived from the 2007 CO solid waste management units (SWMUs), Areas of Concern, leach fields, the 1 tritium impact area, and 2 groundwater areas not identified in the 2007 CO. Twelve of the groundwater investigation areas are DOE's responsibility, while seven are Boeing's responsibility. These areas are segregated by the types of historic operations within each area. This section introduces 19 investigation areas, while **Table 2-7** lists the Area IV locations their relationship to the 2007 CO. Several of the locations have been combined into one groundwater investigation area due to close proximity or similarity in operations. The groundwater investigation areas under DOE's responsibility are a focus of this Work Plan. Operational history and sources for groundwater impact for each area that are DOE's responsibility are described in Section 4 of this RFI Work Plan.

Table 2-7. Relationship of Groundwater Investigation Areas with 2007 Consent Order

Area IV Location	2007 CO[1] Responsibility	GW WQSAP Identifier[2]	Associated Wells	Notes
Building 56 Landfill	DOE SWMU 7.1	#16	PZ-124, RS-16, RD-07, RD-74	Bedrock groundwater impacted by TCE up to 52 µg/L.
Building 4133 HWMF	DOE SWMU 7.2	Not identified	RS-25, RD-19	RCRA Permit Closure; no groundwater impact.
FSDF Building 4886	DOE SWMU 7.3	#17	RS-18, RS-54, PZ-098, PZ-100, RD-22, RD-23, RD-33A, RD-33B, RD-33C, RD-54A, RD-54B, RD-54C, RD-57, RD-64, RD-65	Impacted by TCE and perchlorate, concentrations of TCE up to 1,600 µg/L in shallow wells, 230 µg/L in deeper wells. Perched groundwater zone not present in 2014.
Old Conservation Yard, Container Storage Area, and Fuel Tanks	DOE SWMU 7.4	Not identified	PZ-151, RD-14, WS-07	Low detections of TCE.
Building 4100 Trench	DOE SWMU 7.5	Not identified	RD-20	No groundwater impact.
RMHF	DOE SWMU 7.6 Leach field AI-Z5[3] (see below)	#13	RS-28, RD-19, RD-27, RD-30, RD-34A, RD-34B, RD-34C, RD-63, RD-98	RCRA Permit Closure; Shallow and bedrock groundwater impacted by TCE up to 11 µg/L. Sr-90 at 33 pCi/L at the RMHF leach field site. Leach field removed; site partially remediated.

Table 2-7. Relationship of Groundwater Investigation Areas with 2007 Consent Order

Area IV Location	2007 CO[1] Responsibility	GW WQSAP Identifier[2]	Associated Wells	Notes
Building 4020 – Rockwell International Hot Lab	DOE SWMU 7.7	Not identified	RD-13, PZ-103	Low concentrations of TCE in PZ-103 (<5 µg/L) may be associated with Building 4020 leachfield
Tritium Plume - Buildings 4010 to 4059 Systems Nuclear Auxiliary Power (SNAP) Facilities DOE Leachfield 2 (AI-Z7)	DOE Leach Field AI-Z6 and AI-Z7 (see below)	#14	RD-87, RD-88, RD-89, RD-90, RD-93, RD-94, RD-95	Bedrock groundwater impacted by tritium up to 40,000 pCi/L (2014). Strong downward trend in tritium concentrations observed since 2008. Leach fields removed; may not be tritium source.
New Conservation Yard	Boeing SWMU 7.8	Not identified	PZ-055, PZ-113, PZ-114, PZ-115, RD-15, RD-92	No groundwater impact.
ESADA Chemical Storage Yard	Boeing SWMU 7.9	Not identified	RD-21, RD-50, RS-23, PZ-100, PZ-101	Impacted by TCE 240 µg/L.
Building 4005/4006 Coal Gasification PDU	Boeing SWMU 7.10 Leach field AI-Z8 (see below)	Not identified		Co-located with HMSA; perched groundwater impacted by TCE. Leach field removed.
Building 4029 Reactive Metals Storage Yard	DOE SWMU 7.11	Not identified	No wells.	RCRA Permit Closure with Building 4133 (HWMF) SWMU 7.2 (above)
Buildings 4059 (4057/4626) Systems Nuclear Auxiliary Power (SNAP) Facilities	DOE SWMU 7.12	Not identified	PZ-109, RD-24, RD-25 (abandoned), RD-28 (abandoned), RD-96, RD-97	Source may be Building 4626; Bedrock groundwater impacted by low concentration of TCE and PCE.
Southeast Drum Yard Area	Boeing SWMU 7.12 (1 of 6 AOCs) Leach field AI-Z9 (see below)	Not identified	ES-31, PZ-051, PZ-052, PZ-106, PZ-107, PZ-110, PZ-111, PZ-112, RS-11, RS-24, RD-16	Sporadic detections of TCE below 1 µg/L, no major impact.
SRE Complex Area	Boeing SWMU 7.12 (1 of 6 AOCs) Leach field AI-Z1 (see below)	Not identified	PZ-150, PZ-160, PZ-161, RS-25, RS-36, RD-18, RD-19, RD-85, RD-86, and RD-102	Sporadic detections of TCE below 1 µg/L, no major impact; United States Environmental Protection Agency (EPA) radionuclides. Leach field removed.
Building 4065 (Metals Clarifier Laboratory) and DOE Leach Fields	DOE SWMU 7.12 (1 of 6 AOCs) Leach fields AI-Z10, AI-Z12, AI-Z13, AI-Z14, AI-Z15 (see below)	Not identified	PZ-005, PZ-103, PZ-104, PZ-105	Low detections of TCE in shallow groundwater, 9.3 µg/L with a decreasing trend. Includes DOE Leach field 3.
Building 4457 HMSA	DOE SWMU 7.12 (1 of 6 AOCs) Leach field AI-Z8 (see below)	#15	PZ-041, PZ-108, PZ-109, PZ-120, PZ-121, PZ-122, RD-24, RD-29	Perched (shallow) groundwater impacted by TCE up to 90 µg/L
Area IV Pond Dredge Area	Boeing SWMU 7.12 (1 of 6 AOCs) Leach field AI-Z2, AI-Z3, AI-Z4 (see below)	Not identified	RD-13	No groundwater impact.

Table 2-7. Relationship of Groundwater Investigation Areas with 2007 Consent Order

Area IV Location	2007 CO[1] Responsibility	GW WQSAP Identifier[2]	Associated Wells	Notes
Area IV Leach Fields				
Building 4003	Boeing Leach field AI-Z1			See SWMU 7.12
DOE Leach Fields 1 Building 4064 SRE Fissionable Fuels Storage	DOE Leach field AI-Z2	Not identified	RD-19 in vicinity	Outside of SRE complex – leach field removed.
DOE Leach Fields 1 Building 4030 A6 Counting Room	DOE Leach field AI-Z3	Not identified	RD-17	Mentioned as possible source for contaminants in SE Drum storage RD-16. However, the VOCs detected in nearby soils are not consistent with those observed at RD-16. Leach field removed.
DOE Leach fields 1 Building 4093 Neutron Radiography Building	DOE Leach field AI-Z4	Not identified	RD-17	Leach field removed. Mentioned as possible source for contaminants in SE Drum storage RD-16. However, the VOCs detected in nearby soils are not consistent with those observed at RD-16.
RMHF Building 4021 Leach field	DOE Leach field AI-Z5 SWMU 7.6	#13	RS-28, RD-19, RD-27, RD-30, RD-34A, RD-34B, RD-34C, RD-63, RD-98	RCRA Permit Closure; Shallow and bedrock groundwater impacted by TCE up to 11 µg/L. Sr-90 at 33 pCi/L at the RMHF leach field. Leach field removed; site partially remediated.
Building 4028 Shield Test Irradiation Reactor Facility	DOE Leach field AI-Z6		RD-89	Included in tritium plume area.
Tritium Plume - Buildings 4010/4012	DOE Not specified in 2007 CO AOC Leach field AI-Z7	#14	RD-87, RD-88, RD-89, RD-90, RD-93, RD-94, RD-95	Bedrock groundwater impacted by tritium up to 40,000 pCi/L (2014). Strong downward trend in tritium concentrations observed since 2008. Leach field removed; may not be tritium source.
Building 4005/4006 Coal Gasification PDU	Boeing Leach field AI-Z8 SWMU 7.10	Not identified	PZ-041, PZ-108, PZ-120, PZ-121, PZ-122, RS-27, RD-29	Co-located with HMSA; perched groundwater impacted by TCE. Leach field removed.
Building 4011 Aerospace Support	Boeing Leach field AI-Z9	Not identified	PZ-106	Leach field removed. Part of Boeing Leach fields RFI area. No downgradient wells.
Building 4383 Liquid Metals Engineering Center DOE Leach Field 3	DOE Leach field AI-Z10 SWMU 7.12	Not identified	PZ-005, PZ-104, PZ-105	Leach field removed.
Building 4009 Organic Moderated Reactor, Sodium Graphite Reactor	DOE Leach field AI-Z11 SWMU 7.12	Not identified	PZ-102 RD-91	Leach field removed.
Building 4020 Rockwell Hot Lab and leach field	DOE Leach field AI-Z12 SWMU 7.12	Not identified	RD-13, PZ-103	Low concentrations of TCE may be associated with Building 4055. Leach field removed.
Building 4373 Mechanical	DOE Leach field AI-Z13	#18	PZ-005, PZ-104, PZ-105	Former leach field site; no groundwater impact. Discussed

Table 2-7. Relationship of Groundwater Investigation Areas with 2007 Consent Order

Area IV Location	2007 CO[1] Responsibility	GW WQSAP Identifier[2]	Associated Wells	Notes
Component/Counting DOE RFI Leach Field 3	SWMU 7.12			with Metals Clarifier Groundwater.
Building 4363 SNAP Critical Facility DOE RFI Leach Field 3	DOE Leach field AI-Z14 SWMU 7.12	#18	PZ-005, PZ-104, PZ-105	Former leach field site; no groundwater impact. Discussed with Metals Clarifier Groundwater.
Building 4353 Organics Reactor Development Building DOE RFI Leach Field 3	DOE Leach Field AI-Z15 SWMU 7.12	Not identified	PZ-005, PZ-104, PZ-105	Leach field removed
Groundwater Investigation Areas not previously identified				
Building 4100 Advanced Epithermal Thorium Reactor	Not specified in 2007 CO; Boeing-owned building.	Not identified	PZ-102 RD-91	Boeing-owned; Bedrock groundwater impacted by TCE up to 270 μg/L.

Notes:
[1] 2007 Consent Order on Corrective Action. DTSC Docket No. P3-07/08-003
[2] Haley & Aldrich, 2010. Site-Wide Water Quality Sampling and Analysis Plan. Revision 1, December
[3] AI-Zx is the leach field identifier presented in the 2007 Consent Order
FSDF – Former Sodium Disposal Facility
DOE – Department of Energy
TCE – trichloroethene
μg/L – microgram per liter
ESADA – Empire State Atomic Development Authority
CO – Consent Order
PCE – tetrachloroethylene
HMSA – Hazardous Materials Storage Area
SNAP – Systems Nuclear Auxiliary Power
pCi/L – picocuries per liter
RMHF – Radioactive Materials Handling Facility
RCRA – Resource Conservation Recovery Act
SRE – Sodium Reactor Experiment
EPA – United States Environmental Protection Agency
OCY – Old Conservation Yard
NCY – New Conservation Yard
Boeing – The Boeing Company
SE – southeast
RFI – RCRA Facility Investigation
VOCs – volatile organic compounds
HWMF – Hazardous Waste Management Facility

Figure 2-7 illustrates the locations of 19 groundwater investigation areas that incorporate the locations in Table 2-7. A description of the area and the associated impact concerns are listed below. Groundwater concerns are based on most recent (2014) or most recent sampling data as available for wells containing water in February 2014. The brief descriptions below include the 2007 CO Area of Concern relationship.

1. FSDF Building 4886 – Impacted by TCE and perchlorate, concentrations of TCE up to 1,600 micrograms per liter (μg/L) in shallow wells, 230 μg/L in deeper wells. Perched groundwater zone not present in 2014. FSDF is Site-Wide Groundwater Monitoring Program Groundwater Investigation Area (GIA) 17. (2007 CO responsibility as a SWMU [7.3] –DOE).

2. Empire State Atomic Development Authority (ESADA) Chemical Storage Yard – Impacted by TCE 240 µg/L. (2007 CO responsibility as a SWMU [7.9] – Boeing).

3. Buildings 4100/4009 – Bedrock groundwater impacted by TCE up to 270 µg/L. (Building 4100 are owned by Boeing but is not addressed in 2007 CO). Building 4009 is associated with Leach Field AI-Z11 (2007 CO responsibility as an area of concern - DOE).

4. Building 4100 Trench – No groundwater impact (2007 CO Responsibility as a SWMU [7.5] – DOE).

5. Building 56 Landfill – Bedrock groundwater impacted by TCE up to 52 µg/L (GIA 16) (2007 CO responsibility as a SWMU [7.1] – DOE).

6. Building 4057/4059/4626 – Bedrock groundwater impacted by low concentration of TCE and tetrachloroethylene (PCE). (Building 4059 identified in 2007 CO as an area of concern- DOE).

7. Building 4457 HMSA – Perched (shallow) groundwater impacted by TCE up to 90 µg/L (GIA 15) (2007 CO responsibility as an area of concern – DOE).

8. Building 4005/4006 - Coal Gasification Process Development Unit (PDU) – Building 4005 (2007 CO responsibility as a SWMU [7.10] – Boeing). Area overlaps the HMSA groundwater impact and includes Leach Field AI-Z8 (2007 CO area of concern - Boeing responsibility).

9. Tritium Plume – Bedrock groundwater impacted by tritium up to 40,000 picocuries per liter (pCi/L) in 2014. Strong decreasing activity trend in tritium concentrations observed since 2008 (GIA 14) (not identified in 2007 CO - DOE). Two leach fields are associated with the tritium area; Leach Field AI-Z6/Building 4028 (believed not to have ever existed per 2007 CO) and Leach Field AI-Z7/Buildings 4010 and 4012 (2007 CO area of concern – DOE).

10. RMHF – Shallow and bedrock groundwater impacted by TCE up to 11 µg/L. Strontium-90 (Sr-90) at 33 pCi/L at the RMHF leach field site (GIA 13) (RMHF is a 2007 CO responsibility as a SWMU [7.6] – DOE); includes RMHF Leach Field AI-Z5/Building 4021 (2007 CO area of concern – DOE) per RCRA Closure Permit.

11. SRE – Sporadic detections of TCE below 1 µg/L, no major impact (2007 CO responsibility as an Area of Concern – Boeing). Area includes Leach Field AI-Z1/Building 4003 (2007 CO area of concern – Boeing).

12. Old Conservation Yard (OCY) – Includes Container Storage Yard and Fuel Tanks. Low detections of TCE (2007 CO responsibility as a SWMU [7.4] – DOE).

13. New Conservation Yard (NCY) – No impact (2007 CO responsibility as a SWMU [7.8] – Boeing).

14. Southeast Drum Storage Yard – Sporadic detections of TCE below 1 µg/L, no major impact (2007 CO responsibility as an area of concern – Boeing). This area also includes Leach Field AI-Z9/Building 4011 (2007 CO area of concern– Boeing).

15. Metals Clarifier Laboratory (Building 4065) – Low detections of TCE in Near surface groundwater, 9.3 µg/L with a decreasing concentration trend (2007 CO responsibility as an area of concern – DOE). This area also includes DOE Leach Fields 3 (AI-Z10/Building 4383; AI-Z13/Building 4373, AI-Z14/Building 4363, AI-Z15/Building 4353 (2007 CO areas of concern –

DOE). No associated groundwater impacts have been identified (GIA 18). Finally, to the southwest, this area includes Building 4020 (2007 CO responsibility as a SWMU [7.7] – DOE. This building has an associated Leach Field AI-Z12 (2007 CO AOC) as well as several adjacent Buildings 4055, 4374, 4462, and 4463. Low concentrations of TCE may be associated with Building 4055.

16. Area IV Pond Dredge Area – No groundwater impact (2007 CO responsibility as an area of concern – Boeing).

17. Area IV Leach Fields not addressed otherwise (2007 CO areas of concern)
    - AI-Z2/Building 4064 (DOE);
    - AI-Z3/Building 4030 (DOE);
    - AI-Z4/Building 4093 (DOE).

18. Building 4133 Hazardous Waste Management Facility (HWMF)/Building 4029 Reactive Metals Storage Yard – No groundwater impact (2007 CO responsibility as SWMUs [7.2 and 7.11, respectively] – DOE). Both buildings are under a RCRA Closure Permit.

The 2007 CO and the several of the Area IV groundwater impact areas identified above include former leach fields areas of concern. The leach fields were used circa 1958 to 1961 after which Area IV buildings were connected to the central sewage treatment plant, then located in Area III. The leach field identifier per the 2007 CO, the associated building, and the approximate year of removal is provided in **Table 2-8**. **Figure 2-7** shows the locations of the 15 former leach fields in Area IV.

Table 2-8. Former Area IV Leach Fields Identified in 2007 CO

Leach Field Identifier	Associated Building	Year of Removal	Source
AI-Z1	B4003	2000	EPA HSA
AI-Z2	B4064	1997	EPA HSA
AI-Z3	B4030	1995	EPA HSA
AI-Z4	B4093	1999	EPA HSA
AI-Z5	B4021	1978	Excavation Report
AI-Z6	B4028	No leach field present	2007 CO
AI-Z7	B4010/4012	Abandoned in place; Not located during 1999-2003 RFI	EPA HSA; RFI Group 5 Report
AI-Z8	B4005/4006	2000/2001	RFI Group 5 Report
AI-Z9	B4011	2000/2001	RFI Group 8 Report
AI-Z10	B4383	2000	EPA HSA
AI-Z11	B4009	2002	RFI Group 8 Report
AI-Z12	B4020	1998	EPA HSA
AI-Z13	B4373	2000	EPA HSA
AI-Z14	B4363	2002	EPA HSA
AI-Z15	B4353	2001	EPA HSA

EPA HSA – HGL, 2012c
RFI Group 5 – CH2MHill, 2008
RFI Group 6 – MWH, 2006
RFI Group 8 – MWH, 2007

2.4 Review of Radionuclides and Chemicals Reported in Groundwater Samples

The most frequently observed chemical in groundwater at Area IV is the solvent TCE. **Figure 2-8** illustrates the distribution of TCE in groundwater using the February 2014 sampling data. Section 4 of this Work Plan is focused on TCE data gap concerns. Metals will also be sampled in all monitoring wells in that are a DOE responsibility per the Water Quality Sampling and Analysis Plan (WQSAP). The remainder of this section addresses radionuclides, perchlorate, and total petroleum hydrocarbons (TPH).

2.4.1 Radionuclides

2.4.1.1 Tritium

Tritium has been a groundwater contaminant of concern (COC) within Area IV since its discovery in the early 1990s within the French drain system of Building 4059. Installation of new wells and sampling of existing wells identified the presence of tritium in wells across Area IV. However, the area most significantly impacted by tritium is the north central portion of Area IV, where several former reactors exist. February 2014 Area IV tritium detections are shown on **Figure 2-9**.

The sources for the observed tritium in Area IV are not clearly understood. The small reactors possibly produced some tritium from the interaction of neutrons and concrete that formed the basement barriers for the reactors. However, physicists have concluded that the reactors were too small to produce the amount of tritium that has been observed in groundwater. Alternatively, tritium use has been documented in nuclear experiments performed in Area IV.

Between 2010 and 2012, EPA collected over 3,700 soil samples as part of a radionuclide investigation in Area IV. Tritium in only detected in one soil sample. Therefore there is no evidence of a significant surficial source of tritium in Area IV.

A tritium source evaluation was performed using the historic operations records and groundwater data. For groundwater investigation areas where tritium was detected in groundwater, tritium activity and frequency of detection and detection history were used to determine the impact of the tritium release, as well as the need for additional source investigation. A multiple lines of evidence approach was used to determine if a tritium source existed and if the source has subsequently been removed. Lines of evidence and rationale on how the information was used in the evaluation are provided below.

- Operational History – Has an operational tritium source area been identified that can explain the presence of tritium detected in groundwater? In cases where no operations were conducted that can explain the presence of tritium, additional tritium source evaluation was performed.

- Low-Level Analysis – Low-level detection methods for tritium have been used exclusively at SSFL. Tritium may be present from atmospheric testing of nuclear weapons and/or from operations conducted in Area IV. Because the detection limit is generally near tritium background activities at SSFL, an occasional detection above the reporting limit may occur. In cases where an occasional detection is accompanied by numerous pre- and post- non-detections, the occasional detection is attributed to analytical variability.

- Detection Frequency – If tritium has been consistently detected in a well, it can be concluded that the well is monitoring the source's effect on groundwater. If tritium is detected occasionally, history of detections and activities is evaluated to determine if a source exists, or if analytical variability is producing the detections.

- Increasing Tritium Activity – If tritium activity is increasing in groundwater, it may indicate that a well has intercepted the plume as it migrates downgradient from the tritium source. In this case, the source is known to exist upgradient of the well and particle track modeling results have been used to identify potential tritium source areas.

- Decreasing Tritium Activity – Decreasing tritium activity can be the result of tritium half-life decay, diffusion, and other natural processes within the groundwater system. Similar to increasing activity in groundwater, the tritium source is known to exist upgradient of the well and particle track model results have been used to identify the potential tritium source.

- Similar Contaminant Profile – In many cases the source and release of other GIA contaminants are known and are believed to have resulted from historic water handling practices. As an example, if tritium and TCE are both present and no tritium operations or disposal methods are known from historical records, by extension, the tritium could have been released in a manner similar to TCE at the Groundwater Investigation Area. In this case, the tritium source is assumed to have been released in a similar manner as the TCE.

Important considerations for characterization tritium sources through additional investigations are as follows:

- Date of Tritium Release and Decay – Area IV tritium producing operation ceased in 1974 (Building 4028, Shield Test Irradiation Facility). Given the fact that tritium was last produced in 1974 and conservatively, the activity has been reduced by several fold (12.3 year half-life) since generation, the chance of an unidentified tritium source capable of generating tritium activity in groundwater above regulatory criteria is unlikely. Additionally, these sources are subject to half-life decay and detection may be problematic in 2015.

- Transport into Bedrock Matrix – As described in the tritium conceptual model, tritium moved through soil down to bedrock, then moved with water into bedrock cracks and fractures, and then diffused into the bedrock matrix. Although tritium in the vadose zone may be present, percolation of water (precipitation) continues to dilute tritium during its migration to the groundwater table, where tritium flows with groundwater downward and laterally from the release location. Because of the amount of time since release, decay, dilution, and transport to the groundwater system, any remaining tritium source in the vadose zone is likely to be minimally present if present at all (except the Tritium Plume groundwater investigation area). Tritium now detected in groundwater is the result of tritium diffusing from the bedrock matrix back into fractures below water table.

- Monitoring Well Network – A monitoring well network has been constructed to monitor and characterize COCs at each GIA. With few exceptions and noted in this Work Plan, the groundwater monitoring well networks have adequate spatial distribution to detect sources of COCs, including tritium. In all but a few areas, the monitoring well network has defined the extent of the tritium groundwater plume and the source is known to exist within the boundary of the monitoring well network. Although the location of the tritium source is not precisely known, the monitoring well network does monitor the source's effect on groundwater. The network allows for observation of tritium's fate and transport and sentry protection for off-site receptors.

Important note for data presented in Section 2 tables – some data are generated from the Boeing Environmental Data Management System (BEDMS) data queries. No additional data qualifiers have been added to the 'legacy data'. However, inconsistencies in the data have been identified to allow the reader a better understanding of the data and environmental condition as they existed at the time of sampling. These data inconsistencies are highlighted with an * and an explanation is provided in the text below.

Former Sodium Disposal Facility

No buildings or operations are reported to have generated tritium at the FSDF. Tritium detected at FSDF is presented in **Table 2-9**. In addition to tritium being reported in samples from RD-23, RD-33A, RD-33B, RD-54A, RD-64, RD-65, and RS-18, TCE was also detected in these wells. Based on this relationship, it is believed that tritium was disposed of at the FSDF in a similar manner described in Section 4.1. This section also describes soil and groundwater removal actions that have occurred at the FSDF. Any tritium source in the soil would have been removed during these removal actions. The groundwater monitoring well network at the FSDF has adequate spatial distribution to detect any additional tritium source in the area.

Table 2-9. Tritium in Groundwater at FSDF

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
36 / 13 / 0 (1,574)	RD-23	234 – 1,574	28 U	18 U	NC
42 / 1 / 0 (360 J)	RD-33A	U	30 U	-9 U	360 J
54 / 2 / 0 (500)	RD-33B	125 J - 500	-32 U	32 U	180 U
37 / 13 / 0 (697)	RD-54A	270 - 697	19 U	23 U	360 J
14 / 3 / 0 (360 J)	RD-64	118 J	78	123	360 J
4 / 2 / 0 (380)	RD-65	322 - 380	15 U	26 U	NC
23 / 7 / 0 (255)	RS-18	102 - 255	-43	26 U	NC
22 / 1 / 0 (1,099) *	RS-54	1,099	NC	-58 U	NC

Units – Picocuries per liter, NC – Not Collected, U – Not Detected, J – Estimated
* On September 11, 1993 tritium was reported in RS-54 at 1,099 pCi/L. An additional sample was collected on September 29, 1993 and was not detected (-98 U pCi/L). Based on sampling history (22 analysis, single detection, and subsequent non-detection), the detection is believed to be erroneous and not a reflection of site conditions at that time.

Based on the frequency of detection, activity, absent of increasing tritium activity trends, and previous soil and groundwater removal actions, it can be concluded that a tritium source does not exist at the FSDF. Tritium activity in groundwater is well below regulatory criteria and no future action is required at the FSDF.

Building 56 Landfill

A single detection of tritium was observed in RS-16 in 1997 (**Table 2-10**). Well RS-16 was sampled in 1992, 1993, 1995, 1998, 2008, and 2011, and reported as non-detected. This single detection may be attributed to analytical variability. Operations and activities that took place at the landfill are described in Section 4.3. The monitoring well network within the GIA is sufficient to detect groundwater impacts from unknown tritium sources.

Table 2-10. Tritium in Groundwater at Building 56 Landfill

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
7 / 1 / 0 (353)	RS-16	353	NC	-21 U	NC

Units – Picocuries per liter
NC – Not Collected
U – Not Detected

Based on the frequency of detection, activity, and removal actions conducted at the landfill, a tritium source at Building 56 Landfill does not exist. Tritium activity in groundwater is below the regulatory criteria and no further action is required for this Groundwater Investigation Area.

Buildings 4057/4059/4626

Building 4059 (SNAP Development Reactor Facility) was operational from 1961 to 1964 and again from 1968 to 1969, and is reported as tritium source. Operations, removal actions, and demolition activities at this GIA are described in Section 4.4. Building 4059 was removed between 2003 and 2004. Removal activities would have removed any tritium sources from this area. Monitoring wells RD-25 and RD-28 were abandoned during building demolition. Tritium detected in this GIA is presented in **Table 2-11**. The remaining monitoring well network, specifically RD-96 and RD-97, are spatially distributed to detect any remaining tritium source in the area. These wells are located downgradient from Building 4059 and would intercept a tritium plume prior to moving off-site of Area IV.

Table 2-11. Tritium in Groundwater at Buildings 4057/4059/4626

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
45 / 18 / 0 (500)	RD-24	187 J - 500	79	54 U	-180 U
30 / 3 / 0 (259)	RD-25	240 - 259	ABD	ABD	ABD
45 / 18 / 0 (15,400)	RD-28	267 – 15,400	ABD	ABD	ABD

Units – Picocuries per liter
NC – Not Collected
U – Not Detected
J – Estimated
ABD - Abandoned

Although the tritium source has been removed from this GIA, it is recommended that tritium be monitored for in RD-96 and RD-97.

Radioactive Materials Handling Facility

The source of tritium at the RMHF is believed to be attributed to neutron-activated lithium in concrete from reactors in the vicinity of Building 4010. The buildings were demolished starting in 1978. The source of tritium to groundwater was removed. The monitoring well network at the RMHF is adequate to detect groundwater impacts from unknown tritium sources at the RMHF. Tritium detected at the RMHF is presented in **Table 2-12**. No further action is required for source determination. However, continued monitoring of tritium in groundwater at RD-34A, RD-34B, and RD-34C should be continued.

Table 2-12. Tritium in Groundwater at RMHF

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
1 / 1 / 0 (119)	PZ-116	NC	NC	119	NC
1 / 1 / 0 (240)	RD-27	240	4 U	12 U	NC
49 / 49 / 0 (240)	RD-34A	275 – 7,155	966	342	530
52 / 19 / 0 (820)	RD-34B	188 J - 820	290	187	NC
61 / 1 / 0 (132)	RD-34C	U	11 U	132	180 U
28 / 6 / 0 (362)	RD-63	266 - 362	43 U	33	0 U

Units – Picocuries per liter
NC – Not Collected
U – Not Detected
J – Estimated

Hazardous Materials Storage Area

No buildings or operations are reported to have generated tritium at the HMSA. Detections at the HMSA may be attributed to analytical variability (**Table 2-13**). The monitoring well network is adequate to detect groundwater impacts from unknown tritium sources in this GIA. Based on frequency of detection and activity, there is not a tritium source at HMSA. Tritium activity in groundwater has not been detected since 2009 and previously was below regulatory criteria; therefore, no further action is required at this area.

Table 2-13. Tritium in Groundwater at Hazardous Materials Storage Area

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
3 / 1 / 0 (105)	PZ-041	NC	18 U	105	180 U
25 / 2 / 0 (126 J)	RD-29	99.2 J - 126 J	-32 U	16 U	NC

Units – Picocuries per liter
NC – Not Collected
U – Not Detected
J – Estimated

Off-Site Wells

No SSFL operations occurred off-site. Sample results for the OS-05 and RD-59A wells are provided in **Table 2-14.** Tritium detection frequency and activity confirm that there are no tritium off-site sources. No future action is required for off-site wells.

Table 2-14. Tritium in Groundwater at Off-Site Wells

Analyzed/Detected/Exceedance (Max. Activity)	Well	1989 - 2010	EPA 09/2010	EPA 04/2011	Boeing 02/2014
19 / 1 / 2000 (620)	OS-05	620	NC	NC	0 U [(a)]
2 / 1 / 2000 (330)	OS-05A	330	NC	NC	NC
4 / 3 / 2000 (110)	RD-59A	29.4 – 69.5	NC	110	0 U

[(a)] Sample collected in 2013.
Units – Picocuries per liter
NC – Not Collected
U – Not Detected
J – Estimated

2.4.1.2 Other Radionuclides

Groundwater sampling for the presence of site-related radionuclides has been ongoing since the early 1990s. The sampling resulted in the identification of the Tritium Plume and Sr-90 impacted area that are described in Sections 4.6 and 4.7, respectively. This section focuses on other radionuclides reported for Area IV groundwater samples and assesses their likelihood of being present and makes recommendations for future sampling for radionuclides.

Although groundwater data exists for radionuclide samples collected prior to 2010, the analysis in this section focuses on data collected starting with EPA's comprehensive groundwater sampling events in 2010 and 2011. EPA (HGL, 2012a) provides the most comprehensive data set for radionuclides in groundwater within Area IV, serving as a primary basis for the review of the radionuclide data. The analysis also includes radionuclide data collected by MWH (2012a, 2013b, 2014a, and 2014b) as part of their annual sampling of Area IV groundwater in 2012, 2013, and 2014. **Table 2-15** provides a summary of the radionuclides reported for each well in samples collected by EPA or MWH. EPA analyzed groundwater samples for 54 radionuclides it deemed potentially present in Area IV (HGL, 2012a). The groundwater sample analyses performed by MWH in 2012a, 2013b, and 2014b included many of the radionuclides reported by EPA.

In the evaluation of the radionuclide results, the reported uncertainty or percent error was used in determining the validity of the results. However, for ease of review in **Table 2-15**, the uncertainty or percent error associated with each radionuclide result was not included. The uncertainty or percent error can be found in the associated documents where the result was originally reported.

Data Evaluation Criteria

The majority of the radionuclides reported were at or below the minimum detectable concentration (MDC). Due to spectral interference and potential for false positive identification at these concentrations, the following criteria were used to evaluate the data for likely detection of a radionuclide:

- Is the radionuclide a naturally-occurring radioactive material (NORM)?
- Is the radionuclide a decay product (daughter) and is the parent present?
- What is the half-life? Could the radionuclide still be present 30 or more years after cessation of nuclear research work in Area IV?
- Is the radionuclide present in the EPA soils data?
- Has the radionuclide been repeatedly detected among groundwater sampling events?
- Is the radionuclide detected near or within an area where nuclear material was handled or used?

A brief description of each of these criteria is presented in the following sections.

NORM

As discussed in EPA's Final Radiological Characterization of Soils, Area IV and the NBZ (HGL, 2012b), NORM are present in soils, sediment, and rock in the Earth's crust. There are two types of naturally-occurring radionuclides in soil. One occurs singly and the other type reflects those occurring as part of a decay series. Potassium (K)-40 is the most common singly-occurring NORM, and thorium (Th)-232, uranium (U)-234/235, and U-238 are NORM analytes that are part of a decay series that are found in rocks and soil. In addressing the variability of its data set, EPA concluded "Considering the greater than 3,000 sample analyses . . ., some (soil) results will exceed (field action levels) FALs simply due to natural and statistical variability." (HGL, 2012b, page 4-16). "The evaluation of NORM (radionuclide threshold level) RTL exceedances produced few results considered potentially site-related, while virtually all NORM radionuclide results exceeded their respective FALs." (HGL, 2012b).

Evaluating the radionuclide concentration ratios within a decay series helps determine whether NORM radionuclide exceedances may be present due to naturally-occurring or site-related activities. Uranium is one of the most important NORM analytes as it is present and detectable at naturally-occurring concentrations and is one of the radioactive elements in nuclear fuel used and handled within Area IV. Enriched uranium would be an indication of site-related effects as uranium ore was not processed in Area IV.

The NORM U-233/234 to U-238 ratio is approximately 1:1. Enriched uranium has an approximate 9 to 1 ratio 233/234 to 238. Comparing the two radionuclides concentrations provides the demonstration of whether uranium observed in groundwater is site-related or not. Elevated levels of uranium observed in groundwater can be related to site geology, and not man-caused contamination. Regarding uranium detects in groundwater, EPA concluded "The gross alpha, gross beta, U-233/234, and U-238 concentrations appear to be attributed to suspended solids; thus, do not reflect actual exceedances of the maximum contaminant levels (MCLs)." (HGL, 2012a, page 6-1).

If uranium products were the only radionuclides detected and/or analyzed for a groundwater well as shown in **Table 2-15**, no recommendation was made to further sample this well as discussed previously since these concentrations are considered naturally occurring.

Decay Products and Half-Life

A decay product (i.e., daughter product) is defined as the remaining nuclide that is left over from radioactive decay. A half-life is the time required for the disintegration of one-half of the radioactive atoms that are present when measurement starts. It does not represent a fixed number of atoms that disintegrate, but a fraction. The half-life indicates how quickly the radioactivity from the radionuclide will decrease.

Detection of a radionuclide and its daughter can be used to support the rationale that the radionuclide is present in groundwater. If the parent is not present, then the daughter cannot be present. Additionally, radionuclides detected with a short half-life without detection of the parent or daughter radionuclide may suggest detection in groundwater is erroneous.

For the radionuclide analytes detected and/or analyzed in SSFL Area IV groundwater wells, americium (Am)-241 (daughter of plutonium [Pu]-241); barium (Ba)-137m (daughter of cesium [Cs]-137); and tellurium (Te)-125m (daughter of tin (Sn)-125) were the only identified decay products. In instances where these analytes were analyzed and/or detected, these wells were designated to be sampled for further characterization.

Radionuclides in Soils

Another evaluation criterion used is whether the radionuclide analyte was detected in associated soil samples in relation to groundwater wells where radionuclides were also detected. During EPA's radiological soil study (HGL, 2012b) EPA compared results to both a FAL and a RTL based on EPA's statistical evaluation of the background threshold value (BTV) or the 2σ (i.e., two standard deviations) upper confidence limit (UCL) MDC as applicable. EPA determined that the site-related radionuclides detected in soil (exceeding FALs) were Cs-137 (61 percent of detections), Sr-90 (32 percent), Pu-238 (<1 percent), Pu-239/240 (3 percent), cobalt (Co)-60 (1 percent), europium (Eu)-152 (1 percent), Am-241 (1 percent), and curium (Cm)-234/244 (<1 percent). EPA also cautioned that even though a soil sample concentration may exceed the FAL, the data may not represent areas of contamination.

The soil data can be used to assess whether a radionuclide detected in soil may have impacted groundwater. If the radionuclide is present in soil and an adjacent monitoring well, there is the possibility that the detection in groundwater is real and further sampling may be necessary. If the radionuclide is identified in a groundwater sample but not detected in soil, the groundwater detection may be a false positive and may not present actual groundwater conditions.

Detected Radionuclides in Groundwater

A review of all detected radionuclide concentrations for the five identified groundwater sampling events was conducted. This evaluation looked at how often the analyte was detected and in what time period it was detected. If the radionuclide analyte was not detected more than twice in a groundwater well, it is considered non-detect and no further sampling is recommended. If an analyte was detected more than two times, a review of when the samples were collected was performed to see if the detected results are considered representative of current conditions and/or if further sampling is required.

Process Areas

The location of a well in relation to radioactive material use and handling areas was also considered in this analysis. The process areas include the SRE, RMHF, SNAP reactor buildings (4019, 4024, 4059), Rockwell Hot Lab (Building 4010), Shield Test Irradiation Reactor (Building 4028), and the FSDF (see **Figure 2-7**), which fall under Boeing or DOE responsibility. A radionuclide observed in groundwater near one of these areas was considered as a possible groundwater contaminant. Radionuclides reported in well samples at locations remote from the process areas were questioned as to their validity.

Summary

Table 2-15 presents the 'detected' radionuclide results from recent sampling of Area IV groundwater. The criterion to determine whether a groundwater well should be further sampled for radionuclides, as discussed above, was applied to each radionuclide analyte reported for each well.

2.4.2 Perchlorate

Chemical compounds containing perchlorate were used at SSFL as rocket engine igniters. Because rocket fuels were formulated within Area IV buildings, it is assumed that engine igniters were also produced. Monitoring wells throughout Area IV have been sampled for the presence of perchlorate. The only locations where perchlorate was observed above the MCL was at the FSDF, ESADA, and Building 56 Landfill. **Table 2-16** summarizes the perchlorate results within Area IV.

Table 2-16 also indicates which wells are recommended for perchlorate sampling. This decision was based on past results, possible trends if enough information is present, whether the investigation area has historical uses of perchlorate during facility operations, and whether enough information is available to appropriately characterize a particular Investigation Area.

Perchlorate remains a COC for the FSDF, ESADA, and Building 56 Landfill areas. Groundwater wells in other investigation areas are being sampled in order to evaluate the movement of perchlorate throughout Area IV.

2.4.3 Total Petroleum Hydrocarbons

Petroleum products are made up of hundreds of hydrocarbon compounds that range from light volatile short-chained organic compounds to heavy long-chained branched compounds. The composition of petroleum products depends on the source of the crude oil and the refining practices used to make the product. At SSFL, diesel fuel was used for various activities with Area IV.

No specific EPA MCLs are developed for TPHs. Past evaluations of this data involved the comparison of analyte concentrations to draft Site-Wide Groundwater Risk-Based Screening Levels proposed in the Groundwater RI Report developed by MWH in 2009 and industry standard taste/odor thresholds. For the purposes of this Work Plan evaluation, all detected results were reported to evaluate the current conditions at the Site.

Table 2-17 summarizes the results for TPH detected results within Area IV. TPHs were detected in groundwater wells within the FSDF, ESADA, Building 56 Landfill, Building 4100/4009, Metals Clarifier/DOE Leach Fields 3, HMSA, Buildings 4057/4059/4626, tritium plume, and RMHF GIAs. Soil sample results of TPH analytes were also reviewed in comparison to concentrations that were above 1,000 mg/kg and their proximity to the groundwater wells.

Recent detected concentrations of TPHs document the need to retain TPH as a COC for the FSDF, ESADA, Building 4100/4009, Metals Clarifier/DOE Leach Fields 3, Buildings 4057/4059/4626, and the RMHF.

Table 2-17also indicates which wells are recommended to be sampled for TPHs. This decision was based on past results, possible trends (if enough data are present), whether the investigation area has past historical uses of TPHs during facility operations, and if soil sample results above 1,000 mg/kg were potentially a concern for possible future groundwater contamination.

References

Dibblee, T.W., 1992. *Geologic Quadrangle Maps: Los Angeles and Ventura Counties, California.*

DTSC 2007 Consent Order on Corrective Action. DTSC Docket No. P3-07/08-003.

Haley & Aldrich, 2010. *Site-Wide Water Quality Sampling and Analysis Plan*. Revision 1, December

HGL, 2012a. *Final Groundwater Report, Area IV Radiological Study*. Prepared for USEPA Region IX. July.

HGL, 2012b. *Final Radiological Characterization of Soils, Area IV and the Northern Buffer Zone.* Prepared for USEPA Region IX. December.

HGL, 2012c. *Final Historical Site Assessment Santa Susana Field Laboratory Radiological Study Ventura County California.* Prepared for USEPA Region IX. October

MWH, 2009. *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory.* December.

MWH, 2013a. *Technical Memorandum, Results of Geologic Mapping and Excavations along the Western and Eastern FSDF Structures (Photolineaments) Area IV. May*

MWH, 2013b. *Report on Annual Groundwater Monitoring, 2012 Santa Susana Field Laboratory.* February

MWH, 2014a. *Report on Annual Groundwater Monitoring, 2013 Santa Susana Field Laboratory.* January

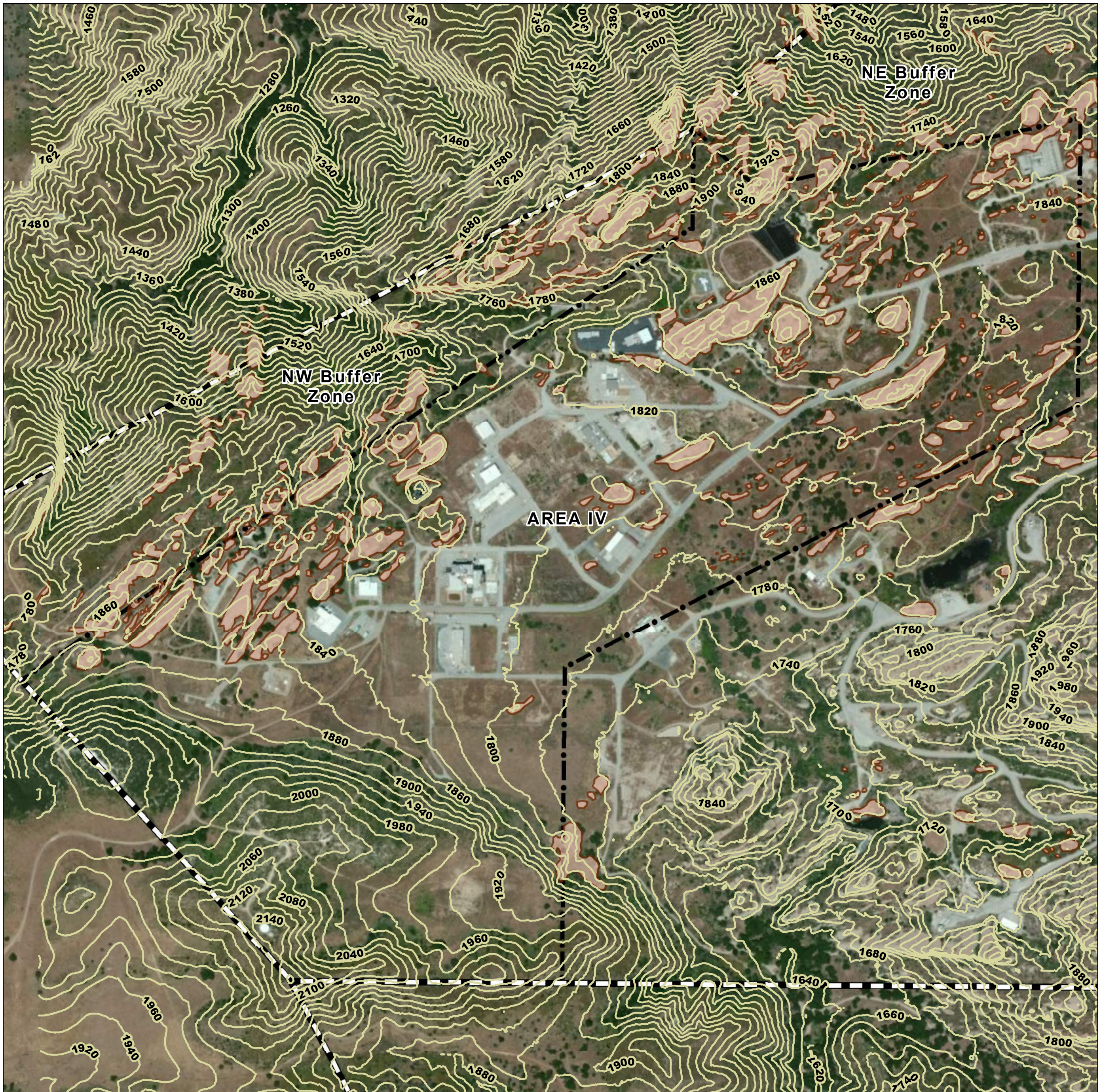
MWH, 2014b. *Groundwater Monitoring Progress Report, First Quarter Report 2014, January through March 2014*. May

MWH 2009. *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory.*

Wagner and Perkins, 2009. *20 Elements of the Santa Susana Field Laboratory Site Conceptual Model of Contaminant Transport, Site Conceptual Model Element 4-1, Technical Memorandum Characteristics of Joints at the Santa Susana Field Laboratory, Simi, California. Draft.* December 10.

USEPA, 2012. *Final Groundwater Report, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County, California.* July

USEPA, 2012. *Final Radiological Characterization of Soils Area IV and the Northern Buffer Zone, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County, California*.



LEGEND

20ft. Contour | Rock Outcrop | Area IV Boundary | SSFL Property Boundary

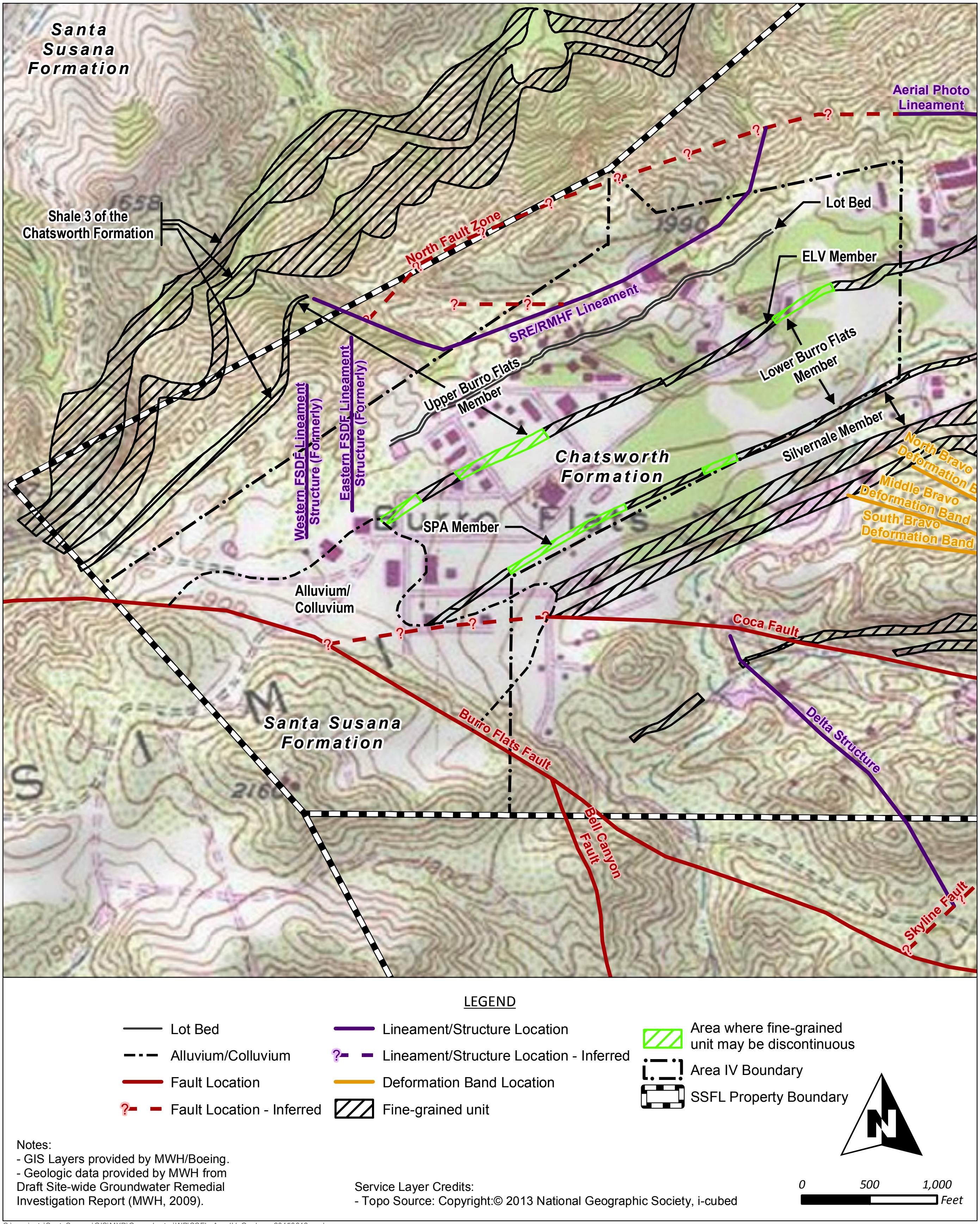
Notes:
- GIS Layers provided by MWH/Boeing.
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

0 425 850 Feet

C:_projects\SantaSusana\GIS\MXD\EIS\SSFL_AreaIV_Topography_20141024.mxd

CDM Smith

FIGURE 2-1
Area IV Topography



Notes:
- GIS Layers provided by MWH/Boeing.
- Geologic data provided by MWH from Draft Site-wide Groundwater Remedial Investigation Report (MWH, 2009).

Service Layer Credits:
- Topo Source: Copyright:© 2013 National Geographic Society, i-cubed

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Geology_20150612.mxd

CDM Smith

FIGURE 2-2
Area IV Geology

Notes:
- GIS Layers provided by MWH/Boeing.
- Groundwater Elevations provided by MWH (1st Quarter 2014).
- Water levels are feet MSL and were collected in February 2014.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

LEGEND

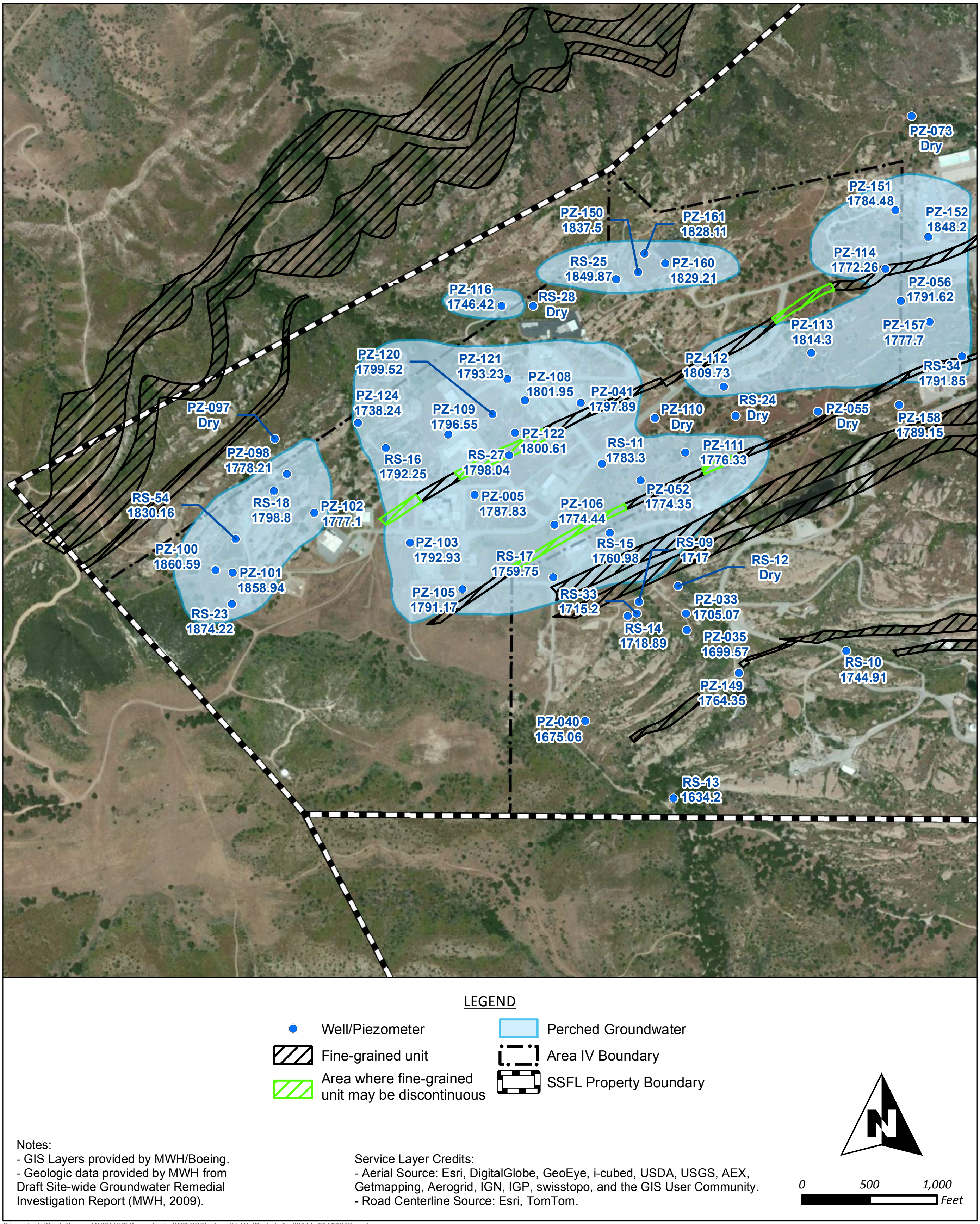
GW Elevation | Approx GW Elevation | Road Centerline | Area IV Boundary | SSFL Property Boundary

0 275 550 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_1Q2014_GW_Elevations_20150612.mxd 6/12/2015

CDM Smith

FIGURE 2-3
2014 Groundwater Elevations



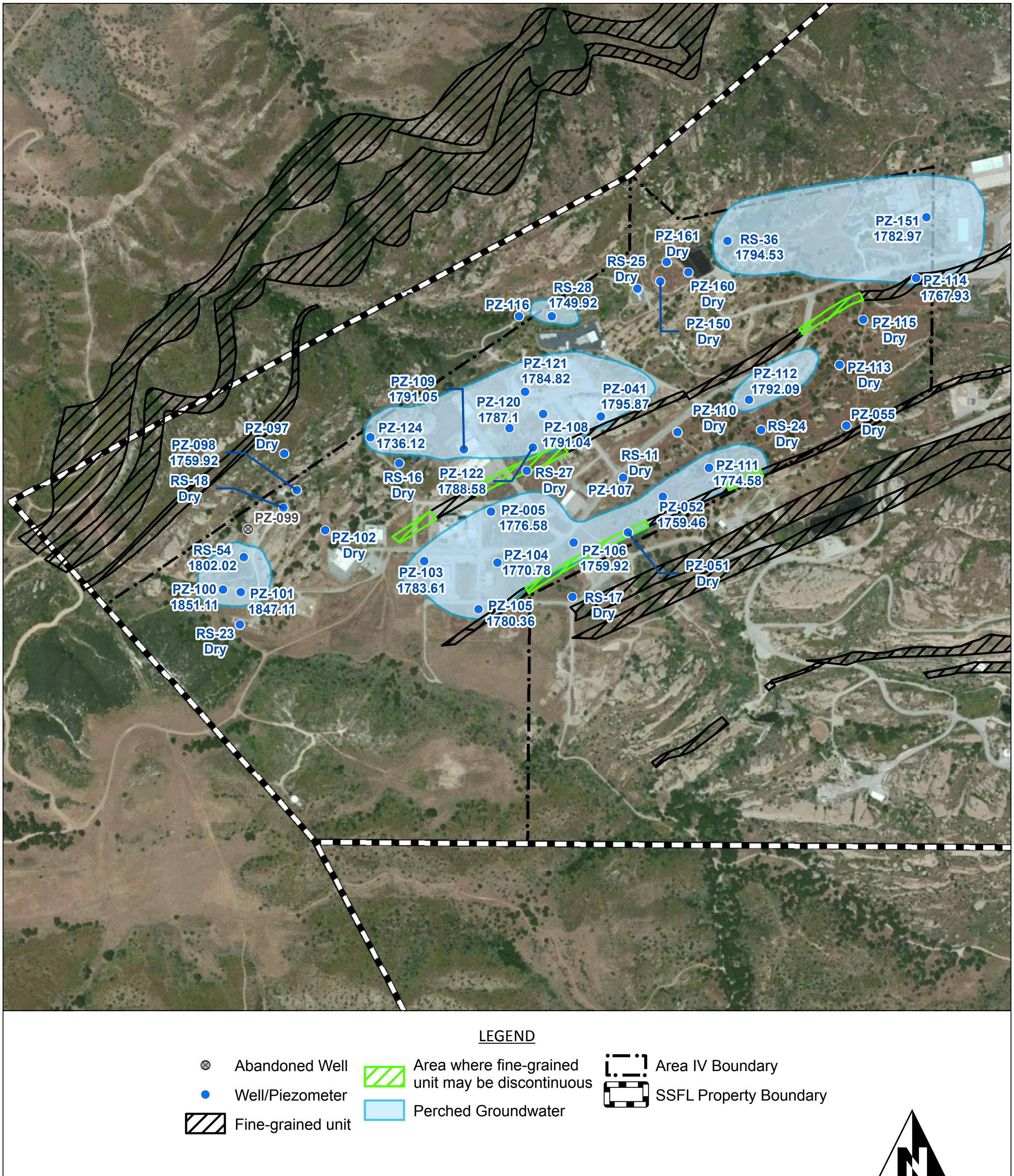
Notes:
- GIS Layers provided by MWH/Boeing.
- Geologic data provided by MWH from Draft Site-wide Groundwater Remedial Investigation Report (MWH, 2009).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_WetPeriod_April2011_20150612.mxd

CDM Smith

FIGURE 2-4
Near-Surface Groundwater During April 2011 (Wet Period)



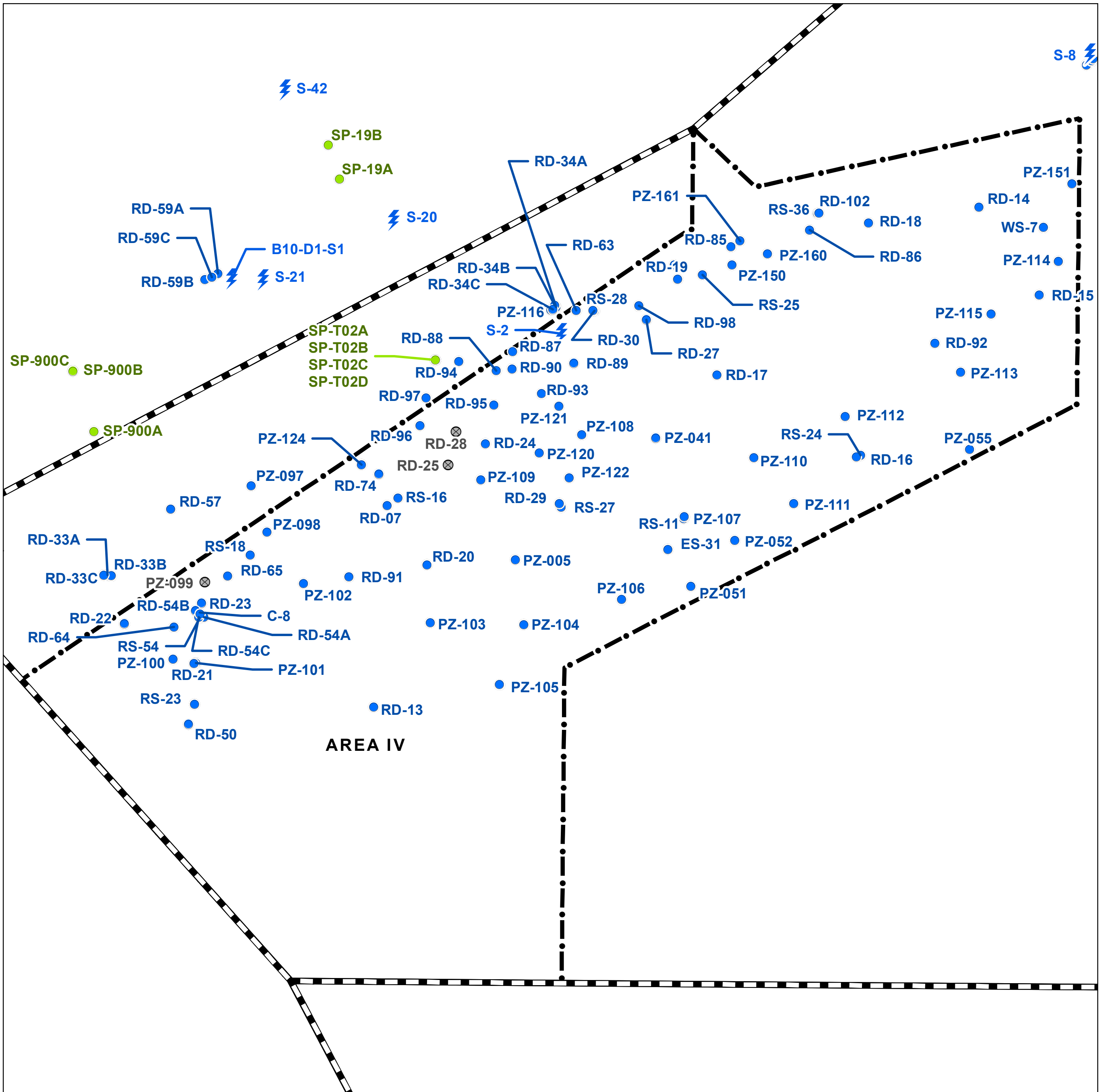
Notes:
- GIS Layers provided by MWH/Boeing.
- Geologic data provided by MWH from Draft Site-wide Groundwater Remedial Investigation Report (MWH, 2009).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_DryPeriod_February2014_20150612.mxd

CDM Smith

FIGURE 2-5
Near-Surface Groundwater During February 2014 (Dry Period)



LEGEND

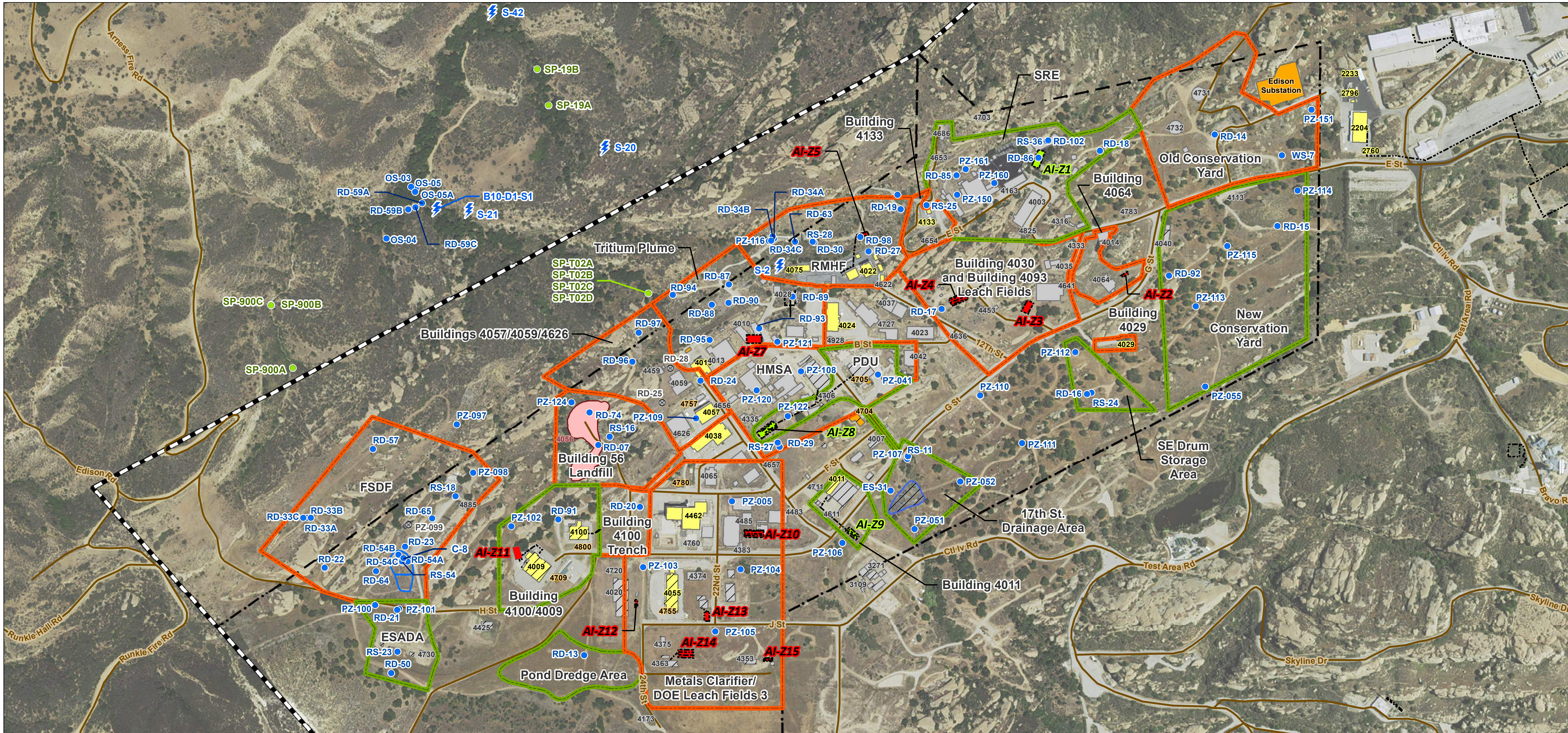
- Well/Piezometer
- Abandoned Well
- Seep Well
- Seep
- Area IV Boundary
- SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
- *Well PZ-099 abandoned in 2006.
- **Wells RD-25 and RD-28 abandoned in April 2004.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_GW_Network_20150612.mxd

CDM Smith

FIGURE 2-6
Area IV Groundwater Monitoring Network

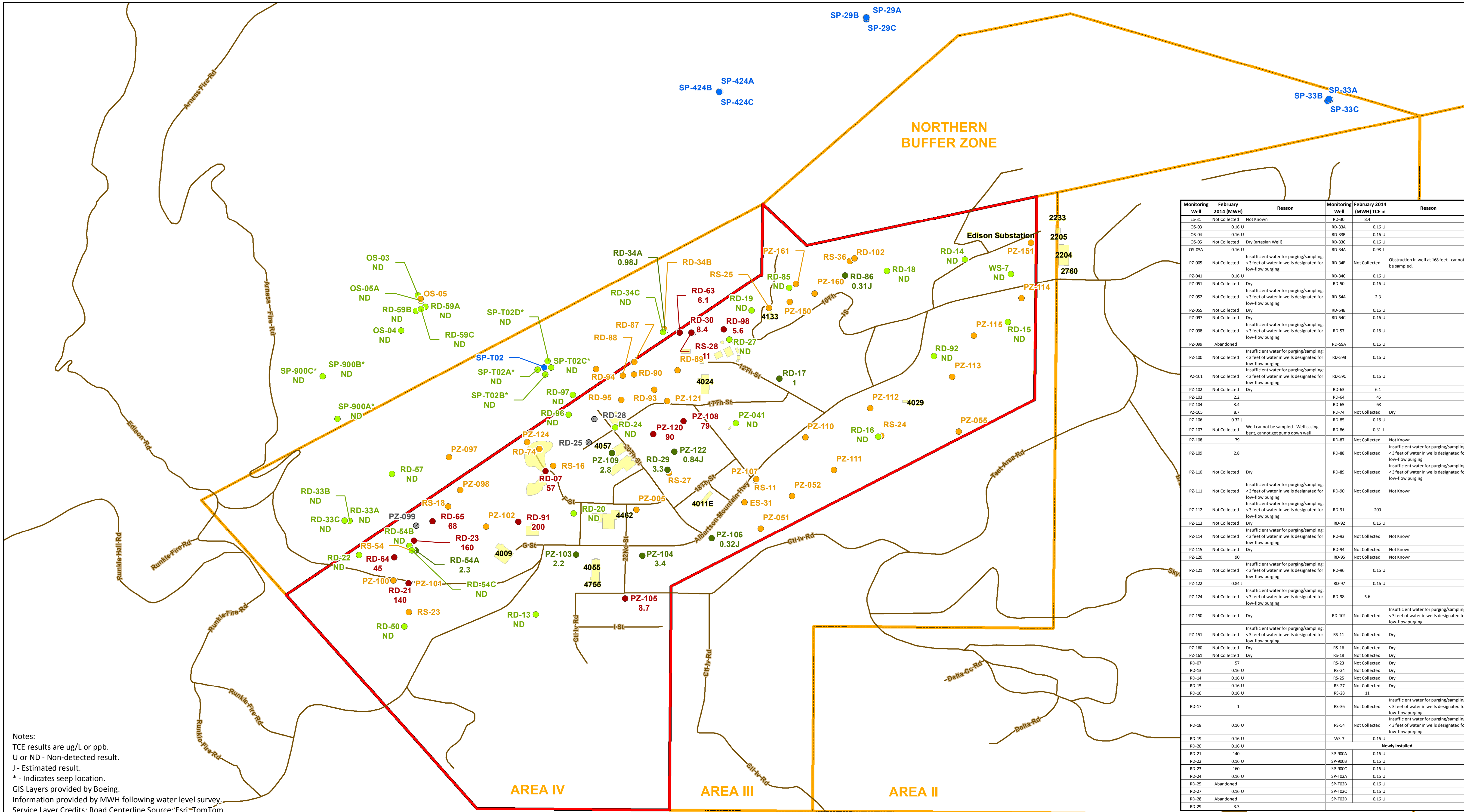


Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_GW_Investigation_Areas_S2_20150824.mxd 8/24/2015

CDM Smith

FIGURE 2-7
Area IV Groundwater Investigation Areas



Monitoring Well	February 2014 (MWH)	Reason	Monitoring Well	February 2014 (MWH) TCE in	Reason
ES-31	Not Collected	Not Known	RD-30	8.4	
OS-03	0.16 U		RD-33A	0.16 U	
OS-04	0.16 U		RD-33B	0.16 U	
OS-05	Not Collected	Dry (artesian Well)	RD-33C	0.16 U	
OS-05A	0.16 U		RD-34A	0.98 J	
PZ-005	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-34B	Not Collected	Obstruction in well at 168 feet - cannot be sampled.
PZ-041	0.16 U		RD-34C	0.16 U	
PZ-051	Not Collected	Dry	RD-50	0.16 U	
PZ-052	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-54A	2.3	
PZ-055	Not Collected	Dry	RD-54B	0.16 U	
PZ-097	Not Collected	Dry	RD-54C	0.16 U	
PZ-098	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-57	0.16 U	
PZ-099	Abandoned		RD-59A	0.16 U	
PZ-100	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-59B	0.16 U	
PZ-101	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-59C	0.16 U	
PZ-102	Not Collected	Dry	RD-63	6.1	
PZ-103	2.2		RD-64	45	
PZ-104	3.4		RD-65	68	
PZ-105	8.7		RD-74	Not Collected	Dry
PZ-106	0.32 J		RD-85	0.16 U	
PZ-107	Not Collected	Well cannot be sampled - Well casing bent, cannot get pump down well	RD-86	0.31 J	
PZ-108	79		RD-87	Not Collected	Not Known
PZ-109	2.8		RD-88	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
PZ-110	Not Collected	Dry	RD-89	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
PZ-111	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-90	Not Collected	Not Known
PZ-112	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-91	200	
PZ-113	Not Collected	Dry	RD-92	0.16 U	
PZ-114	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-93	Not Collected	Not Known
PZ-115	Not Collected	Dry	RD-94	Not Collected	Not Known
PZ-120	90		RD-95	Not Collected	Not Known
PZ-121	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-96	0.16 U	
PZ-122	0.84 J		RD-97	0.16 U	
PZ-124	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RD-98	5.6	
PZ-150	Not Collected	Dry	RD-102	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
PZ-151	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging	RS-11	Not Collected	Dry
PZ-160	Not Collected	Dry	RS-16	Not Collected	Dry
PZ-161	Not Collected	Dry	RS-18	Not Collected	Dry
RD-07	57		RS-23	Not Collected	Dry
RD-13	0.16 U		RS-24	Not Collected	Dry
RD-14	0.16 U		RS-25	Not Collected	Dry
RD-15	0.16 U		RS-27	Not Collected	Dry
RD-16	0.16 U		RS-28	11	
RD-17	1		RS-36	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
RD-18	0.16 U		RS-54	Not Collected	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
RD-19	0.16 U		WS-7	0.16 U	
RD-20	0.16 U		**Newly Installed**		
RD-21	140		SP-900A	0.16 U	
RD-22	0.16 U		SP-900B	0.16 U	
RD-23	160		SP-900C	0.16 U	
RD-24	0.16 U		SP-T02A	0.16 U	
RD-25	Abandoned		SP-T02B	0.16 U	
RD-27	0.16 U		SP-T02C	0.16 U	
RD-28	Abandoned		SP-T02D	0.16 U	
RD-29	3.3				

Notes:
TCE results are ug/L or ppb.
U or ND - Non-detected result.
J - Estimated result.
* - Indicates seep location.
GIS Layers provided by Boeing.
Information provided by MWH following water level survey.
Service Layer Credits: Road Centerline Source: Esri, TomTom.

Legend

- TCE above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)

Abandoned Well
Seep Location
Road Centerline
Existing Structure
Area IV
SSFL Boundary

February 2014 TCE Levels in Area IV Monitoring Wells

0 350 700 1,400 Feet

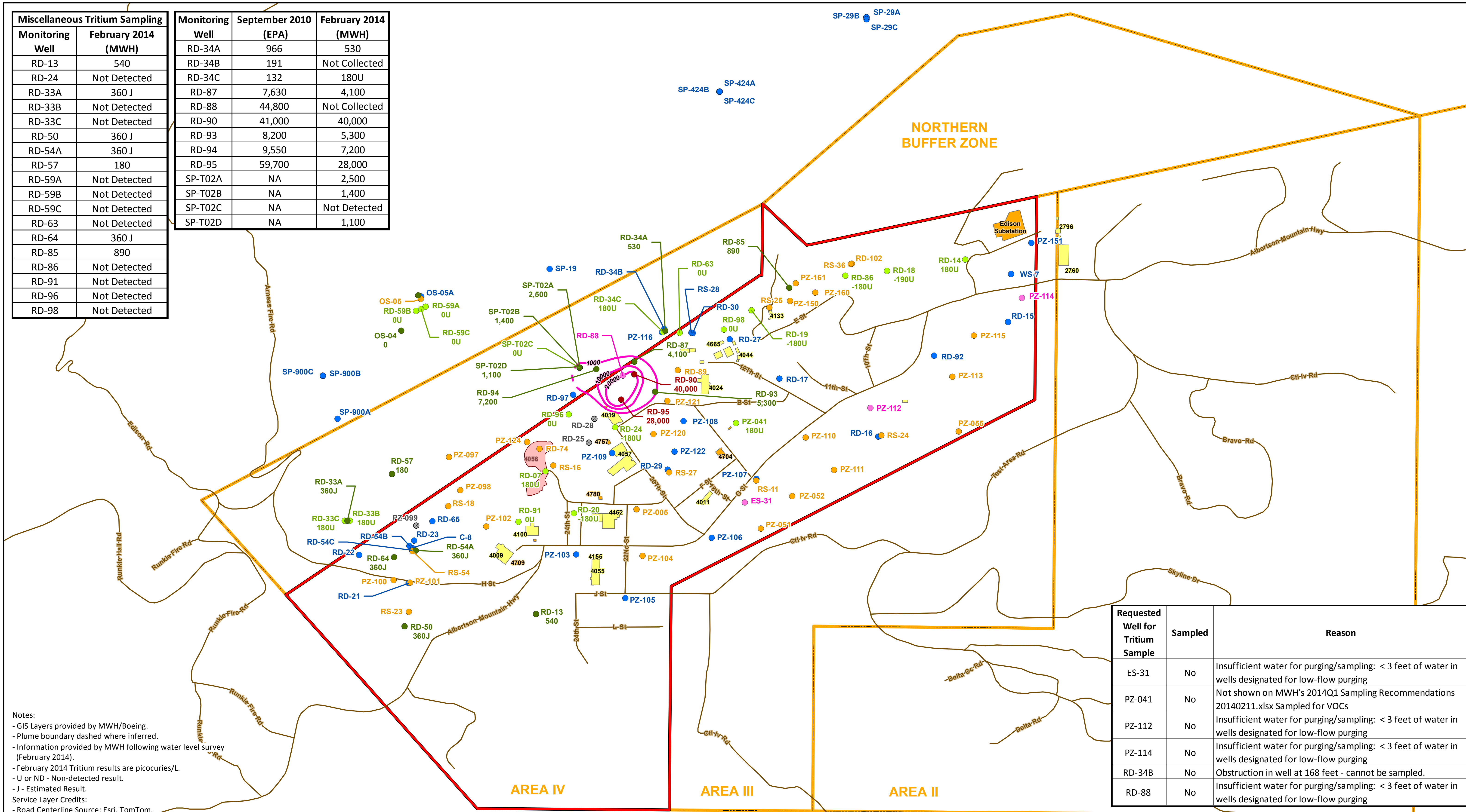
Santa Susana
Ventura County, California
Figure 2-8

CDM Smith

FarmerRA C:_projects\SantaSusana\GIS\MXD\SSFL_Layout_AreaIV_Groundwater_Feb2014_TCE_20140507.mxd 5/8/2014

Miscellaneous Tritium Sampling	
Monitoring Well	February 2014 (MWH)
RD-13	540
RD-24	Not Detected
RD-33A	360 J
RD-33B	Not Detected
RD-33C	Not Detected
RD-50	360 J
RD-54A	360 J
RD-57	180
RD-59A	Not Detected
RD-59B	Not Detected
RD-59C	Not Detected
RD-63	Not Detected
RD-64	360 J
RD-85	890
RD-86	Not Detected
RD-91	Not Detected
RD-96	Not Detected
RD-98	Not Detected

Monitoring Well	September 2010 (EPA)	February 2014 (MWH)
RD-34A	966	530
RD-34B	191	Not Collected
RD-34C	132	180U
RD-87	7,630	4,100
RD-88	44,800	Not Collected
RD-90	41,000	40,000
RD-93	8,200	5,300
RD-94	9,550	7,200
RD-95	59,700	28,000
SP-T02A	NA	2,500
SP-T02B	NA	1,400
SP-T02C	NA	Not Detected
SP-T02D	NA	1,100



Requested Well for Tritium Sample	Sampled	Reason
ES-31	No	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
PZ-041	No	Not shown on MWH's 2014Q1 Sampling Recommendations 20140211.xlsx Sampled for VOCs
PZ-112	No	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
PZ-114	No	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging
RD-34B	No	Obstruction in well at 168 feet - cannot be sampled.
RD-88	No	Insufficient water for purging/sampling: < 3 feet of water in wells designated for low-flow purging

Notes:
- GIS Layers provided by MWH/Boeing.
- Plume boundary dashed where inferred.
- Information provided by MWH following water level survey (February 2014).
- February 2014 Tritium results are picocuries/L.
- U or ND - Non-detected result.
- J - Estimated Result.
Service Layer Credits:
- Road Centerline Source: Esri, TomTom.

Legend
- Tritium above MCL of 20,000 picocuries/L
- Tritium above detection limit, below MCL
- Tritium not detected above detection limits (ND)
- Tritium sample not collected
- Dry well or insufficient water for purging/sampling (<3 feet of water in wells designated for low-flow purging)
- Well available for sampling in February 2014
- Abandoned Well
- Tritium at 20,000 Picocuries/L
- Road Centerline
- Existing Landfill
- Existing Structure
- Existing Substation
- Area IV
- SSFL Boundary

February 2014 Tritium Levels in Area IV Monitoring Wells

0 350 700 1,400 Feet

Santa Susana
Ventura County, California
Figure 2-9

CDM Smith

FarmerRA C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_Layout_AreaIV_Groundwater_Feb2014_Tritium_20150617.mxd 6/17/2015

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
PZ-098	FSDF	Niobium-94 (Nb-94)	707	0.58 / 0.02U	0.002 U / 0.17U	NC	NC	Dry	No	No	No	No/Yes	Yes	No - Niobium-94 has very low probability of being site process related; Thuilium-171 half-life too short to be site process related
PZ-098		Thulium-171 (Tm-171)	1000	130 U / 33U	166 / 55	NC	NC	Dry	No	No	Yes	No/Yes		
RD-22	FSDF	Holmium-166m (Ho-166m)	90	0.27 U / 0.49U	0.72 K, S / 0.29U	NC	NC	-1.1 U / -0.25 U	No	No	No	No/Yes	Yes	No - Very low yield fission product and low probability of being site process related
RD-54A	FSDF	Uranium-233/234 (U-233/234)	20	3.74/0.0237	3.27/0.057	4.57 / 0.05 UJ	2.3 J /0.008 UJ	3.2 J/0.22 J	Yes	Yes	No	Yes/Yes	Yes	No - Uranium products naturally occurring
RD-54A		Uranium-238 (U-238)	20	2.76/0.0243	2.51/0.06	3.03 / -0.01 UJ	1.9 J / 0.044 UJ	1.6 J/0.26 J	Yes	Yes	No	Yes/Yes		
RD-54B	FSDF	Neptunium-239 (Np-239)	300	5.2 / -0.8U	4 U / -0.9U	NC	NC	NC	No	No	Yes	No/Yes	Yes	No - Half-life too short to be site process related
RD-64	FSDF	Niobium-94 (Nb-94)	707	0.69 / 0.15	-0.004 U / -0.005	NC	NC	-1 U / 0.14 U	No	No	No	Yes/Yes	Yes	No - Niobium-94 has very low probability of being site process related
RD-33A	FSDF	Cesium-137 (Cs-137)	200	-0.31 U / 0.14U	0.37 U / -0.12U	-0.65 U / 0.28 U	4.7 J / 0.21 U	2.5 U / 0.3 U	Yes	No	No	No/Yes	Yes	**Yes - Cobalt-60 is a reactor activation product and is possibly site process related**
RD-33A		Cobalt-60 (Co-60)	100	0.66 / 0U	0 U / -0.003U	-0.68 U / 1.4 U	Not Analyzed	-2.7 U / 0.25 U	Yes	No	No	No/Yes		
RD-33A		Thulium-171 (Tm-171)	1000	230 / 1U	140 U / 44U	NC	Not Analyzed	1200 U / -380 U	No	No	Yes	No/Yes		
RD-33A		Uranium-233/234 (U-233/234)	20	0.031/-0.0069 U	1.92 / 0.0083	2.36 / 0.05 U	3 J / 0.057 UJ	3.1 J / 0.041 UJ	Yes	Yes	No	Yes/Yes		
RD-33A		Uranium-235 (U-235)	20	1.61 / 0.004U	0.071/-0.0021 U	0.11 U / 0.12 U	0.13 UJ / 0.075 UJ	0.26 J/0.1 U	Yes	Yes	No	Yes/Yes		
RD-33A		Uranium-238 (U-238)	20	1.17 / 0.0036U	1.17 / 0.0052	1.96 / 0.02 U	2.3 / 0.13 J	1.8 J / 0.16 UJ	Yes	Yes	No	Yes/Yes		
RD-33B	FSDF	Americium-241 (Am-241)	15	0.023 / 0.0101U	0.0159 / -0.0046U	Not Analyzed	-16 U / 2.6 U	-0.021 U / 0.062 U	Yes	No	No	Yes/Yes	Yes	**Yes - Americium-241 is daughter of Plutonium-241, a neutron capture product of reactor fuel, and is possibly site process related; Plutonium-238 is a neutron capture product of reactor fuel and is site process related**
RD-33B		Curium-243/244 (Cm-243/244)	15	0.025 U/0.024 U	-0.0044 U/0 U	Not Analyzed	Not Analyzed	-0.03 U/0.023	No	No	No	No/Yes		
RD-33B		Curium-245/246 (Cm-245/246)	15	0.028 / 0.017	0.0092 J / 0.009	Not Analyzed	Not Analyzed	-0.054 U / 0.2 R	No	No	No	Yes/Yes		
RD-33B		Plutonium-238 (Pu-238)	15	0.003 U / 0.059	0.0106 / 0.0262	Not Analyzed	Not Analyzed	-0.007 U / 0.042 U	Yes	No	No	Yes/Yes		
RD-33B		Thulium-171 (Tm-171)	1000	66.8 U / -26U	410 / 50U	Not Analyzed	Not Analyzed	-170 U / -320 U	No	No	Yes	No/Yes		
RD-33B		Uranium-233/234 (U-233/234)	20	0.214 / -0.003U	0.042 / 0.0128	0.26 J / 0.09 UJ	0.29 UJ / 0.058 U	0.081 UJ / 0.039 UJ	Yes	Yes	No	Yes/Yes		
RD-33C	FSDF	Cesium-134 (Cs-134)	80	0.71 K, S / -0.02U	-0.55 U / -0.09U	1.19 U / -0.65 U	-0.73 U / -1.6 U	-3.2 U/0.45 U	No	No	Yes	No/Yes	Yes	No - Cesium-134 half-life too short to be site process related
RD-33C		Cesium-137 (Cs-137)	200	0.28 U/0.02 U	-0.45 U/-0.02 U	-0.74 U / -0.21 U	0.51 U / 0.29 U	0.85 U/1.3 U	No	No	No	No/Yes		
RD-33C		Uranium-233/234 (U-233/234)	20	0.223 / -0.001U	0.209 / -0.021U	0.07 UJ / 0.06 U	0.021 UJ / 0.12 J	0.17 J / 0.11 UJ	Yes	Yes	No	Yes/Yes		
RD-33C		Uranium-238 (U-238)	20	0.11 / -0.0022U	0.116 / 0.0052U	0.03 UJ / -0.01 U	0.042 U / 0.016 UJ	0.09 UJ / 0.03 UJ	Yes	Yes	No	Yes/Yes		
RD-57	FSDF	Barium-137m (Ba-137m)	2150000	0.66 / 0.08U	-0.14 U / 0.13U	0.12 U / 0.32 U	Not Analyzed	2.9 U / 1.1 U	No	No	Yes	No/Yes	Yes	**Yes - Barium-137m is equilibrium daughter of Cesium-137, a fission product, and site process related**
RD-57		Cesium-137 (Cs-137)	200	0.7 / 0.09U	-0.15 U / -0.14U	0.12 U / 0.32 U	0.26 U / 0.46 U	2.9 U / 1.1 U	Yes	No	No	No/Yes		
RD-57		Potassium-40 (K-40)	4 mrem/yr	-19 U / -3.2U	-4.9 U / 4.9	43.01 J / -2.98 U	-1.6 U / -1.3 U	51 U / 14 U	Yes	Yes	No	Yes/Yes		
RD-57		Thulium-171 (Tm-171)	1000	100 U / 29U	220 / -25U	Not Analyzed	Not Analyzed	-2100 U / -1700 U	No	No	Yes	No/Yes		
RD-57		Uranium-233/234 (U-233/234)	20	5.03/0.004 U	4.46/0.0046	3.83 J / 0.15 U	2.7 / 0.06 U	1.6 J/0.21 U	Yes	Yes	No	Yes/Yes		
RD-57		Uranium-235 (U-235)	20	0.203/-0.0023 U	0.133/0.0024 U	0.22 J / 0.06 U	0.1 U / 0.007 U	0.22 J/0.034 U	Yes	Yes	No	Yes/Yes		
RD-57		Uranium-238 (U-238)	20	3.86/-0.0044 U	3.55/-0.0041 U	2.55 J / 0.03 U	2.1 / 0.06 U	1.1 J/0.028 U	Yes	Yes	No	Yes/Yes		
PZ-100	ESADA	Thulium-171 (Tm-171)	1000	167 / 29U	29 U / 21U	NC	Not Analyzed	Dry	No	No	Yes	No/Yes	Yes	No - Half-life too short to be site process related

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
PZ-101	ESADA	Europium-152 (Eu-152)	200	NC	1.42 / 0.48U	NC	NC	Dry	Yes	No	No	No/No	Yes	**Yes - Europium-152 is a reactor activation product and is possibly site process related**
PZ-101		Thulium-171 (Tm-171)	1000	NC	170 / 3U	NC	NC	Dry	No	No	Yes	No/No		
RD-21	ESADA	Tin-126 (Sn-126)	293	0.05 U / 0.26U	0.44 / 0.29U	NC	NC	-17 U/-0.8 U	No	No	No	No/Yes	Yes	**Yes - Tin-126 is a fission product and is possibly site process related**
RD-50	ESADA	Uranium-233/234 (U-233/234)	20	13.3/0.02	12.1/-0.0021 U	8.29 J / 0.02 UJ	11 J / 0.14 U	11 J/0.39 U	Yes	Yes	No	Yes/Yes	Yes	No - Uranium products naturally occurring
RD-50		Uranium-235 (U-235)	20	0.72/0.008 U	0.489/0.0051 U	0.332 J / 0.05 UJ	0.5 J / 0.12 U	0.51 J/0.17 U	Yes	Yes	No	Yes/Yes		
RD-50		Uranium-238 (U-238)	20	10.6/0.007 U	9.32/0.0084 K	6.19 J / 0 U	8.8 J / 0.17 U	7.8 J/0.24 U	Yes	Yes	No	Yes/Yes		
RD-13	Pond Dredge Area	Americium-241 (Am-241)	15	0.018 U / -0.17U	0.009 / 0.006U	Not Analyzed	Not Analyzed	-0.032 U / 0.084	Yes	No	No	Yes/Yes	No	**Yes - Americium-241 is daughter of Plutonium-241, a neutron capture product of reactor fuel, and is possibly site process related; Plutonium-239/240 is a neutron capture product of reactor fuel and is site process related**
RD-13		Cesium-137 (Cs-137)	200	-0.4 U/0.31	0.049 U/0.13 U	0.78 U / 0.47 U	-0.64 U / 0.69 U	-1.8 U/-0.088	Yes	No	No	Yes/Yes		
RD-13		Curium-245/246 (Cm-245/246)	15	0.021 / 0.015U	0.0046 UJ / 0.0149 J	Not Analyzed	Not Analyzed	0.049 U / 0.22 U	No	No	No	Yes/Yes		
RD-13		Plutonium-239/240 (Pu-239/240)	15	-0.0023 U / R	0.0068 / 0.011U	Not Analyzed	Not Analyzed	-0.008 U / 0.083 U	Yes	No	No	No/Yes		
RD-13		Potassium-40 (K-40)	4 mrem/yr	-19 U / -2.2U	1 U / 3.2U	-16.69 U / -4.78 U	41 J / -5.3 U	46 U / 14 U	Yes	Yes	No	No/Yes		
RD-13		Uranium-233/234 (U-233/234)	20	2.54 / -0.012	2.57 / 0.123	3 / 0 U	2.6 J / 0.074 U	2.9/ 0.15 U	Yes	Yes	No	Yes/Yes		
RD-13		Uranium-238 (U-238)	20	1.85 / -0.003	2.06 / 0.0018U	2.34 / 0.06 U	2 J / 0.11 U	1.7/ 0.24 J	Yes	Yes	No	Yes/Yes		
PZ-124	Building 56 Landfill	Europium-154 (Eu-154)	60	NC	4.2 / -1U	NC	Dry	Dry	Yes	No	No	No/No	No	**Yes - Europium-154 is a reactor activation and fission product, and is possibly site process related; Tin-126 is a fission product and is possibly site process related**
PZ-124		Thulium-171 (Tm-171)	1000	NC	190 / -1.4	NC	Dry	Dry	No	No	Yes	No/No		
PZ-124		Tin-126 (Sn-126)	293	NC	0.54 / -0.0009U	NC	Dry	Dry	No	No	No	No/No		
PZ-124		Uranium-233/234 (U-233/234)	20	NC	36.7 / 0.0202	NC	Dry	Dry	Yes	Yes	No	No/No		
PZ-124		Uranium-238 (U-238)	20	NC	35.6 / 0.0124	NC	Dry	Dry	Yes	Yes	No	No/No		
RD-07	Building 56 Landfill	Barium-137m (Ba-137m)	2150000	0.58 / -0.09U	-0.4 U / -0.21U	-1.15 U / 0.81 U	Not Analyzed	0.43 U / 0.51 U	No	No	Yes	No/Yes	No	**Yes - Barium-137m is equilibrium daughter of Cesium-137, is a fission product, and is site process related; Cobalt-60 is a reactor activation product and is possibly site process related**
RD-07		Cesium-137 (Cs-137)	200	0.61 / -0.09U	-0.42 U / 0.22U	-1.15 U / 0.81 U	0.81 U / 0.005 U	0.43 U / 0.51 U	Yes	No	No	No/Yes		
RD-07		Cobalt-60 (Co-60)	100	0.22 U / 0.01U	0.51 / 0.01U	1.14 U / -0.08 U	1 U / 0.29 U	1.4 U / 0.87 U	Yes	No	No	No/Yes		
RD-07		Potassium-40 (K-40)	4 mrem/yr	-13 U / 6.2U	-3.8 U / 9U	2.69 U / 11.02 J	5.7 U / 12 U	30 U / 8.2 U	Yes	Yes	No	No/Yes		
RD-07		Uranium-233/234 (U-233/234)	20	10.8 K / 0.0201	11 / 0.0181	13.4 J / 0.08 U	3.8 / 0.19 J	4.5 / 0.26 J	Yes	Yes	No	Yes/Yes		
RD-07		Uranium-235 (U-235)	20	0.482/0.0025 U	0.435/0.0052	0.81 / 0.09 U	0.24 J / 0.11 UJ	0.36 J/0.082 U	Yes	Yes	No	Yes/Yes		
RD-07		Uranium-238 (U-238)	20	8.79 / 0.0141	8.76 / 0.028	11.4 J / 0.05 U	3.7 / 0.18 J	3.8 / 0.096 U	Yes	Yes	No	Yes/Yes		
RD-20	Building 4100 Trench	Niobium-94 (Nb-94)	707	0.002 U / -0.04U	0.46 / 0.14U	Not Analyzed	Not Analyzed	-0.003 U / 0.74 U	No	No	No	No/Yes	No	No - Niobium-94 has very low probability of being site process related and Uranium products are naturally occurring
RD-20		Uranium-233/234 (U-233/234)	20	3.8 K / 0.0024U	3.86 / 0.024	4.75 J / 0.14 UJ	5.2 J / 0.23 UJ	4.2/0.12 U	Yes	Yes	No	Yes/Yes		
RD-20		Uranium-235 (U-235)	20	0.144/0.0024 U	0.201/0U	0.28 J / 0.06 UJ	0.44J / 0.041 UJ	0.35 J/0.089 U	Yes	Yes	No	Yes/Yes		
RD-20		Uranium-238 (U-238)	20	3.37/0.0176	3.16/0.006 U	4.83 J / 0.07 UJ	4.9 J / 0.05 UJ	3.7/0.079 U	Yes	Yes	No	Yes/Yes		
PZ-102	Building 4100/4009	Europium-154 (Eu-154)	60	NC	4.4 / 0.2U	NC	NC	Dry	Yes	No	No	No/No	No	**Yes - Europium-154 is a reactor activation and fission product, and is possibly site process related**
PZ-102		Thulium-171 (Tm-171)	1000	NC	210 / 3U	NC	NC	Dry	No	No	Yes	No/No		
RD-91	Building 4100/4009	Niobium-94 (Nb-94)	707	-0.2 U / 0U	0.5 / 0U	NC	NC	-0.68 U / 0.32 U	No	No	No	No/Yes	No	No - Niobium-94 has very low probability of being site process related

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
PZ-005	Metals Clarifier/DOE Leach Fields 3	Barium-137m (Ba-137m)	2150000	0 U / 0.07U	0.67 / 0.08U	NC	NC	NC	No	No	Yes	No/Yes	No	**Yes - Barium-137m is equilibrium daughter of Cesium-137, a fission product, and is site process related**
PZ-005		Cesium-137 (Cs-137)	200	0 U / -0.07 U	0.71 / 0.09	NC	NC	NC	Yes	No	No	No/Yes		
PZ-005		Thulium-171 (Tm-171)	1000	-20 U / 10U	180 / 28U	NC	NC	NC	No	No	Yes	No/Yes		
PZ-105	Metals Clarifier/DOE Leach Fields 3	Tin-126 (Sn-126)	293	0.81 / 0.05U	0.62 / 0.22	NC	NC	-3.91 U/-1.19 U	No	No	No	No/Yes	No	**Yes - Tin-126 is a fission product and is possibly site process related**
PZ-105		Uranium-235 (U-235)	20	0.454/0 U	0.43/0.015	NC	NC	16 J/0.1 UJ	Yes	Yes	No	Yes/Yes		
PZ-105		Uranium-238 (U-238)	20	10.4/0.041	9.58/0.426	NC	NC	9.5 /0.004 UJ	Yes	Yes	No	Yes/Yes		
PZ-105		Uranium-233/234 (U-233/234)	20	10.9 K/0.048	10.2/0.42	NC	NC	10/0.29 J	Yes	Yes	No	Yes/Yes		
RS-27	HMSA	Thulium-171 (Tm-171)	1000	NC	200 / 1U	NC	NC	NC	No	No	Yes	No/No	No	No - Half-life too short to be site process related
RD-29	HMSA	Americium-241 (Am-241)	15	0.022 / 0.011U	0.0203 / 0.0002U	NC	NC	0.086 U / 0.008 UJ	Yes	No	No	Yes/Yes	No	**Yes - Americium-241 is daughter of Plutonium-241, a neutron capture product of reactor fuel, and is possibly site process related; Plutonium products are neutron capture products of reactor fuel and are site process related; Strontium-90 was detected in soil and is highly mobile**
RD-29		Curium-245/246 (Cm-245/246)	15	0.0191 / 0.014U	0.0166 J / 0.0251	NC	NC	0.25 U / 0.11 U	No	No	No	Yes/Yes		
RD-29		Plutonium-238 (Pu-238)	15	0.013 U / 0.035U	0.0152 / 0.0209	NC	NC	-0.006 U / 0 U	Yes	No	No	No/Yes		
RD-29		Plutonium-239/240 (Pu-239/240)	15	0.0086 / 0.006U	0.003 U / 0.0045	NC	NC	-0.012 U / 0.036 U	Yes	No	No	Yes/Yes		
RD-29		Strontium-90 (Sr-90)	8	0.0109/-0.069 U	0.094/0.078	NC	NC	0.037 U/0.87 J	Yes	No	No	Yes/Yes		
PZ-108	HMSA	Cobalt-60 (Co-60)	100	0 U / 0.11U	0.63 / 0.02U	NC	NC	-1.5 U/0.73 U	Yes	No	No	No/Yes	No	**Yes - Cobalt-60 is a reactor activation product and is possibly site process related**
PZ-120	HMSA	Strontium-90 (Sr-90)	8	0.031 U/-0.015 U	0.059 U/0.009 U	NC	NC	0.15 U/-0.036 U	Yes	No	No	No/Yes	No	No - Strontium-90 nondetect for three sampling events and Uranium products are naturally occurring
PZ-120		Uranium-233/234 (U-233/234)	20	4.82/0.017 U	2.79/0.006	NC	NC	Not Analyzed	Yes	Yes	No	Yes/Yes		
PZ-120		Uranium-235 (U-235)	20	0.219/0.0026 U	0.129/0.0026 U	NC	NC	Not Analyzed	Yes	Yes	No	Yes/Yes		
PZ-120		Uranium-238 (U-238)	20	4.61/0.014 K	2.72/0.0108	NC	NC	Not Analyzed	Yes	Yes	No	Yes/Yes		
PZ-122	HMSA	Thulium-171 (Tm-171)	1000	10 U / 25U	177 / -31U	NC	NC	-1900 U/-570 U	No	No	Yes	No/Yes	No	No - Half-life too short to be site process related
RD-17	Building 4030 and Building 4093 Leach Fields	Holmium-166m (Ho-166m)	90	-0.33 U / -0.14U	1.4 K, S / 0.17U	NC	NC	2.5 U / 0.25 U	No	No	No	No/Yes	No	**Yes - Plutonium-238 is a neutron capture product of reactor fuel and is site process related**
RD-17		Plutonium-238 (Pu-238)	15	0.054 / 0.044	0.0022 U / 0.0231	NC	NC	-0.02 U / 0.006 U	Yes	No	No	Yes/Yes		
RD-17		Thulium-171 (Tm-171)	1000	140 U / 8U	330 / 17U	NC	NC	-1400 U /177 U	No	No	Yes	No/Yes		
RS-11	SE Drum Storage Area	Uranium-233/234 (U-233/234)	20	NC	30.9 / 0.0218	Not Analyzed	NC	NC	Yes	Yes	No	Yes/No	No	No - Uranium products are naturally occurring
RS-11		Uranium-238 (U-238)	20	NC	28.1 / 0.0144	Not Analyzed	NC	NC	Yes	Yes	No	Yes/No		
ES-31	SE Drum Storage Area	Niobium-94 (Nb-94)	707	0.53 / 0U	-0.22 U / 0.17U	NC	NC	Dry	No	No	No	No/Yes	No	No - Niobium-94 has very low probability of being site process related
PZ-052	SE Drum Storage Area	Tin-126 (Sn-126)	293	0.7 / 0.35U	0.56 / 0.29U	NC	NC	Dry	No	No	No	Yes/Yes	No	**Yes - Tin-126 is a fission product and is possibly site process related**

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012) Analyte Activity Phase I (filtered/suspended) (pCi/L)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012) Analyte Activity Phase II (filtered/suspended) (pCi/L)	Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012) Analyte Activity (dissolved/particulate) (pCi/L)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013) Analyte Activity (dissolved/particulate) (pCi/L)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014) Analyte Activity (dissolved/particulate) (pCi/L)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
PZ-111	SE Drum Storage Area	Holmium-166m (Ho-166m)	90	NC	0.74 SK / 0.25	NC	NC	Dry	No	No	No	No/No	No	No - Low probability of being site process related
PZ-114	New Conservation Yard	Thulium-171 (Tm-171)	1000	NC	650 / 170	NC	NC	Dry	No	No	Yes	No/No	No	No - Half-life too short to be site process related
RD-92	New Conservation Yard	Europium-154 (Eu-154)	60	1.2 U / 0.03U	4 / -1.6U	NC	Not Analyzed	1.5 U / -2.1 U	Yes	No	No	Yes/Yes	No	**Yes - Reactor activation and fission product and possibly site process related**
RD-15	New Conservation Yard	Cesium-134 (Cs-134)	80	-0.28 U / -0.17U	0.46 K, S / 0.15U	NC	NC	1.3 U /-1.3 U	No	No	Yes	No/Yes	No	**Yes - Tin-126 is a fission product and is possibly site process related**
RD-15		Cesium-137 (Cs-137)	200	0 U/0.57	0 U/0.06 U	NC	NC	1.5 U/1.2 U	Yes	No	No	No/Yes		
RD-15		Tin-126 (Sn-126)	293	0.047 U / 0.56	0.56 / 0.18U	NC	NC	-6.2 U/-0.42 U	No	No	No	No/Yes		
RD-14	Old Conservation Yard	Uranium-233/234 (U-233/234)	20	2.35 / 0.013U	3.11 / 3.12	1.23 J / -0.03 UJ	1.2 J / 0.23 J	1.5 / 0.1 UJ	Yes	Yes	No	Yes/Yes	No	No - Uranium products are naturally occurring
RD-14		Uranium-238 (U-238)	20	2.07 / 0.022	2.72 / 0.025	0.78 J / -0.1 UJ	1.1 J / 0.29 J	1 / 0.078 UJ	Yes	Yes	No	Yes/Yes		
PZ-151	Old Conservation Yard	Holmium-166m (Ho-166m)	90	Not Analyzed	1.45 / 3.31U	NC	Dry	Dry	No	No	No	No/No	No	No - Low probability of being site process related
RD-85	SRE	Barium-137m (Ba-137m)	2150000	0.04 U / 0.15U	0.7 / -0.04U	-0.22 U / -0.03 U	Not Analyzed	2.2 U / 0.24 U	No	No	Yes	No/Yes	Yes	**Yes - Barium-137m is equilibrium daughter of Cesium-137, is a fission product, and is site process related**
RD-85		Cesium-137 (Cs-137)	200	0.04 U / 0.16U	0.73 / -0.04U	-0.22 U / -0.03 U	1.2 U / -0.44 U	2.2 U / 0.24 U	Yes	No	No	No/Yes		
RD-85		Niobium-94 (Nb-94)	707	0.19 U / 0.08U	0.5 K, S / 0.18U	Not Analyzed	Not Analyzed	0.88 U / -0.71 U	No	No	No	No/Yes		
RD-85		Uranium-233/234 (U-233/234)	20	2.35/0.037	1.98/-0.0043 U	4.1 J / -0.01 UJ	3.8 J / 0.097 UJ	2.2/-0.042 U	Yes	Yes	No	Yes/Yes		
RD-85		Uranium-235 (U-235)	20	0.159/0.0015 U	0.082/0 U	0.24 J / -0.01 UJ	0.25 J / 0.03 UJ	-0.07 U/0.019	Yes	Yes	No	Yes/Yes		
RD-85		Uranium-238 (U-238)	20	1.93/0.019 U	1.63/0.0087	3.92 J / 0.04 UJ	3.1 J / 0.016 UJ	2/0.015 U	Yes	Yes	No	Yes/Yes		
RD-86	SRE	Cesium-134 (Cs-134)	80	-0.31 U / 0.09U	.0.71 K, S / 0.005U	-5.27 U / 0.15 U	-1.7 U / -1.5 U	0.13 U/-0.55 U	No	No	Yes	No/Yes	Yes	**Yes - Plutonium-238 is a neutron capture product of reactor fuel and is site process related**
RD-86		Curium-243/244 (Cm-243/244)	15	Not Analyzed	-0.0059 U/-0.0025 U	Not Analyzed	Not Analyzed	-0.013/0.036 UJ	No	No	No	No/Yes		
RD-86		Curium-245/246 (Cm-245/246)	15	Not Analyzed	0.015 J / 0.0168	Not Analyzed	Not Analyzed	0.054 U / -0.028 U	No	No	No	No/Yes		
RD-86		Plutonium-238 (Pu-238)	15	Not Analyzed	0.0192 / 0.006	Not Analyzed	Not Analyzed	-0.007 U / 0.069 U	Yes	No	No	No/Yes		
RD-86		Uranium-233/234 (U-233/234)	20	1.98 / 0.024	2.41 / 0.079	2.27 J / 0.01 UJ	14 J / 0.049 UJ	0.53 UJ / 0.31 J	Yes	Yes	No	Yes/Yes		
RD-86		Uranium-235 (U-235)	20	0.102 / 0U	0.109 / 0.0051U	0.19 UJ / 0.05 UJ	0.94 J / 0.12 UJ	0.27 J / 0.072 U	Yes	Yes	No	Yes/Yes		
RD-86		Uranium-238 (U-238)	20	2 / 0.024	2.33 / 0.058	2.13 J / 0.04 UJ	12 J / 0.02 UJ	0.71 J / 0.23 J	Yes	Yes	No	Yes/Yes		
RD-18	SRE	Radium-228 (Ra-228)	5	Not Analyzed	Not Analyzed	Not Analyzed	4.4 / 2	1.8 J/0.54 U	Yes	Yes	No	Yes/No	Yes	**Yes - Radium-228 is decay product of natural Thorium and is site process related; Tin-126 is a fission product and is possibly site process related**
RD-18		Tin-126 (Sn-126)	293	0.5 / 0.002U	0.46 U / 0.15U	Not Analyzed	Not Analyzed	-17 U/-0.15 U	No	No	No	Yes/Yes		
RD-18		Uranium-233/234 (U-233/234)	20	3.39 / 0.015U	3.3 / 0.077	4.28 J / 0.06 UJ	4.8 J / 0.072 U	4.3 J / 0.13 U	Yes	Yes	No	Yes/Yes		
RD-18		Uranium-235 (U-235)	20	0.146 / 0.0094	0.124 / 0.0053	0.18 UJ / 0.04 U	0.26 J / 0.15 U	0.34 J / 0.13 U	Yes	Yes	No	Yes/Yes		
RD-18		Uranium-238 (U-238)	20	2.48 / 0.018	2.61 / 0.057	3.47 / -0.01 UJ	4.1 J / 0.051 U	4 /0.098 U	Yes	Yes	No	Yes/Yes		
PZ-161	SRE	Niobium-94 (Nb-94)	707	-0.32 U / -0.04U	0.67 K,S / -0.14U	Not Analyzed	Dry	Dry	No	No	No	Yes/Yes	Yes	**Yes - Tin-126 is a fission product and is possibly site process related**
PZ-161		Tin-126 (Sn-126)	293	0 U / 0.27U	0.79 / 0.1U	Not Analyzed	Dry	Dry	No	No	No	Yes/Yes		
RS-36	SRE	Radium-228 (Ra-228)	5	NC	NC	1.06 U / 1.2 U	.025 U / 1.1 J	Not Analyzed	Yes	Yes	No	No/Yes	Yes	**Yes - Radium-228 is a decay product of natural Thorium and is site process related**
RS-36		Uranium-233/234 (U-233/234)	20	NC	NC	1.13 J / 0 UJ	-0.016 UJ / 0.03 UJ	NC	Yes	Yes	No	No/Yes		
RS-36		Uranium-238 (U-238)	20	NC	NC	0.48 J / 0.08 UJ	0.069 UJ / 0.026 UJ	NC	Yes	Yes	No	No/Yes		
RD-102	SRE	Radium-226 (Ra-226)	5	Not installed	Not installed	0.32 / 0.46	Not Analyzed	Not Analyzed	Yes	Yes	No	No/No	Yes	No - Radium-226 and the Uranium products are naturally occurring
RD-102		Uranium-233/234 (U-233/234)	20	Not installed	Not installed	6.59 / 0.42 J	3.5 J / 0.15 UJ	Not Analyzed	Yes	Yes	No	Yes/Yes		
RD-102		Uranium-238 (U-238)	20	Not installed	Not installed	5.38 / 0.52 J	3.7 J / 0.17 J	Not Analyzed	Yes	Yes	No	Yes/Yes		

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
RD-96	Buildings 4057/4059/4626	Tin-126 (Sn-126)	293	0.93 / 0.26U	0.23 U / 0.36U	Not Analyzed	Not Analyzed	7.2 U/-0.076 U	No	No	No	No/Yes	Yes	**Yes - Tin-126 is a fission product and is possibly site process related**
RD-96		Uranium-233/234 (U-233/234)	20	3.89 / 0.396	4.1 / 0.107	6.91 / 0 UJ	6.2 / 0.071 U	8.8 J / 0.14 U	Yes	Yes	No	Yes/Yes		
RD-96		Uranium-235 (U-235)	20	0.225/0.0056 U	0.242/0.00109	0.15 U / 0.05 UJ	0.13 U / 0.029 U	0.72 J/0.13 U	Yes	Yes	No	Yes/Yes		
RD-96		Uranium-238 (U-238)	20	3.83 / 0.249	3.8 / 0.062	5.93 / 0.04 UJ	6.1 / 0.028 U	10 J / 0.054 U	Yes	Yes	No	Yes/Yes		
RD-97	Buildings 4057/4059/4626	Americium-241 (Am-241)	15	NC	0.0119 / 0.0011U	NC	NC	0.14 U / 0.076 U	Yes	No	No	No/Yes	Yes	**Yes - Americium-241 is daughter of Plutonium-241, a neutron capture product of reactor fuel, and is a possibly site process related**
RD-97		Curium-245/246 (Cm-245/246)	15	NC	0.0099 J / 0.0207	NC	NC	0.15 U / 0.19 U	No	No	No	No/Yes		
RD-24	Buildings 4057/4059/4626	Niobium-94 (Nb-94)	707	0.64 / -0.005U	-0.37 U / 0.003U	NC	NC	0.27 U /0.293 U	No	No	No	Yes/Yes	Yes	No - Low probability of being site process related
PZ-109	Buildings 4057/4059/4626	Cadmium-113m (Cd-113m)	4 mrem/yr	7500 / 1100U	3700 U / 1100U	NC	NC	2500 U / -1300 U	No	No	No	No/Yes	Yes	**Yes - Neutron Activation of Cadium-112 used in reactor control rods - possibly site process related**
RD-90	Tritium Plume	Tin-126 (Sn-126)	293	0.88 / 0U	-0.08 U / 0.24U	NC	Not Analyzed	-8.8 U/0.24 U	No	No	No	No/Yes	Yes	**Yes - Tin-126 is a fission product and is possibly site process related**
RD-88	Tritium Plume	Antimony-125 (Sb-125)	300	7.3 K, S / -0.06U	-3.5 U / -1.7U	NC	NC	Not Requested	No	No	Yes	No/Yes	Yes	**Yes - Tellurium-125m is daughter of Antimony-125, a fission product and is possibly site process related since Antimony-125 is present**
RD-88		Tellurium-125m (Te-125m)	600	1.7 K, S / -0.01U	-0.81 U / -0.4U	NC	NC	Not Requested	No	No	Yes	No/yes		
RD-94	Tritium Plume	Barium-137m (Ba-137m)	2150000	0.0005 U / -0.03U	0.5 / 0.48	NC	NC	3.1 U / 1.2 U	No	No	Yes	No/Yes	Yes	**Yes - Barium-137m is equilibrium daughter of Cesium-137, is a fission product, and is site process related**
RD-94		Cesium-137 (Cs-137)	200	0.0006 U / -0.03U	0.53 / 0.51	NC	NC	3.1 U / 1.2 U	Yes	No	No	No/Yes		
RD-94		Niobium-94 (Nb-94)	707	0.42 / 0.18U	0.09U / 0.25	NC	NC	Not Analyzed	No	No	No	No/Yes		
RD-95	Tritium Plume	Barium-133 (Ba-133)	1520	Rejected	Rejected	NC	Not Analyzed	-2.4 U / -0.4 U	No	No	No	No/No	Yes	No - Low probability of being site process related
RD-93	Tritium Plume	Neptunium-236 (Np-236)	5960	1.23 K, S / -0.05U	-0.31 U / -0.36U	NC	Not Analyzed	-0.001 U / 0.033 U	No	No	No	No/Yes	Yes	No - Very low probability of being site process related
RD-19	Building 4133	Americium-241 (Am-241)	15	-0.02 U / 0.005U	0.0257 / -0.007U	Not Analyzed	Not Analyzed	0.013 UJ / 0.07 U	Yes	No	No	No/Yes	Yes	**Yes - Americium-241 is daughter of Plutonium-241, a neutron capture product of reactor fuel, and is possibly site process related**
RD-19		Carbon-14 (C-14)	2000	1.18 / 2.76 R	Rejected	Not Analyzed	Not Analyzed	0 U / 0 U	No	No	No	No/Yes		
RD-19		Curium-243/244 (Cm-243/244)	15	0.021 U / 0.052	0.0275 / 0U	Not Analyzed	Not Analyzed	0.004 UJ / 0.17 U	Yes	No	No	Yes/Yes		
RD-19		Curium-245/246 (Cm-245/246)	15	0.0067 U / 0.0109U	0.0218 J / 0.0138	Not Analyzed	Not Analyzed	0.031 U / 0.18 U	No	No	No	No/Yes		
RD-19		Uranium-233/234 (U-233/234)	20	14.1/0.028	14/0.0275	13.8 J / 0.09 U	13 J / 0.064 UJ	11 J/0.23 U	Yes	Yes	No	Yes/Yes		
RD-19		Uranium-235 (U-235)	20	0.719/-0021 U	0..598/0.005 U	1.05 J / 0.06 U	0.46 J / 0.019 UJ	0.63 J/0.19 U	Yes	Yes	No	Yes/Yes		
RD-19		Uranium-238 (U-238)	20	13.3/0.027	13.2/0.0021 U	11.56 J / 0.06 U	11 J / -0.016 UJ	11 J/0.16 U	Yes	Yes	No	Yes/Yes		

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
RD-98	RMHF	Americium-241 (Am-241)	15	0.023 / 0.019	0.0036 U / -0.0003U	-11.36 U / -1.64 U	Not Analyzed	0.17 U / -0.011 U	Yes	No	No	No/Yes	Yes	**Yes - Strontium-90 Impact Area**
RD-98		Carbon-14 (C-14)	2000	1.11/Rejected	Rejected	Not Analyzed	Not Analyzed	4.1 U / 2.1 U	No	No	No	No/Yes		
RD-98		Curium-243/244 (Cm-243/244)	15	0.0172 / 0.0228	0.009 J / 0.0122	Not Analyzed	Not Analyzed	-0.052 U / 0.31 R	No	No	No	Yes/Yes		
RD-98		Iodine-129 (I-129)	1	0.29 / 0.03U	0.21 U / 0.2U	Not Analyzed	Not Analyzed	0.39 U / 1.2 R	No	No	No	No/Yes		
RD-98		Plutonium-242 (Pu-242)	15	0.0139 / 0.0058	0.0042 U / 0.0032U	Not Analyzed	Not Analyzed	0.11 U / 0.072 U	No	No	No	No/Yes		
RD-98		Strontium-90 (Sr-90)	8	7/0.167	183/0.16	62.27 / 4	23 / 0.73 U	33/1.4	Yes	No	No	Yes/Yes		
RD-98		Thulium-171 (Tm-171)	1000	0.04 U / 12U	300 / 15U	Not Analyzed	Not Analyzed	-1800 U / -480 U	No	No	Yes	No/Yes		
RD-98		Uranium-233/234 (U-233/234)	20	2.18/0.141	4.82/0.008	4.11 / 0.11 UJ	2.6 J / 0.097 UJ	2.8/0.077 UJ	Yes	Yes	No	Yes/Yes		
RD-98		Uranium-235 (U-235)	20	0.098 / 0.0066	0.182 / 0.0074	0.29 J / 0.08 UJ	0.093 UJ / 0.031 UJ	0.38 J / 0.084 UJ	Yes	Yes	No	Yes/Yes		
RD-98		Uranium-238 (U-238)	20	1.52/0.108	1.54/0.0204	2.05 / 0.08 UJ	1.4 J / 0.1 UJ	1.8/0.084 UJ	Yes	Yes	No	Yes/Yes		
RD-27	RMHF	Barium-137m (Ba-137m)	2150000	-0.21 U / 0.11U	0.77 / 0.01U	NC	NC	2.6 U / 0.35 U	No	No	Yes	No/Yes	Yes	**Yes - Barium-137m is equilibrium daughter of Cesium-137, is a fission product, and is site process related; Cobalt-60 is a reactor activation product and is possibly site process related**
RD-27		Cesium-137 (Cs-137)	200	-0.23 U / -0.12U	0.82 / 0.01U	NC	NC	2.6 U / 0.35 U	Yes	No	No	No/Yes		
RD-27		Cobalt-60 (Co-60)	100	-0.44 U / 0.13U	0.009 / 0U	NC	NC	2.7 U / -1.2 U	Yes	No	No	No/Yes		
RD-30	RMHF	Strontium-90 (Sr-90)	8	NC	NC	NC	NC	0.11 U/0.81 J	Yes	No	No	No/No	Yes	**Yes - Strontium-90 Impact Area**
RS-28	RMHF	Strontium-90 (Sr-90)	8	NC	NC	NC	NC	2.5/13	Yes	No	No	No/No	Yes	**Yes - Strontium-90 Impact Area**
RD-63	RMHF	Barium-133 (Ba-133)	1520	Rejected	6.6 / 0.8U	-1.35 U / -0.25 U	-0.63 U / 0.59 U	-1.2 U / -0.74 U	No	No	No	Yes/Yes	Yes	**Yes - Barium-137m is equilibrium daughter of Cesium-137, is a fission product, and is site process related; Tin-126 is a fission product and is possibly site process related**
RD-63		Barium-137m (Ba-137m)	2150000	0.8 / 0.37	0.22 U / 0.220	-0.83 U / 0.27 U	Not Analyzed	1.9 U / 1.1 U	No	No	Yes	Yes/Yes		
RD-63		Cesium-137 (Cs-137)	200	0.84 / 0.39	0.23 U / 0.24	-0.83 U / 0.27 U	-0.86 U / -0.83 U	1.9 U / 1.1 U	Yes	No	No	Yes/Yes		
RD-63		Tin-126 (Sn-126)	293	0.64 / 0.160	0.03 U / -0.13	Not Analyzed	Not Analyzed	-4.5 U/-0.64 U	No	No	No	Yes/Yes		
RD-63		Uranium-233/234 (U-233/234)	20	5.32/0.001 U	5.63/0.09	4.77 J / 0.04 UJ	4.9 J / 0.038 UJ	4.5 J/0.24 U	Yes	Yes	No	Yes/Yes		
RD-63		Uranium-238 (U-238)	20	5.43/0.0084	5.65/0.06	4.67 J / -0.01 UJ	5.6 J / 0.057 UJ	4.4 J/-0.086 U	Yes	Yes	No	Yes/Yes		
RD-34A	RMHF	Uranium-233/234 (U-233/234)	20	10.8/0.016	10.4/0.09	12.15 J / 0.04 U	10 J / 0.1 U	7.9 J/0.3 J	Yes	Yes	No	Yes/Yes	Yes	No - Uranium products are naturally occurring
RD-34A		Uranium-235 (U-235)	20	0.578/-0.0023 U	0.52/0U	0.68 J / -0.01 U	0.48 J / 0.081 U	0.55 J/0.058 UJ	Yes	Yes	No	Yes/Yes		
RD-34A		Uranium-238 (U-238)	20	10.9/0.03	11/0.09	13.22 J / 0.05 U	8.6 J / -0.017 U	8.3 J/0.07 UJ	Yes	Yes	No	Yes/Yes		
RD-34B	RMHF	Cadmium-113m (Cd-113m)	4 mrem/yr	7600 / 600U	-2100 U / -2000U	NC	Not Analyzed	Well Obstruction	No	No	No	No/Yes	Yes	**Yes - Cadmium-113m neutron activation of Cadium-112 used in reactor control rods - possibly site process related; Tin-126 is a fission product and is possibly site process related**
RD-34B		Tin-126 (Sn-126)	293	-0.13 U / 0.28U	0.99 / 0.22U	Not Analyzed	NC	Well Obstruction	No	No	No	No/Yes		
RD-34C	RMHF	Uranium-233/234 (U-233/234)	20	0.293/0.004U	0.253/-0.0099 U	0.06 U / 0.02 UJ	0.12 J / 0.16 UJ	0.21 J/0.12 J	Yes	Yes	No	Yes/Yes	Yes	No - Uranium is naturally occurring
OS-02	Offsite	Uranium-233/234 (U-233/234)	20	NC	0.432/0.026	0.41 J / 0.16 J	0.51 J / 0.084 UJ	0.37 J/0.1 U	Yes	Yes	No	Yes/Yes	No	No - Uranium is naturally occurring
OS-03	Offsite	Uranium-233/234 (U-233/234)	20	NC	0.271 / -0.0001U	0.2 J / 0.02 UJ	0.34 J / 0.028 UJ	0.25 J / -0.001 U	Yes	Yes	No	Yes/Yes	No	No - Uranium products are naturally occurring
OS-03		Uranium-238 (U-238)	20	NC	0.092 / 0.0055U	0.18 J / 0.04 UJ	0.04 UJ / 0.075 UJ	0.23 J / 0.11 UJ	Yes	Yes	No	Yes/Yes		

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						
OS-04	Offsite	Uranium-238 (U-238)	20	0.191/0.0009 U	0.003 U	0.05 UJ / 0.02 UJ	0.3 J / -0.004 UJ	0.33 J/0.093 UJ	Yes	Yes	No	Yes/Yes	No	naturally occurring
OS-05	Offsite	Uranium-233/234 (U-233/234)	20	NC	NC	NC	0.39 / 0.094 U	NC	Yes	Yes	No	No/No	No	No - Uranium products are naturally occurring
OS-05		Uranium-238 (U-238)	20	NC	NC	NC	0.56 / -0.006 U	NC	Yes	Yes	No	No/No		
OS-10	Offsite	Uranium-233/234 (U-233/234)	20	NC	NC	NC	NC	0.57 J/0.502 U	Yes	Yes	No	No/No	No	No - Uranium products are naturally occurring
OS-10		Uranium-238 (U-238)	20	NC	NC	NC	NC	0.19 J/0.355 U	Yes	Yes	No	No/No		
RD-59A	Offsite	Cadmium-113m (Cd-113m)	4 mrem/yr	NC	9700 / -9000	Not Analyzed	Not Analyzed	-4200 U / -220 U	No	No	No	No/Yes	No	**Yes - Cadmium-113m neutron activation of Cadium-112 used in reactor control rods - possibly site process related**
RD-59A		Uranium-233/234 (U-233/234)	20	NC	0.922/-0.0034 U	0.84 J / 0 UJ	0.75 / 0.11 U	0.89 J/0.079 UJ	Yes	Yes	No	Yes/Yes		
RD-59A		Uranium-238 (U-238)	20	NC	0.607 / 0.0107	0.64 J / 0 UJ	0.66 / -0.028 U	0.46 J / 0.063 UJ	Yes	Yes	No	Yes/Yes		
RD-59B	Offsite	Thulium-171 (Tm-171)	1000	NC	170 / -2U	NC	Not Analyzed	-640 U / -600 U	No	No	Yes	No/Yes	No	**Yes - Tin-126 is a fission product and is possibly site process related**
RD-59B		Tin-126 (Sn-126)	293	NC	0.74 / 0.21U	Not Analyzed	Not Analyzed	-8.4 U/0.077 U	No	No	No	No/Yes		
RD-59B		Uranium-233/234 (U-233/234)	20	NC	0.209 / 0.009	0.5 J / 0.06 UJ	0.26 J / -0.017 U	0.33 J / 0.18 UJ	Yes	Yes	No	Yes/Yes		
RD-59B		Uranium-238 (U-238)	20	NC	0.135 / -0.0021U	0.16 J / 0 UJ	0.047 U / -0.006 U	0.19 J / -0.033 UJ	Yes	Yes	No	Yes/Yes		
RD-59C	Offsite	Uranium-233/234 (U-233/234)	20	NC	0.222 /-0.001 U	0.32 J / 0.07 UJ	0.26 J / 0.13 UJ	0.32 J/0.16 U	Yes	Yes	No	Yes/Yes	No	No - Uranium is naturally occurring

Notes
R - Rejected
K - Analyte present. Reported value may be biased high. Actual value is expected to be lower.
S - Analyte result is subject to spectral interference.
U - Result nondetect
J - Estimated value
UJ - Result is an estimated nondetect value
MCL - Maximum Contaminant Level
pCi/L - picocuries per liter
mrem/yr - millirems per year
MDC - Minimum Detectable Concentration minimum detectable concentration
NC - Not collected
NORM - Naturally Occurring Radioactive Material
FSDF - Former Sodium Disposal Facility
ESADA - Empire State Atomic Development Authority
HMSA - Hazardous Materials Storage Area
SE Drum Storage Area - South East Drum Storage Area
SRE - Sodium Reactor Experiment
RMHF - Radioactive Materials Handling Facility
DOE - Department of Energy

Half Life Reference Source: Lawrence Berkeley National Laboratory Isotopes Project DOE LBNL 2004 Version 2.1

Table 2-15
Radionuclides Evaluation

Well	Groundwater Investigation Area	Radionuclide	MCL (pCi/L or otherwise noted)	Final Groundwater Report Area IV Radiological Study, (USEPA 2012)		Report on Annual Groundwater Monitoring, 2012, SSFL (MWH 2012)	Report on Annual Groundwater Monitoring, 2013, SSFL (MWH 2013)	MWH Groundwater Monitoring Progress Report, First Quarter 2014 (MWH 2014)	Radionuclide Detected in Soil Yes/No	Radionuclide a NORM Yes/No	Half-Life Three Years or Less Yes/No	Radionuclide Detected in Groundwater Two or More Times and was it Analyzed Two or More Times Yes/No	Detected Radionuclide Within an Area Where Nuclear Material was Present/Used Yes/No	Well Location Recommended for Future Sampling Yes/No
				Analyte Activity Phase I (filtered/suspended) (pCi/L)	Analyte Activity Phase II (filtered/suspended) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)	Analyte Activity (dissolved/particulate) (pCi/L)						

<u>MCL References</u>

Analyte From Table	MCL Reference
Americium-241 (Am-241)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Antimony-125 (Sb-125)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ does limit for gross beta (EPA, 2000)
Barium-133 (Ba-133)	Isotope-specific MCL for beta emitters based on the 4 mrem/yr effective dose equivalent for gross beta (EPA, 2000)
Barium-137m (Ba-137m)	Isotope-specific MCL for beta emitters based on the 4 mrem/yr effective dose equivalent for gross beta (EPA, 2000)
Cadmium-113m (Cd-113m)	http://water.epa.gov/drink/contaminants/index.cfm#Radionuclides
Carbon-14 (C-14)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Cesium-134 (Cs-134)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000)
Cesium-137 (Cs-137)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000)
Cobalt-60 (Co-60)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000)
Curium-243/244 (Cm-243/244)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Curium-245/246 (Cm-245/246)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Europium-152 (Eu-152)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000); www.epa.gov/…/pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Europium-154 (Eu-154)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Holmium-166m (Ho-166m)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Iodine-129 (I-129)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000); www.epa.gov/…/pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Neptunium-236 (Np-236)	Isotope-specific MCL for beta emitters based on the 4 mrem/yr effective dose equivalent for gross beta (EPA, 2000)
Neptunium-239 (Np-239)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Niobium-94 (Nb-94)	Isotope-specific MCL for beta emitters based on the 4 mrem/yr effective dose equivalent for gross beta (EPA, 2000)
Plutonium-238 (Pu-238)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Plutonium-239/240 (Pu-239/240)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Plutonium-242 (Pu-242)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Potassium-40 (K-40)	http://water.epa.gov/drink/contaminants/index.cfm#Radionuclides
Radium-226 (Ra-226)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Radium-228 (Ra-228)	USEPA - http://water.epa.gov/drink/contaminants/index.cfm
Strontium-90 (Sr-90)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Tellurium-125m (Te-125m)	www.epa.gov/.../pdfs/guide_radionuclides_table-betaphotonemitters.pdf
Thulium-171 (Tm-171)	Isotope-specific MCL for beta emitters based on Primary MCL of 4 mrem/yr critical organ dose limit for gross beta (EPA, 2000)
Tin-126 (Sn-126)	Isotope-specific MCL for beta emitters based on the 4 mrem/yr effective dose equivalent for gross beta (EPA, 2000)
Uranium-233/234 (U-233/234)	Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS California, November 2008 - California Specific
Uranium-235 (U-235)	Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS California, November 2008 - California Specific
Uranium-238 (U-238)	Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS California, November 2008 - California Specific

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
PZ-98	FSDF	2/21/2003	2.35 J	Yes	No	Insufficient Information	Yes	**Yes - Not sampled since 2003 and potential soil impacts**
PZ-98		4/3/2003	2.16					
PZ-099	FSDF	**Well Abandoned**						
RS-54	FSDF	11/3/1997	**8.2**	Yes	Yes	No	Yes	**Yes - Perchlorate consistently detected and potential soil impacts**
RS-54		2/8/1998	4 U					
RS-54		5/4/1998	4 U					
RS-54		8/4/1998	**12**					
RS-54		11/18/1998	**8**					
RS-54		2/2/1999	**8**					
RS-54		8/18/1999	**12**					
RS-54		3/15/2000	**6**					
RS-54		10/26/2001	5.5					
RS-54		3/1/2002	**6**					
RS-54		11/7/2002	**8.3**					
RS-54		1/22/2013	0.9					
RD-22	FSDF	5/28/1998	4 U	Yes	Yes	Yes	Yes	**Yes - Need post FLUTe removal data and potential soil impacts**
RD-22		8/19/1998	4 U					
RD-22		2/24/2003	2.9 J to **17**					
RD-22		1/15/2013	0.0088 U					
RD-22		1/15/2013	0.0088 U					
RD-22		2/12/2014	0.0088 U					
RD-23	FSDF	2/26/2003	3.8 J	Yes	No	Yes	Yes	**Yes - Need post FLUTe removal data and potential soil impacts**
RD-23		2/12/2014	0.0088 U					
RD-54A	FSDF	11/5/1997	**10.7**	Yes	Yes	Yes	Yes	**Yes - Need post FLUTe removal data and potential soil impacts**
RD-54A		2/8/1998	**6**					
RD-54A		5/7/1998	**10**					
RD-54A		8/7/1998	**18**					
RD-54A		11/13/1998	**16**					
RD-54A		2/8/1999	**16**					
RD-54A		3/15/2000	**9**					
RD-54A		2/18/2003	**24 to 56**					
RD-54A		7/21/2011	0.28 U					
RD-54A		1/26/2012	0.28 U					
RD-54A		2/5/2013	0.28 U					
RD-54A		2/12/2014	0.05 U					
RD-54B	FSDF	2/8/1998	4 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-54B		5/6/1998	4 U					
RD-54B		2/8/1999	4 U					
RD-54B		3/15/2000	4 U					
RD-54B		10/25/2001	0.43 U					
RD-54C	FSDF	2/8/1998	4 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-54C		5/6/1998	4 U					
RD-54C		2/9/1999	4 U					
RD-54C		3/15/2000	4 U					
RD-54C		11/2/2001	0.43 U					
RS-18	FSDF	5/5/1998	4 U	Yes	Yes	Insufficient Information	Yes	**Yes - 2011 Perchlorate result above the MCL and potential soil impacts**
RS-18		5/12/1999	5					
RS-18		5/9/2000	4					
RS-18		2/19/2001	1 U					
RS-18		5/2/2003	0.8 U					
RS-18		7/14/2011	**6.3**					
RD-64	FSDF	5/28/1998	4 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-64		2/19/2003	0.8 U					
RD-65	FSDF	5/6/1998	4 U	Yes	Yes	Yes	Yes	**Yes - Potential soil impacts**
RD-65		2/17/2003	1.8 J to 3.8 J					
RD-65		2/11/2003	1.6 J to **6.2 J**					
RD-65		2/19/2003	0.8 U					
RD-65		2/13/2014	0.0088 UJ					
RD-33A	FSDF	5/27/1998	4 U	Yes	No	Yes	No	No - 2013 and 2014 results both nondetect - Other wells being sampled to characterize FSDF Investigation Area and potential soil impacts low
RD-33A		8/18/2010	0.28 U					
RD-33A		1/19/2011	0.28 U					
RD-33A		7/21/2011	0.28 U					
RD-33A		2/20/2003	3.8 J					
RD-33A		2/1/2012	1.2 J					
RD-33A		1/16/2013	0.0088 U					
RD-33A		2/12/2014	0.0088 U					

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-33B	FSDF	5/27/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-33B		1/15/2013	0.0088 U					
RD-33B		1/13/2011	0.28 U					
RD-33B		1/19/2012	0.28 U					
RD-33B		7/12/2011	0.28 U					
RD-33B		9/2/2010	0.28 U					
RD-33B		2/13/2014	0.0088 UJ					
RD-33C	FSDF	5/27/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-33C		9/3/2010	0.28 U					
RD-33C		1/25/2011	0.28 U					
RD-33C		7/12/2011	0.28 U					
RD-33C		1/19/2021	0.28 U					
RD-33C		1/16/2013	0.0088 U					
RD-33C		2/13/2014	0.0088 U					
RD-57	FSDF	5/26/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-57		2/21/2003	0.8 U					
RD-57		8/18/2010	0.28 U					
RD-57		1/19/2011	0.28 U					
RD-57		7/22/2011	0.28 U					
RD-57		1/27/2012	0.28 U					
RD-57		1/16/2013	0.0088 U					
RD-57		2/18/2014	0.0088 U					
PZ-100	ESADA	4/9/2002	2 U	No	Nondetect	Insufficient Information	Yes	**Yes - Potential soil impacts**
PZ-100		2/21/2003	1 U					
PZ-101	ESADA	6/2/2005	4.1 J	Yes	No	Insufficient Information	Yes	**Yes - Not sampled since 2005 and potential soil impacts**
RD-21	ESADA	5/5/1998	5	Yes	Yes	Insufficient Information	Yes	**Yes - Perchlorate consistently detected and potential soil impacts**
RD-21		8/4/1998	**8**					
RD-21		11/11/1998	4 U					
RD-21		2/16/1999	**9**					
RD-21		3/15/2000	5					
RD-21		10/24/2001	3.7					
RD-21		2/12/2003	**9.7 to 12**					
RD-21		2/5/2013	**6.2**					
RD-21		2/7/2014	4.1 J					
RD-50	ESADA	5/28/1998	4 U	Yes	No	Nondetect in 2013 and 2014	No	No - 2013 and 2014 results nondetect and potential soil impacts low
RD-50		2/17/2003	0.8 U					
RD-50		8/18/2010	0.28 U					
RD-50		1/19/2011	0.28 U					
RD-50		7/21/2011	0.81 J					
RD-50		1/26/2012	1.8 J					
RD-50		1/17/2013	0.28 U					
RD-50		2/12/2014	0.5 U					
RS-23	ESADA	**Not Sampled - Well Dry**						
RD-13	Pond Dredge Area	11/4/1997	1 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-13		5/26/1998	4 U					
RD-13		11/17/2000	1 U					
RD-13		2/20/2008	0.7 U					
RD-13		5/13/2008	0.7 U					
RD-13		9/3/2008	0.7 U					
RD-13		11/12/2008	0.7 U					
RD-13		3/9/2009	0.7 U					
RD-13		5/6/2009	0.7 U					
RD-13		7/15/2009	0.7 U					
RD-13		10/21/2009	0.28 U					
PZ-124	Building 56 Landfill	**Not Sampled - Well Dry**						
RD-07	Building 56 Landfill	2/6/1999	4 U	Yes	Yes	Insufficient Information	No	**Yes - Need post FLUTe removal data**
RD-07		3/16/2000	4 U					
RD-07		2/23/2001	1 U					
RD-07		8/25/2004	0.8 U					
RD-07		2/10/2003	3.1 J to **11**					
RD-07		2/7/2014	0.18 J					
RS-16	Building 56 Landfill	2/23/2005	0.8 U	No	Nondetect	Well Dry	No	**Yes - If groundwater present**
RS-16		2/1/2008	0.7 U					
RD-74	Building 56 Landfill	8/19/1999	4 U	No	Nondetect	Well Dry	No	**Yes - If groundwater present**
RD-20	Building 4100 Trench	2/15/1999	4 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-20		2/3/2000	4 U					
RD-20		2/8/2001	1 U					
RD-20		5/1/2002	0.43 U					
RD-20		2/14/2003	0.8 U					
RD-20		2/6/2004	0.8 U					
PZ-102	Building 4100/4009	**Not Sampled - Well Dry**						

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-91	Building 4100/4009	3/25/2004	0.8 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-91		4/15/2004	0.8 U					
PZ-005	Metals Clarifier/DOE Leach Fields 3	**Not Sampled**					No	No - Potential soil impacts low
PZ-104	Metals Clarifier/DOE Leach Fields 3	**Not Sampled**					Yes	**Yes - Potential soil impacts**
PZ-105	Metals Clarifier/DOE Leach Fields 3	**Not Sampled**					No	No - Potential soil impacts low
PZ-103	Metals Clarifier/DOE Leach Fields 3	**Not Sampled**					No	No - Potential soil impacts low
RS-27	HMSA	**Not Sampled**					No	No - Potential soil impacts
RD-29	HMSA	2/7/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-29		2/5/2000	4 U					
RD-29		5/9/2001	1 U					
RD-29		5/3/2002	0.43 U					
RD-29		5/13/2003	0.8 U					
RD-29		2/24/2004	0.8 U					
PZ-041	HMSA	**Not Sampled**					No	No - Potential soil impacts low
PZ-108	HMSA	2/20/2008	0.7 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
PZ-108		5/13/2008	0.7 U					
PZ-108		8/20/2008	0.7 U					
PZ-108		11/12/2008	0.7 U					
PZ-108		2/18/2009	0.7 U					
PZ-108		5/5/2009	0.7 U					
PZ-108		7/14/2009	0.7 U					
PZ-108		10/14/2009	0.28 U					
PZ-120	HMSA	**Not Sampled**					No	No - Potential soil impacts low
PZ-122	HMSA	8/21/2008	0.7 U	No	Nondetect	Nondetect	No	No - results consistently nondetect and potential soil impacts low
PZ-122		11/12/2008	0.7 U					
PZ-122		2/19/2009	0.7 U					
PZ-122		5/5/2009	0.7 U					
PZ-122		7/14/2009	0.7 U					
PZ-122		10/13/2009	0.28 U					
RD-17	Building 4030 and Building 4093 Leach Fields	2/8/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-17		2/21/2000	4 U					
RD-17		2/14/2001	1 U					
RD-17		3/1/2002	0.43 U					
RD-17		2/24/2003	0.8 U					
RD-17		2/23/2004	0.8 U					
RS-11	SE Drum Storage Area	2/6/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RS-11		2/15/2000	4 U					
RS-11		11/6/2000	1 U					
RS-11		2/6/2001	1 U					
RS-11		5/1/2003	0.8 U					
RS-24	SE Drum Storage Area	**Not Sampled**					No	No - Potential soil impacts low
ES-31	SE Drum Storage Area	2/6/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
ES-31		2/6/2000	4 U					
ES-31		2/15/2001	1 U					
ES-31		2/18/2002	0.43 U					
ES-31		2/19/2003	0.8 U					
RD-16	SE Drum Storage Area	11/5/1997	1 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-16		5/27/1998	4 U					
RD-16		8/8/1998	4 U					
RD-16		11/7/2000	1 U					
PZ-051	SE Drum Storage Area	4/4/2003	0.562 J	Yes	No	Insufficient Information	No	No - Potential soil impacts low
PZ-052	SE Drum Storage Area	2/27/2003	1 U	No	Nondetect	Insufficient Information	No	No - Potential soil impacts low
PZ-112	SE Drum Storage Area	**Not Sampled**					No	No - Potential soil impacts low

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
PZ-110	SE Drum Storage Area	**Not Sampled**					Yes	**Yes - Potential soil impacts**
PZ-111	SE Drum Storage Area	**Not Sampled**					No	No - Potential soil impacts low
PZ-107	SE Drum Storage Area	**Not Sampled**					No	No - Potential soil impacts low
PZ-106	SE Drum Storage Area	4/4/2003	1 U	No	Nondetect	Insufficient Information	Yes	**Yes - No results since 2003 and potential soil impacts**
PZ-114	New Conservation Yard	**Not Sampled**					No	No - Potential soil impacts low
PZ-115	New Conservation Yard	**Not Sampled**					No	No - Potential soil impacts low
PZ-113	New Conservation Yard	**Not Sampled**					No	No - Potential soil impacts low
RD-92	New Conservation Yard	3/25/2004	0.8 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-92		4/15/2004	0.8 U					
RD-15	New Conservation Yard	5/14/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-15		2/22/2000	4 U					
RD-15		2/15/2001	1 U					
RD-15		3/6/2002	0.43 U					
RD-15		2/26/2003	0.8 U					
RD-15		2/24/2004	0.8 U					
PZ-055	New Conservation yard	**Not Sampled**					No	No - Potential soil impacts low
RD-14	Old Conservation Yard	3/4/2002	0.43 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-14		2/22/2001	1 U					
RD-14		2/8/2000	4 U					
RD-14		2/9/1999	4 U					
RD-14		2/9/2004	0.8 U					
RD-14		2/26/2003	0.8 U					
WS-7	Old Conservation Yard	**Not Sampled**					No	No - Potential soil impacts low
PZ-151	Old Conservation Yard	**Not Sampled**					No	No - Potential soil impacts low
RS-25	Building 4133	2/25/2003	2.1 J	Yes	No	Insufficient Information	No	No - Potential soil impacts low
RS-25		5/1/2003	0.8 U					
RD-19	Building 4133	2/17/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-19		2/8/2000	4 U					
RD-19		2/9/2001	1 U					
RD-19		2/20/2002	0.43 U					
RD-19		2/26/2003	0.8 U					
RD-19		2/17/2004	0.8 U					
RD-85	SRE	**Not Sampled**					Yes	**Yes - Potential soil impacts**
RD-86	SRE	**Not Sampled**					No	No - Potential soil impacts low
RD-18	SRE	2/20/2002	0.43 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-18		2/17/1999	4 U					
RD-18		2/8/2000	4 U					
RD-18		2/9/2001	1 U					
RD-18		2/20/2002	0.43 U					
RD-18		2/17/2003	0.8 U					
RD-18		2/9/2004	0.8 U					
PZ-161	SRE	**Not Sampled**					Yes	**Yes - Potential soil impacts**
PZ-160	SRE	**Not Sampled**					Yes	**Yes - Potential soil impacts**
PZ-150	SRE	**Not Sampled**					Yes	**Yes - Potential soil impacts**
RS-36	SRE	**Not Sampled**					No	No - Potential soil impacts low
RD-102	SRE	**Not Sampled**					No	No - Potential soil impacts low

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-96	Buildings 4057/4059/4626	**Not Sampled**					Yes	**Yes - Potential soil impacts**
RD-97	Buildings 4057/4059/4626	**Not Sampled**					Yes	**Yes - Potential soil impacts**
RD-24	Buildings 4057/4059/4626	2/2/1999	4 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
RD-24		2/3/2000	4 U					
RD-24		2/6/2001	1 U					
RD-24		2/25/2002	0.43 U					
RD-24		2/12/2003	0.8 U					
RD-24		2/23/2004	0.8 U					
PZ-109	Buildings 4057/4059/4626	**Not Sampled**					Yes	**Yes - Potential soil impacts**
RD-90	Tritium Plume	3/25/2004	0.8 U	No	Nondetect	Nondetect	No	No - Potential soil impacts low
RD-90		4/15/2004	0.8 U					
RD-89	Tritium Plume	**Not Sampled**					No	No - Potential soil impacts low
RD-88	Tritium Plume	**Not Sampled**					No	No - Potential soil impacts low
RD-87	Tritium Plume	**Not Sampled**					No	No - Potential soil impacts low
RD-94	Tritium Plume	**Not Sampled**					No	No - Potential soil impacts low
PZ-121	Tritium Plume	2/20/2008	0.7 U	No	Nondetect	Nondetect	Yes	**Yes - Potential soil impacts**
PZ-121		5/13/2008	0.7 U					
PZ-121		8/20/2008	0.7 U					
PZ-121		11/12/2008	0.7 U					
RD-95	Tritium Plume	**Not Sampled**					No	No - Potential soil impacts low
RD-93	Tritium Plume	2/11/2014	1	Yes	No	Insufficient Information	Yes	**Yes - Potential soil impacts**
PZ-116	RMHF	**Not Sampled**					No	No - Potential soil impacts low
RD-98	RMHF	6/26/2008	0.7 UJ	No	Nondetect	Insufficient Information	No	No - Potential soil impacts low
RD-98		9/11/2008	0.7 U					
RD-27	RMHF	2/16/1999	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-27		2/21/2000	4 U					
RD-27		2/14/2001	1 U					
RD-27		3/6/2002	0.43 U					
RD-27		2/21/2003	0.8 U					
RD-27		2/23/2004	0.8 U					
RD-30	RMHF	3/11/2002	0.43 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-30		2/5/1999	4 U					
RD-30		5/5/2000	1 U					
RD-30		5/9/2001	1 U					
RD-30		3/11/2002	0.43 U					
RD-30		2/7/2003	0.8 U					
RD-30		2/24/2004	0.8 U					
RS-28	RMHF	5/5/2000	1 U	No	Nondetect	Nondetect	No	No - Potential soil impacts low
RS-28		5/10/2001	1 U					
RD-63	RMHF	5/4/1998	8 U	No	Nondetect	Nondetect	No	No - Potential soil impacts low
RD-34A	RMHF	8/18/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-34A		8/20/2010	0.28 U					
RD-34A		1/26/2011	0.28 U					
RD-34B	RMHF	8/18/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-34B		8/20/2010	0.28 U					
RD-34B		1/25/2011	0.28 U					

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-34C	RMHF	8/17/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-34C		8/30/2010	0.28 U					
RD-34C		1/24/2011	0.28 U					
RD-59A	Off-Site Wells	8/19/1998	5	Yes	No	Yes	No	No - Results consistently nondetect and potential soil impacts low
RD-59A		11/12/1998	4 U					
RD-59A		2/16/1999	4 U					
RD-59A		5/10/1999	4 U					
RD-59A		8/6/1999	4 U					
RD-59A		11/6/1999	4 U					
RD-59A		3/14/2000	4 U					
RD-59A		5/16/2000	1 U					
RD-59A		8/10/2000	1 U					
RD-59A		11/3/2000	1 U					
RD-59A		5/16/2001	1 U					
RD-59A		11/12/2001	0.43 U					
RD-59A		2/28/2002	0.43 U					
RD-59A		5/14/2002	0.43 U					
RD-59A		8/8/2002	0.43 U					
RD-59A		11/12/2002	1.5 U					
RD-59A		1/31/2003	1 U					
RD-59A		5/15/2003	0.8 U					
RD-59A		8/8/2003	0.8 U					
RD-59A		11/14/2003	0.8 U					
RD-59A		11/16/2004	0.8 U					
RD-59A		9/7/2005	0.8 U					
RD-59A		8/23/2006	0.8 U					
RD-59A		8/16/2007	0.65 U					
RD-59A		5/20/2008	0.7 U					
RD-59A		8/11/2010	0.28 U					
RD-59A		1/12/2011	0.28 U					
RD-59A		7/11/2011	0.28 U					
RD-59A		1/12/2012	0.28 U					
RD-59A		1/16/2013	0.0088 U					
RD-59A		2/10/2014	0.0088 U					
RD-59B	Off-Site Wells	8/19/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-59B		2/16/1999	4 U					
RD-59B		8/6/1999	4 U					
RD-59B		3/14/2000	4 U					
RD-59B		8/10/2000	1 U					
RD-59B		2/17/2001	1 U					
RD-59B		11/12/2001	0.43 U					
RD-59B		2/28/2002	0.43 U					
RD-59B		8/8/2002	0.43 U					
RD-59B		1/31/2003	1 U					
RD-59B		8/8/2003	0.8 U					
RD-59B		12/4/2003	0.8 U					
RD-59B		11/5/2004	0.8 U					
RD-59B		9/7/2005	0.8 U					
RD-59B		2/22/2006	0.8 U					
RD-59B		5/23/2007	0.65 U					
RD-59B		5/20/2008	0.7 U					
RD-59B		1/12/2011	0.28 U					
RD-59B		8/11/2010	0.28 U					
RD-59B		7/11/2011	0.28 U					
RD-59B		1/12/2012	0.28 U					
RD-59B		1/16/2013	0.0088 U					
RD-59B		2/10/2014	0.0088 U					
RD-59C	Off-Site Wells	8/19/1998	4 U	No	Nondetect	Nondetect	No	No - Results consistently nondetect and potential soil impacts low
RD-59C		2/16/1999	4 U					
RD-59C		8/6/1999	4 U					
RD-59C		3/14/2000	4 U					
RD-59C		8/10/2000	1 U					
RD-59C		2/17/2001	1 U					
RD-59C		11/12/2001	0.43 U					
RD-59C		2/28/2002	0.43 U					
RD-59C		8/8/2002	0.43 U					
RD-59C		1/31/2003	1 U					
RD-59C		8/8/2003	0.8 U					
RD-59C		12/4/2003	0.8 U					
RD-59C		11/5/2004	0.8 U					
RD-59C		9/7/2005	0.8 U					
RD-59C		2/22/2006	0.8 U					
RD-59C		5/23/2007	0.65 U					
RD-59C		5/20/2008	0.7 U					
RD-59C		8/11/2010	0.28 U					
RD-59C		1/12/2011	0.28 U					
RD-59C		7/11/2011	0.28 U					
RD-59C		1/12/2012	0.28 U					
RD-59C		1/16/2013	0.0088 U					
RD-59C		2/5/2014	0.0088 U					

Table 2-16. Perchlorate Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Sample Results (µg/L)	Was Perchlorate Detected? Yes/No	Was the Detected Perchlorate Concentration above the MCL of 6 µg/L? Yes/No	Is there a Trend of Perchlorate Concentrations Declining? Yes/No	Are There Detected Soil Perchlorate Concentrations in the Area of This Groundwater Well That Have or Could Contribute to Perchlorate Concentrations in Groundwater Wells? Yes/No	Well Location Recommended for Future Sampling? Yes/No

Notes:

Bolded Result - Value above Maximum Contaminant Level of 6 microgram per liter (µg/L)

MCL Reference - California Environmental Protection Agency, State Water Resources Control Board, October 2007, California Code of Regulations Title: 22

U - Value is nondetect

J - Value is estimated

UJ - Value is estimated and nondetect

FSDF - Former Sodium Disposal Facility

ESADA - Empire State Atomic Development Authority

HMSA - Hazardous Materials Storage Area

SE Drum Storage Area - South East Drum Storage Area

SRE - Sodium Reactor Experiment

RMHF - Radioactive Materials Handling Facility

µg/L - microgram per liter

DOE - Department of Energy

Table 2-17
TPH Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Analyte Name	Sample Results (mg/L)	Were TPHs Detected? Yes/No	Is There a Trend of TPH Concentrations Declining? Yes/No	Are There Detected Soil TPH Concentrations above 1000 mg/kg that are in the vicinity of the groundwater well that have or could contribute to TPH concentrations in the Groundwater Well? Yes/No	Well Location Recommended for Future Sampling? Yes/No
PZ-098	FSDF	4/3/2003	Kerosene Range Organics (C11-C14)	0.1 U	No	Insufficient Information	No	No - Potential soil impacts low
PZ-098		4/3/2003	Diesel Range Organics (C14-C20)	0.1 U				
PZ-098		4/3/2003	Diesel Range Organics (C20-C30)	0.1 U				
PZ-098		4/3/2003	Gasoline Range Organics (C8-C11)	0.1 U				
RS-54	FSDF	2/12/2008	Total Petroleum Hydrocarbons	0.28 U	No	Insufficient Information	No	No - Potential soil impacts low
RS-54		2/12/2008	Diesel Range Organics (C12-C14)	0.28 U				
RS-54		2/12/2008	Diesel Range Organics (C15-C20)	0.28 U				
RS-54		2/12/2008	Diesel Range Organics (C21-C30)	0.28 U				
RS-54		2/12/2008	Gasoline Range Organics (C8-C11)	0.28 U				
RD-23	FSDF	2/12/2014	Gasoline Range Organics (C6-C12)	**0.086 J**	Yes	Insufficient Information	No	**Yes - 2014 detected results**
RD-23		2/12/2014	Diesel Range Organics (C12-C14)	0.096 U				
RD-23		2/12/2014	Diesel Range Organics (C21-C30)	0.096 U				
RD-23		2/12/2014	Gasoline Range Organics (C8-C11)	0.096 U				
RD-23		2/12/2014	Diesel Range Organics (C15-C20)	**17**				
RD-23		2/12/2014	Diesel Range Organics (C8-C30)	**17 J**				
RD-65	FSDF	3/15/2013	Gasoline Range Organics (C6-C12)	**0.037 J**	Yes	Yes	No	**Yes - 2013 detected results**
RD-65		3/15/2013	Diesel Range Organics (C12-C14)	0.097 U				
RD-65		3/15/2013	Diesel Range Organics (C15-C20)	**0.7**				
RD-65		3/15/2013	Diesel Range Organics (C21-C30)	0.097 U				
RD-65		3/15/2013	Diesel Range Organics (C8-C30)	**0.8**				
RD-65		3/15/2013	Gasoline Range Organics (C8-C11)	0.097 U				
RD-65		2/7/2014	Gasoline Range Organics (C6-C12)	0.1 UJ				
RD-65		2/7/2014	Diesel Range Organics (C12-C14)	0.098 U				
RD-65		2/7/2014	Diesel Range Organics (C15-C20)	0.098 U				
RD-65		2/7/2014	Diesel Range Organics (C21-C30)	0.098 U				
RD-65		2/7/2014	Diesel Range Organics (C8-C30)	0.098 U				
RD-65		2/7/2014	Gasoline Range Organics (C8-C11)	0.098 U				
RD-21	ESADA	2/24/2009	Diesel Range Organics (C12-C14)	9.5 U	Yes	Yes	Yes	**Yes - 2009 detected results and the other ESADA sampled well had 2014 detected results**
RD-21		2/24/2009	Diesel Range Organics (C15-C20)	**18 J**				
RD-21		2/24/2009	Diesel Range Organics (C21-C30)	9.5 U				
RD-21		2/24/2009	Diesel Range Organics (C8-C30)	**18 J**				
RD-21		2/24/2009	Gasoline Range Organics (C8-C11)	9.5 U				
RD-21		4/29/2009	Diesel Range Organics (C12-C14)	9.5 U				
RD-21		4/29/2009	Diesel Range Organics (C15-C20)	**13 J**				
RD-21		4/29/2009	Diesel Range Organics (C21-C30)	9.5 U				
RD-21		4/29/2009	Diesel Range Organics (C8-C30)	**13 J**				
RD-21		4/29/2009	Gasoline Range Organics (C8-C11)	9.5 U				
RD-21		2/7/2014	Gasoline Range Organics (C6-C12)	0.1 UJ				
RD-21		2/7/2014	Diesel Range Organics (C12-C14)	0.095 U				
RD-21		2/7/2014	Diesel Range Organics (C15-C20)	0.095 U				
RD-21		2/7/2014	Diesel Range Organics (C21-C30)	0.095 U				
RD-21		2/7/2014	Diesel Range Organics (C8-C30)	0.095 U				
RD-21		2/7/2014	Gasoline Range Organics (C8-C11)	0.095 U				
RD-50	ESADA	2/16/1999	Total Petroleum Hydrocarbons	0.5 U	Yes	Insufficient Information	No	**Yes - 2014 detected results**
RD-50		2/16/1999	Diesel Range Organics (C13-C22)	0.5 U				
RD-50		2/16/1999	Gasoline Range Organics (C4-C12)	0.5 U				
RD-50		2/16/1999	Oil Range Organics (C23-C32)	0.5 U				
RD-50		2/20/2002	Gasoline Range Organics (C6-C12)	**0.013 JB**				
RD-50		2/17/2003	Gasoline Range Organics (C6-C12)	**0.15 QC**				
RD-50		11/11/2004	Gasoline Range Organics (C6-C12)	**0.035 J**				
RD-50		2/16/2005	Gasoline Range Organics (C6-C12)	**0.06 QC**				
RD-50		2/20/2009	Diesel Range Organics (C12-C14)	9.4 U				
RD-50		2/20/2009	Diesel Range Organics (C15-C20)	**19 J**				
RD-50		2/20/2009	Diesel Range Organics (C21-C30)	9.4 U				
RD-50		2/20/2009	Diesel Range Organics (C8-C30)	**19 J**				
RD-50		2/20/2009	Gasoline Range Organics (C8-C11)	9.4 U				
RD-50		4/29/2009	Diesel Range Organics (C12-C14)	12 U				
RD-50		4/29/2009	Diesel Range Organics (C15-C20)	**17 J**				
RD-50		4/29/2009	Diesel Range Organics (C21-C30)	12 U				
RD-50		4/29/2009	Diesel Range Organics (C8-C30)	**17 J**				
RD-50		4/29/2009	Gasoline Range Organics (C8-C11)	12 U				
RD-50		2/12/2014	Gasoline Range Organics (C6-C12)	0.1 U				
RD-50		2/12/2014	Diesel Range Organics (C12-C14)	0.099 U				
RD-50		2/12/2014	Diesel Range Organics (C21-C30)	0.099 U				
RD-50		2/12/2014	Gasoline Range Organics (C8-C11)	0.099 U				
RD-50		2/12/2014	Diesel Range Organics (C15-C20)	**6.9**				
RD-50		2/12/2014	Diesel Range Organics (C8-C30)	**7.2 J**				
RD-07	Building 56 Landfill	11/6/2007	Diesel Range Organics (C12-C14)	0.095 U	Yes	Yes	No	No - 2008 and 2014 results nondetect
RD-07		11/6/2007	Diesel Range Organics (C15-C20)	0.095 U				
RD-07		11/6/2007	Diesel Range Organics (C21-C30)	0.095 U				
RD-07		11/6/2007	Diesel Range Organics (C8-C30)	**0.53**				
RD-07		11/6/2007	Gasoline Range Organics (C8-C11)	**0.51**				
RD-07		2/5/2008	Total Petroleum Hydrocarbons	380 U				
RD-07		2/5/2008	Diesel Range Organics (C12-C14)	380 U				
RD-07		2/5/2008	Diesel Range Organics (C15-C20)	380 U				
RD-07		2/5/2008	Diesel Range Organics (C21-C30)	380 U				
RD-07		2/5/2008	Gasoline Range Organics (C8-C11)	380 U				
RD-07		2/7/2014	Gasoline Range Organics (C6-C12)	0.1 UJ				
RD-07		2/7/2014	Diesel Range Organics (C12-C14)	0.1 U				
RD-07		2/7/2014	Diesel Range Organics (C15-C20)	0.1 U				
RD-07		2/7/2014	Diesel Range Organics (C21-C30)	0.1 U				
RD-07		2/7/2014	Diesel Range Organics (C8-C30)	0.1 U				
RD-07		2/7/2014	Gasoline Range Organics (C8-C11)	0.1 U				
RD-74	Building 56 Landfill	No analytical data					Yes	**Yes - Potential soil impacts**

Table 2-17
TPH Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Analyte Name	Sample Results (mg/L)	Were TPHs Detected? Yes/No	Is There a Trend of TPH Concentrations Declining? Yes/No	Are There Detected Soil TPH Concentrations above 1000 mg/kg that are in the vicinity of the groundwater well that have or could contribute to TPH concentrations in the Groundwater Well? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-20	Building 4100 Trench	1/17/2013	Gasoline Range Organics (C6-C12)	0.01 U	No	Nondetect	No	No - Results consistently nondetect
RD-20		1/17/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-20		1/17/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-20		1/17/2013	Diesel Range Organics (C21-C30)	0.095 U				
RD-20		1/17/2013	Diesel Range Organics (C8-C30)	0.095 U				
RD-20		1/17/2013	Gasoline Range Organics (C8-C11)	0.095 U				
RD-20		2/7/2014	Gasoline Range Organics (C6-C12)	0.01 U				
RD-20		2/7/2014	Diesel Range Organics (C12-C14)	0.098 U				
RD-20		2/7/2014	Diesel Range Organics (C15-C20)	0.098 U				
RD-20		2/7/2014	Diesel Range Organics (C21-C30)	0.098 U				
RD-20		2/7/2014	Diesel Range Organics (C8-C30)	0.098 U				
RD-20		2/7/2014	Gasoline Range Organics (C8-C11)	0.098 U				
RD-91	Building 4100/4009	1/17/2013	Gasoline Range Organics (C6-C12)	**0.019 J**	Yes	Insufficient Information	Yes	**Yes - 2014 detected result**
RD-91		1/17/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-91		1/17/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-91		1/17/2013	Diesel Range Organics (C21-C30)	0.095 U				
RD-91		1/17/2013	Diesel Range Organics (C8-C30)	0.095 U				
RD-91		1/17/2013	Gasoline Range Organics (C8-C11)	0.095 U				
RD-91		2/13/2014	Gasoline Range Organics (C6-C12)	**0.014 J**				
RD-91		2/13/2014	Diesel Range Organics (C12-C14)	0.097 U				
RD-91		2/13/2014	Diesel Range Organics (C15-C20)	0.097 U				
RD-91		2/13/2014	Diesel Range Organics (C21-C30)	0.097 U				
RD-91		2/13/2014	Diesel Range Organics (C8-C30)	0.097 UJ				
RD-91		2/13/2014	Gasoline Range Organics (C8-C11)	0.097 U				
PZ-005	Metals Clarifier/DOE Leach Fields 3	5/25/2001	Kerosene Range Organics (C11-C14)	0.1 U	No	Nondetect	No	No - Results consistently nondetect
PZ-005		5/25/2001	Diesel Range Organics (C14-C20)	0.1 U				
PZ-005		5/25/2001	Diesel Range Organics (C20-C30)	0.1 U				
PZ-005		5/25/2001	Gasoline Range Organics (C8-C11)	0.1 U				
PZ-005		4/10/2002	Kerosene Range Organics (C11-C14)	0.1 U				
PZ-005		4/10/2002	Diesel Range Organics (C14-C20)	0.1 U				
PZ-005		4/10/2002	Diesel Range Organics (C20-C30)	0.1 U				
PZ-005		4/10/2002	Gasoline Range Organics (C8-C11)	0.1 U				
PZ-104	Metals Clarifier/DOE Leach Fields 3	4/10/2002	Kerosene Range Organics (C11-C14)	0.1 U	No	Insufficient Information	No	No - Potential soil impacts low
PZ-104		4/10/2002	Diesel Range Organics (C14-C20)	0.1 U				
PZ-104		4/10/2002	Diesel Range Organics (C20-C30)	0.1 U				
PZ-104		4/10/2002	Gasoline Range Organics (C8-C11)	0.1 U				
PZ-105	Metals Clarifier/DOE Leach Fields 3	11/10/2008	Diesel Range Organics (C12-C14)	0.094 U	Yes	Insufficient Information	No	**Yes - 2014 detected results**
PZ-105		11/10/2008	Diesel Range Organics (C15-C20)	**0.28 J**				
PZ-105		11/10/2008	Diesel Range Organics (C21-C30)	**0.17 J**				
PZ-105		11/10/2008	Diesel Range Organics (C8-C30)	**0.48 J**				
PZ-105		11/10/2008	Gasoline Range Organics (C8-C11)	0.094 U				
PZ-105		2/11/2009	Diesel Range Organics (C12-C14)	0.095 U				
PZ-105		2/11/2009	Diesel Range Organics (C15-C20)	0.095 U				
PZ-105		2/11/2009	Diesel Range Organics (C21-C30)	0.095 U				
PZ-105		2/11/2009	Diesel Range Organics (C8-C30)	0.095 U				
PZ-105		2/11/2009	Gasoline Range Organics (C8-C11)	0.095 U				
PZ-105		4/29/2009	Diesel Range Organics (C12-C14)	0.099 U				
PZ-105		4/29/2009	Diesel Range Organics (C15-C20)	0.099 U				
PZ-105		4/29/2009	Diesel Range Organics (C21-C30)	0.099 U				
PZ-105		4/29/2009	Diesel Range Organics (C8-C30)	0.099 U				
PZ-105		4/29/2009	Gasoline Range Organics (C8-C11)	0.099 U				
PZ-105		7/10/2009	Diesel Range Organics (C12-C14)	0.095 U				
PZ-105		7/10/2009	Diesel Range Organics (C15-C20)	0.095 U				
PZ-105		7/10/2009	Diesel Range Organics (C21-C30)	0.095 U				
PZ-105		7/10/2009	Diesel Range Organics (C8-C30)	0.095 U				
PZ-105		7/10/2009	Gasoline Range Organics (C8-C11)	0.095 U				
PZ-105		10/12/2009	Diesel Range Organics (C12-C14)	0.03 U				
PZ-105		10/12/2009	Diesel Range Organics (C15-C20)	0.13 U				
PZ-105		10/12/2009	Diesel Range Organics (C21-C30)	0.088 U				
PZ-105		10/12/2009	Gasoline Range Organics (C8-C11)	0.03 U				
PZ-105		2/11/2014	Gasoline Range Organics (C6-C12)	0.01 U				
PZ-105		2/11/2014	Diesel Range Organics (C12-C14)	0.097 U				
PZ-105		2/11/2014	Diesel Range Organics (C15-C20)	0.097 U				
PZ-105		2/11/2014	Diesel Range Organics (C21-C30)	**0.17 J**				
PZ-105		2/11/2014	Diesel Range Organics (C8-C30)	**0.19 J**				
PZ-105		2/11/2014	Gasoline Range Organics (C8-C11)	0.097 U				
PZ-103	Metals Clarifier/DOE Leach Fields 3	4/9/2002	Kerosene Range Organics (C11-C14)	0.1 UJ	No	Nondetect	Yes	**Yes - Potential soil impacts**
PZ-103		4/9/2002	Diesel Range Organics (C14-C20)	0.1 UJ				
PZ-103		4/9/2002	Diesel Range Organics (C20-C30)	0.1 UJ				
PZ-103		4/9/2002	Gasoline Range Organics (C8-C11)	0.1 UJ				
PZ-103		2/10/2014	Gasoline Range Organics (C6-C12)	0.01 U				
PZ-103		2/10/2014	Diesel Range Organics (C12-C14)	0.098 U				
PZ-103		2/10/2014	Diesel Range Organics (C15-C20)	0.098 U				
PZ-103		2/10/2014	Diesel Range Organics (C21-C30)	0.098 U				
PZ-103		2/10/2014	Diesel Range Organics (C8-C30)	0.098 U				
PZ-103		2/10/2014	Gasoline Range Organics (C8-C11)	0.098 U				
RD-29	HMSA	1/16/2013	Gasoline Range Organics (C6-C12)	**0.029 J**	Yes	Insufficient Information	No	**Yes - 2014 detected results**
RD-29		1/16/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-29		1/16/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-29		1/16/2013	Diesel Range Organics (C21-C30)	**0.13 J**				
RD-29		1/16/2013	Diesel Range Organics (C8-C30)	**0.13 J**				
RD-29		1/16/2013	Gasoline Range Organics (C8-C11)	0.095 U				
RD-29		2/7/2014	Gasoline Range Organics (C6-C12)	**0.027 J**				
RD-29		2/7/2014	Diesel Range Organics (C12-C14)	0.095 U				
RD-29		2/7/2014	Diesel Range Organics (C15-C20)	0.095 U				
RD-29		2/7/2014	Diesel Range Organics (C21-C30)	0.095 U				
RD-29		2/7/2014	Diesel Range Organics (C8-C30)	0.095 U				
RD-29		2/7/2014	Gasoline Range Organics (C8-C11)	0.095 U				
PZ-041	HMSA	No analytical data					Yes	**Yes - Potential soil impacts**
PZ-120	HMSA	4/2/2003	Kerosene Range Organics (C11-C14)	0.1 U	No	Insufficient Information	No	No - Potential soil impacts low
PZ-120		4/2/2003	Diesel Range Organics (C14-C20)	0.1 U				
PZ-120		4/2/2003	Diesel Range Organics (C20-C30)	0.1 U				
PZ-120		4/2/2003	Gasoline Range Organics (C8-C11)	0.1 U				

Well Location	Groundwater Investigation Area	Date Sampled	Analyte Name	Sample Results (mg/L)	Were TPHs Detected? Yes/No	Is There a Trend of TPH Concentrations Declining? Yes/No	Are There Detected Soil TPH Concentrations above 1000 mg/kg that are in the vicinity of the groundwater well that have or could contribute to TPH concentrations in the Groundwater Well? Yes/No	Well Location Recommended for Future Sampling? Yes/No
PZ-122	HMSA	4/2/2003	Kerosene Range Organics (C11-C14)	0.1 U	No	Nondetect	Yes	**Yes - Potential soil impacts**
PZ-122		4/2/2003	Diesel Range Organics (C14-C20)	0.1 U				
PZ-122		4/2/2003	Diesel Range Organics (C20-C30)	0.1 U				
PZ-122		4/2/2003	Gasoline Range Organics (C8-C11)	0.1 U				
PZ-122		8/20/2008	Diesel Range Organics (C12-C14)	0.19 U				
PZ-122		8/20/2008	Diesel Range Organics (C15-C20)	0.19 U				
PZ-122		8/20/2008	Diesel Range Organics (C21-C30)	0.19 U				
PZ-122		8/20/2008	Diesel Range Organics (C8-C30)	0.19 U				
PZ-122		8/20/2008	Gasoline Range Organics (C8-C11)	0.19 U				
PZ-122		11/12/2008	Diesel Range Organics (C12-C14)	0.095 U				
PZ-122		11/12/2008	Diesel Range Organics (C15-C20)	0.095 U				
PZ-122		11/12/2008	Diesel Range Organics (C21-C30)	0.095 U				
PZ-122		11/12/2008	Diesel Range Organics (C8-C30)	0.095 U				
PZ-122		11/12/2008	Gasoline Range Organics (C8-C11)	0.095 U				
PZ-122		2/19/2009	Diesel Range Organics (C12-C14)	0.099 U				
PZ-122		2/19/2009	Diesel Range Organics (C15-C20)	0.099 U				
PZ-122		2/19/2009	Diesel Range Organics (C21-C30)	0.099 U				
PZ-122		2/19/2009	Diesel Range Organics (C8-C30)	0.099 U				
PZ-122		2/19/2009	Gasoline Range Organics (C8-C11)	0.099 U				
PZ-122		5/5/2009	Diesel Range Organics (C12-C14)	0.096 U				
PZ-122		5/5/2009	Diesel Range Organics (C15-C20)	0.096 U				
PZ-122		5/5/2009	Diesel Range Organics (C21-C30)	0.096 U				
PZ-122		5/5/2009	Diesel Range Organics (C8-C30)	0.096 U				
PZ-122		5/5/2009	Gasoline Range Organics (C8-C11)	0.096 U				
PZ-122		7/14/2009	Diesel Range Organics (C12-C14)	0.098 U				
PZ-122		7/14/2009	Diesel Range Organics (C15-C20)	0.098 U				
PZ-122		7/14/2009	Diesel Range Organics (C21-C30)	0.098 U				
PZ-122		7/14/2009	Diesel Range Organics (C8-C30)	0.098 U				
PZ-122		7/14/2009	Gasoline Range Organics (C8-C11)	0.098 U				
PZ-122		10/13/2009	Diesel Range Organics (C12-C14)	0.031 U				
PZ-122		10/13/2009	Diesel Range Organics (C15-C20)	0.031 U				
PZ-122		10/13/2009	Diesel Range Organics (C21-C30)	0.031 U				
PZ-122		10/13/2009	Gasoline Range Organics (C8-C11)	0.031 U				
RD-17	Building 4030 and Building 4093 Leach Fields	1/29/2013	Diesel Range Organics (C12-C14)	0.096 U	No	Insufficient Information	Yes	**Yes - Potential soil impacts**
RD-17		1/29/2013	Diesel Range Organics (C15-C20)	0.096 U				
RD-17		1/29/2013	Diesel Range Organics (C21-C30)	0.096 U				
RD-17		1/29/2013	Diesel Range Organics (C8-C30)	0.096 U				
RD-17		1/29/2013	Gasoline Range Organics (C8-C11)	0.096 U				
RD-17		1/29/2013	Gasoline Range Organics (C6-C12)	0.01 U				
PZ-106	SE Drum Storage Area	4/3/2002	Kerosene Range Organics (C11-C14)	0.1 U	No	Insufficient Information	No	No - Potential soil impacts low
PZ-106		4/3/2002	Diesel Range Organics (C14-C20)	0.1 U				
PZ-106		4/3/2002	Diesel Range Organics (C20-C30)	0.1 U				
PZ-106		4/3/2002	Gasoline Range Organics (C8-C11)	0.1 U				
RD-92	New Conservation Yard	No analytical data					Yes	**Yes - Potential soil impacts**
RD-14	Old Conservation Yard	8/28/2007	Diesel Range Organics (C12-C14)	0.095 U	No	Insufficient Information	Yes	**Yes - Not sampled since 2007 and potential soil impacts**
RD-14		8/28/2007	Diesel Range Organics (C15-C20)	0.095 U				
RD-14		8/28/2007	Diesel Range Organics (C21-C30)	0.095 U				
RD-14		8/28/2007	Diesel Range Organics (C8-C30)	0.095 U				
RD-14		8/28/2007	Gasoline Range Organics (C8-C11)	0.095 U				
RD-86	SRE	8/29/2007	Diesel Range Organics (C12-C14)	0.096 U	No	Nondetect	Yes	**Yes - Potential soil impacts**
RD-86		8/29/2007	Diesel Range Organics (C15-C20)	0.096 U				
RD-86		8/29/2007	Diesel Range Organics (C21-C30)	0.096 U				
RD-86		8/29/2007	Diesel Range Organics (C8-C30)	0.096 U				
RD-86		8/29/2007	Gasoline Range Organics (C8-C11)	0.096 U				
RD-86		3/6/2008	Total Petroleum Hydrocarbons	0.19 U				
RD-86		3/6/2008	Diesel Range Organics (C12-C14)	0.19 U				
RD-86		3/6/2008	Diesel Range Organics (C15-C20)	0.19 U				
RD-86		3/6/2008	Diesel Range Organics (C21-C30)	0.19 U				
RD-86		3/6/2008	Gasoline Range Organics (C8-C11)	0.19 U				
PZ-160	SRE	No analytical data					Yes	**Yes - Potential soil impacts**
RD-18	SRE	No analytical data					Yes	**Yes - Potential soil impacts**
RD-96	Buildings 4057/4059/4626	1/23/2013	Gasoline Range Organics (C6-C12)	0.01 U	Yes	Insufficient Information	Yes	**Yes - 2013 detected results and potential soil impacts**
RD-96		1/23/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-96		1/23/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-96		1/23/2013	Diesel Range Organics (C21-C30)	0.095 U				
RD-96		1/23/2013	Diesel Range Organics (C8-C30)	**0.1 J**				
RD-96		1/23/2013	Gasoline Range Organics (C8-C11)	**0.099 J**				
RD-96		2/13/2014	Gasoline Range Organics (C6-C12)	0.1 U				
RD-96		2/13/2014	Diesel Range Organics (C12-C14)	0.1 U				
RD-96		2/13/2014	Diesel Range Organics (C15-C20)	0.1 U				
RD-96		2/13/2014	Diesel Range Organics (C21-C30)	0.1 U				
RD-96		2/13/2014	Diesel Range Organics (C8-C30)	0.1 UJ				
RD-96		2/13/2014	Gasoline Range Organics (C8-C11)	0.1 U				
RD-24	Buildings 4057/4059/4626	1/15/2013	Gasoline Range Organics (C6-C12)	0.01 U	No	Insufficient Information	No	No - Potential soil impacts low
RD-24		1/15/2013	Diesel Range Organics (C12-C14)	0.096 UJ				
RD-24		1/15/2013	Diesel Range Organics (C15-C20)	0.096 U				
RD-24		1/15/2013	Diesel Range Organics (C21-C30)	0.096 UJ				
RD-24		1/15/2013	Diesel Range Organics (C8-C30)	0.096 UJ				
RD-24		1/15/2013	Gasoline Range Organics (C8-C11)	0.096 UJ				
PZ-121	Tritium Plume	4/2/2003	Kerosene Range Organics (C11-C14)	0.1 U	Yes	Insufficient Information	Yes	**Yes - Not sampled since 2008 - Detected result in 2008 and potential soil impacts**
PZ-121		4/2/2003	Diesel Range Organics (C14-C20)	0.1 U				
PZ-121		4/2/2003	Diesel Range Organics (C20-C30)	0.1 U				
PZ-121		4/2/2003	Gasoline Range Organics (C8-C11)	0.1 U				
PZ-121		2/20/2008	Total Petroleum Hydrocarbons	0.2 U				
PZ-121		2/20/2008	Diesel Range Organics (C12-C14)	0.2 U				
PZ-121		2/20/2008	Diesel Range Organics (C15-C20)	0.2 U				
PZ-121		2/20/2008	Diesel Range Organics (C21-C30)	0.2 U				
PZ-121		2/20/2008	Gasoline Range Organics (C8-C11)	0.2 U				
PZ-121		5/13/2008	Diesel Range Organics (C12-C14)	0.19 U				
PZ-121		5/13/2008	Diesel Range Organics (C15-C20)	0.19 U				
PZ-121		5/13/2008	Diesel Range Organics (C21-C30)	0.19 U				
PZ-121		5/13/2008	Diesel Range Organics (C8-C30)	**0.25 J**				
PZ-121		5/13/2008	Gasoline Range Organics (C8-C11)	0.19 U				

Table 2-17
TPH Evaluation

Well Location	Groundwater Investigation Area	Date Sampled	Analyte Name	Sample Results (mg/L)	Were TPHs Detected? Yes/No	Is There a Trend of TPH Concentrations Declining? Yes/No	Are There Detected Soil TPH Concentrations above 1000 mg/kg that are in the vicinity of the groundwater well that have or could contribute to TPH concentrations in the Groundwater Well? Yes/No	Well Location Recommended for Future Sampling? Yes/No
RD-95	Tritium Plume	1/23/2013	Gasoline Range Organics (C6-C12)	0.1 U	No	Insufficient Information	Yes	**Yes - Potential soil impacts**
RD-95		1/23/2013	Diesel Range Organics (C12-C14)	0.098 U				
RD-95		1/23/2013	Diesel Range Organics (C15-C20)	0.098 U				
RD-95		1/23/2013	Diesel Range Organics (C21-C30)	0.098 U				
RD-95		1/23/2013	Diesel Range Organics (C8-C30)	0.098 U				
RD-95		1/23/2013	Gasoline Range Organics (C8-C11)	0.098 U				
RD-93	Tritium Plume	1/16/2013	Gasoline Range Organics (C6-C12)	0.01 U	No	Insufficient Information	Yes	**Yes - Potential soil impacts**
RD-93		1/16/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-93		1/16/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-93		1/16/2013	Diesel Range Organics (C21-C30)	0.095 U				
RD-93		1/16/2013	Diesel Range Organics (C8-C30)	0.095 U				
RD-93		1/16/2013	Gasoline Range Organics (C8-C11)	0.095 U				
RD-19	Building 4133	8/11/2008	Diesel Range Organics (C12-C14)	0.19 U	No	Nondetect	Yes	**Yes - Potential soil impacts**
RD-19		8/11/2008	Diesel Range Organics (C15-C20)	0.19 U				
RD-19		8/11/2008	Diesel Range Organics (C21-C30)	0.19 U				
RD-19		8/11/2008	Diesel Range Organics (C8-C30)	0.19 U				
RD-19		8/11/2008	Gasoline Range Organics (C8-C11)	0.19 U				
RD-98	RMHF	6/26/2008	Diesel Range Organics (C12-C14)	0.2 U	No	Nondetect	No	No - Potential soil impacts low
RD-98		6/26/2008	Diesel Range Organics (C15-C20)	0.2 U				
RD-98		6/26/2008	Diesel Range Organics (C21-C30)	0.2 U				
RD-98		6/26/2008	Diesel Range Organics (C8-C30)	0.2 U				
RD-98		6/26/2008	Gasoline Range Organics (C8-C11)	0.2 U				
RD-98		9/11/2008	Diesel Range Organics (C12-C14)	0.21 U				
RD-98		9/11/2008	Diesel Range Organics (C15-C20)	0.21 U				
RD-98		9/11/2008	Diesel Range Organics (C21-C30)	0.21 U				
RD-98		9/11/2008	Diesel Range Organics (C8-C30)	0.21 U				
RD-98		9/11/2008	Gasoline Range Organics (C8-C11)	0.21 U				
RD-98		1/23/2013	Gasoline Range Organics (C6-C12)	0.01 U				
RD-98		1/23/2013	Diesel Range Organics (C12-C14)	0.098 U				
RD-98		1/23/2013	Diesel Range Organics (C15-C20)	0.098 U				
RD-98		1/23/2013	Diesel Range Organics (C21-C30)	0.098 U				
RD-98		1/23/2013	Diesel Range Organics (C8-C30)	0.098 U				
RD-98		1/23/2013	Gasoline Range Organics (C8-C11)	0.098 U				
RD-30	RMHF	8/13/2008	Diesel Range Organics (C12-C14)	0.19 U	No	Nondetect	Yes	**Yes - Potential soil impacts**
RD-30		8/13/2008	Diesel Range Organics (C15-C20)	0.19 U				
RD-30		8/13/2008	Diesel Range Organics (C21-C30)	0.19 U				
RD-30		8/13/2008	Diesel Range Organics (C8-C30)	0.19 U				
RD-30		8/13/2008	Gasoline Range Organics (C8-C11)	0.19 U				
RS-28	RMHF	11/14/2008	Diesel Range Organics (C12-C14)	0.095 U	No	Nondetect	Yes	**Yes - Potential soil impacts**
RS-28		11/14/2008	Diesel Range Organics (C15-C20)	0.095 U				
RS-28		11/14/2008	Diesel Range Organics (C21-C30)	0.095 U				
RS-28		11/14/2008	Diesel Range Organics (C8-C30)	0.095 U				
RS-28		11/14/2008	Gasoline Range Organics (C8-C11)	0.095 U				
RD-34A	RMHF	1/28/2013	Gasoline Range Organics (C6-C12)	**0.03 J**	Yes	Yes	Yes	**Yes - Potential soil impacts**
RD-34A		1/28/2013	Diesel Range Organics (C12-C14)	0.095 U				
RD-34A		1/28/2013	Diesel Range Organics (C15-C20)	0.095 U				
RD-34A		1/28/2013	Diesel Range Organics (C21-C30)	0.095 U				
RD-34A		1/28/2013	Diesel Range Organics (C8-C30)	0.095 U				
RD-34A		1/28/2013	Gasoline Range Organics (C8-C11)	0.095 U				
RD-34A		2/11/2014	Gasoline Range Organics (C6-C12)	0.011 U				
RD-34A		2/11/2014	Diesel Range Organics (C12-C14)	0.095 U				
RD-34A		2/11/2014	Diesel Range Organics (C15-C20)	0.095 U				
RD-34A		2/11/2014	Diesel Range Organics (C21-C30)	0.095 U				
RD-34A		2/11/2014	Diesel Range Organics (C8-C30)	0.095 U				
RD-34A		2/11/2014	Gasoline Range Organics (C8-C11)	0.095 U				

Notes:
Detected Results Bolded
U - Value is nondetect
J - Value is estimated
UJ - Value is estimated and nondetect
FSDF - Former Sodium Disposal Facility
ESADA - Empire State Atomic Development Authority
HMSA - Hazardous Materials Storage Area
SE Drum Storage Area - South East Drum Storage Area
SRE - Sodium Reactor Experiment
RMHF - Radioactive Materials Handling Facility
TPH - Total Petroleum Hydrocarbon
mg/L - microgram per liter
DOE - Department of Energy

Section 3

Groundwater Data Gaps Process

The primary objectives of the Groundwater RCRA Facility Investigation (RFI) are to: (1) identify groundwater input locations; (2) define the nature and extent of contamination, (3) determine the rate of contamination migration, and (4) collect adequate data to support risk assessment and evaluation of remedial alternatives. In support of these objectives, the data gaps process for Area IV is designed to: (1) evaluate the existing monitoring well network adequacy for delineating Area IV plumes under Department of Energy's (DOE's) responsibility, (2) identify/ characterize release points within Area IV, and (3) confirm that the proper analytical tests are being used to characterize groundwater contamination in Area IV. In addition to presenting the rationale and approach to minimize data gaps, the Groundwater RFI Work Plan will facilitate Stakeholder (primarily the California Department of Toxic Substances Control [DTSC]) concurrence of data collection activities and analytical protocols for timely completion of the revised Groundwater RFI Report. This section describes a process to identify groundwater data needs and evaluate whether or not existing data are sufficient to mitigate data gaps within Area IV of the SSFL. Data gap mitigation strategies are discussed in Section 4.0.

3.1 Data Gaps Identified in 2009 Site-wide Groundwater Remedial Investigation (RFI) Report

Several groundwater-related data gaps were identified in the 2009 Site-wide Groundwater Remedial Investigation (RFI) Report for SSFL (MWH, 2009). Data gaps identified in the report specific to Area IV include:

1. Influence of North Fault, western segment, west of RD-56 (no well in or near fault zone)
2. Influence of Burro Flats Fault (distribution of monitoring wells and hydraulic testing are insufficient for demonstrating the effect of the fault)
3. Influence of former Sodium Disposal Facility (FSDF) Structures (possible channel alignment and groundwater contour inflection)

These data gaps are discussed in Section 6 - Fault Studies.

In addition, DTSC provided a number of comments on the 2009 Site-wide Groundwater RI (RFI) report in their December 21, 2011 comment letter to Boeing (DTSC, 2011). Many of the DTSC comments were specific to comprehensiveness of and interpretations within the RI (RFI) Report and Areas I, II, and III. However, there were comments related to Area IV. As such, an attempt was made to extract and summarize these Area IV comments and provide responses, which are incorporated in the analysis presented in Section 4.0 of this RFI Work Plan for Area IV.

3.2 Data Gap Process Overview

DOE adopted portions of the Boeing data gap process to guide the Area IV data gap process described in this section. The following review steps were developed for the Area IV data gap process:

- Determine operational status of each existing monitoring well
- Determine the adequacy of analytical data to represent current groundwater conditions
- Evaluate historic groundwater conditions
- Evaluate well location with respect to historic operations, physical structures, and surface water
- Evaluate well location with respect to soil/soil gas impacted areas
- Evaluate understanding of the groundwater hydraulic system
- Develop a conceptual site model for each groundwater injection area

These steps are described in detail in the following section.

Following implementation of this work plan, the site-wide data gap process will be performed iteratively to ensure that all site-wide data gaps have been identified and resolved to the extent necessary.

This RFI Work Plan presents data collection and analysis activities needed to allow timely completion of the revised Groundwater RFI Report for Area IV. During fall 2013, DOE initiated a two-part comprehensive review of Area IV data to determine:

- If all potential sources of releases to groundwater in Area IV had been identified, and
- If the monitoring well network, i.e., the location and depth of the screened interval were sufficient to characterize Area IV groundwater.

Part 1 of the data review focused on identifying groundwater sample analytical parameters for the February 2014 (1st quarter) groundwater sample event (also termed the "snap-shot" event). This sampling was intended to provide a better understanding of current groundwater conditions in Area IV and to provide data on wells and locations that had not been sampled for up to 10 years. Data produced from the February 2014 event were incorporated into the overall data review to inform the 1st Quarter 2015 groundwater sampling event.

Included in Part 1 was identification of groundwater release locations based on review of historic operational features (e.g., sumps, leach fields, tanks, chemical use/storage areas, etc.), soil and soil gas data, and groundwater quality trends. The review examined geographical "groundwater investigation areas" (shown on **Figure 2-7**) that roughly incorporate the solid waste management units and areas of concern listed in the 2007 Consent Order (CO). This data review used historic groundwater data, the geographic information system (GIS) to display Area IV features and soil data, well placement, and groundwater flow direction to assess Area IV for release locations.

Part 2 of the data gap process which is still ongoing includes the review of the February 2014 data as well as the June 2014 gas sampling data. Recent soil and soil gas data were used to ensure that all operational features and sources are known and subsequently evaluated for the adequacy of the monitoring well network to define contaminant plume boundaries within Area IV. As data are received through implementation of this RFI Work Plan, the iterative process to address the remaining Area IV groundwater data gaps will be described in the Area IV Groundwater RI Report.

Although the majority of the data gap work has focused on solvents, the most common groundwater contaminant in Area IV, the data gap assessment includes characterization of anthropogenic radioisotopes, metals, perchlorate, and total petroleum hydrocarbons (TPH). Metals will continue to be part of the analytical protocol per the Water Quality Sampling and Analysis Plan.

In Section 2, anthropogenic radioisotopes identified in the United States Environmental Protection Agency's (EPA's) 2010 and 2011 study of Area IV groundwater, were screened against maximum contaminant levels (MCLs). Using the database, historic releases of radioisotopes have been identified and are discussed in Section 2. Future actions for the RMHF Sr-90 and SNAP tritium source areas are addressed in Section 4.

Section 2 also provides groundwater data on perchlorate and TPH. Perchlorate was observed above the MCL at the FSDF, ESADA, and Building 56 Landfill. TPH remains a contaminant of concern at the FSDF, ESADA, Building 4100/4009, Metals Clarifier/DOE Leach Fields 3, Building 4057/4059/4626, and the RMHF as described for DOE areas in Section 4. Evaluation of contaminant source areas and adequacy of monitoring well network was performed.

The data gaps identification process (Section 3.3) involves seven steps. The first six steps involves addressing specific questions, while the seventh step uses the data to formulate conceptual site models (CSM) for the Area IV investigation areas discussed in Section 4.

3.3 Groundwater Data Gap Review Steps and Questions

Step 1 – Determine Operational Status of Each Existing Monitoring Well

Question 1: Is the design of the existing monitoring well adequate to characterize groundwater?

If Yes: Go to Question 4
If No: Go to Question 2

Question 2: Is the well needed to for groundwater characterization relative to identified groundwater input locations?

If Yes:

a. Modify well – Go to Question 3
b. Repair well – Go to Question 3
c. Replace well – Go to Question 3

If No: No further recommended for well

Question 3: Is groundwater being sampled representative of the conditions of interest/ concern (depth of groundwater sample from borehole or Flexible Liner Underground Technologies [FLUTe™], based on pump depth, well ports, and contaminants of concern)?

If Yes: Go to Question 4

If No:

a. Modify pump/sampling port (possibly change depth of pump or ports or replace FLUTe™) – Go to Question 4
b. Modify well (possibly drill deeper, isolate screen interval) – Go to Question 4

Step 2 – Determine Adequacy of Analytical Data to Represent Current Groundwater Conditions

Question 4: Has the well been sampled within the last 2-year period and representative of current groundwater conditions including plume definition – Chemicals and Radionuclides?

If Yes: Sample again to establish two consecutive years of groundwater data – Go to Question 5

If No: Sample well as part of current site condition assessment (collect groundwater sample to complete groundwater concentration trend and/or well deposition assessment) – Go to Question 5

Step 3 – Evaluate Historic Groundwater Conditions

Question 5: Has a chemical been detected in soil where (1) there is less than 30 feet of separation from groundwater and/or (2) based on concentration, there is a reasonable potential for groundwater impact? If so, is the chemical included in the current site assessment analytical suite?

If Yes: Sample for chemical in groundwater to confirm if concentration is above regulatory standards – Go to Question 6

If No: Sample as required under the Water Quality Sampling and Analysis Plan – Go to Question 6

Question 6: Was a radionuclide reported in EPA's Final Groundwater Report Area IV Radiological Study (HGL, 2012) findings for anthropogenic exceedances or reported for prior sampling?

If Yes: Sample for EPA's anthropogenic constituent(s) or prior detects

If No: Radionuclides not included in analytical suite

Step 4 – Evaluate Well Location with Respect to Historic Operations, Physical Structures, and Surface Water

Question 7: Based on operational history, including groundwater input locations (tanks, leach fields, drainages, impoundments, collection facilities, etc.), are monitoring well(s) located appropriately relative to flow direction? (The assumption is that contaminants move first downward through bedrock fractures and then laterally, following bedrock fractures. This question will need to be revisited once particle tracking modeling is updated.)

If Yes: Continue sampling well as is

If No: Evaluate optimal location and design of new well, install new well

Question 8: Based on operational history, including groundwater input locations (tanks, leach fields, drainages, impoundments, collection facilities, etc.), have the well(s) been sampled for appropriate analytical suite?

If Yes: Sample well for default analytical suite

If No: Add constituent(s) to the analytical suite

Step 5 – Evaluate Well Location~~s~~ with Respect to Soil/Soil Gas Impacted Areas

Question 9: Based on soil/soil gas data, are monitoring well(s) located appropriately to the area?

If Yes: Sample well for default analytical suite

If No: Evaluate optimal location; design new well; install new well

Question 10: Based on soil/soil gas data, have the well(s) been sampled for appropriate analytical suite?

If Yes: Sample well for default analytical suite

If No: Add constituent(s) to the analytical suite

Step 6 – Evaluate Understanding of the Groundwater Hydraulic System

Question 11: Is the groundwater hydraulic system sufficiently understood to allow for determination of the adequacy of the existing monitoring well network?

If Yes: No further evaluation (system is understood and existing monitoring well network is adequate)

If No:

a. Additional modeling and particle tracking presentation will be necessary as a result of new understanding of current site conditions (e.g., drought, FSDF lineaments, fault investigations, pump tests)

b. Apply simplistic water movement approach

c. Springs and other investigations may compliment system evaluation/ understanding

d. Review constituents in groundwater and plume characteristics versus monitoring well location

e. Review groundwater responses to historical transient changes in conditions such as pumping of water supply wells, and extraction at RD-63, RD-25, and RD-21

Step 7 – Develop a Conceptual Site Model for Each Groundwater Investigation Area

A CSM for the groundwater investigation area combines the information collected and evaluated in the previous six steps. The CSM represents the current understanding of the pathway that known or suspected contaminants travel through site media. The existing data are used to both develop and test the CSM. If the CSM cannot explain the current conditions, a data gap may be present. The CSM is examined to determine if additional groundwater monitoring wells, analytical data, hydrogeologic data, modeling, or other data collection are required to minimize/eliminate the data gap. Section 4.0 provides descriptions of the CSMs for the Groundwater Investigation Areas.

3.4 Data Gap Process Outcome

The completion of the data gap process will identify additional characterization work that is introduced in Section 4. Section 4 is divided by the identified Groundwater Investigation Areas. Within Section 4 there are data presentations for what is currently known for each Area, a CSM for each Area, and recommendations for additional characterization work. The recommendations can involve:

- Identification of any previously unidentified release areas from soil gas study
- Conducting additional hydrogeologic studies
- Installation of additional monitoring wells
- Identification of groundwater depth sampling intervals for existing wells
- Conducting additional groundwater sampling using focused analytical suites
- Conducting groundwater flow and contaminant transport modeling
- Incorporation of results into the revised Groundwater RI Report

References

DTSC, 2011. *Department of Toxic Substances Control Comments on the Site-wide Groundwater Remedial Investigation Report for Santa Susana Field Laboratory, Ventura County, California*. December.

HGL, 2012. *Final Groundwater Report, Area IV Radiological Study, Santa Susana Field Laboratory Ventura County, California.* July

MWH, 2009. *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. December.

Section 4

Area IV Groundwater Investigation Areas

As was introduced in Section 2.0, Area IV has been subdivided into 19 investigation areas based on historic operations and groundwater issues. Per the 2007 Consent Order (CO), the responsibilities for the characterization of the investigation areas have been divided up by the Department of Energy (DOE) and The Boeing Company. The 12 areas being investigated by DOE are the Former Sodium Disposal Facility (FSDF), Building 4100 Trench, Building 56 Landfill, Buildings 4057/4059/4626 area, Building 4457 Hazardous Materials Storage Area (HMSA), Tritium Plume, Radioactive Materials Handling Facility (RMHF), Old Conservation Yard (OCY), Metals Clarifier/DOE leach fields 3, Building 4064 leach field/Buildings 4030 and 4093 leach fields, and the Hazardous Waste Management Facility (HWMF) Building 4133/Building 4029. The eight areas under Boeing's responsible charge are Empire States Atomic Development Authority, Pond Dredge, Sodium Reactor Experiment area, New Conservation Yard (NCY), Southeast Drum Storage Area, Building 4008 Warehouse, and Process Development Unit/17 St. Drainage area. Due to building ownership and releases not related to DOE activities, DOE will jointly investigate Buildings 4100/4009 with Boeing. The evaluation of the groundwater investigation areas under DOE's responsibility is presented in this section. Boeing will be conducting its own assessment of the areas under its responsibility and they are not discussed in this section.

The investigation areas are exhibited in **Figure 4-1**. The following text describes the operations, groundwater quality issues, prior investigation findings, and required work descriptions for each of the areas.

4.1 Former Sodium Disposal Facility – Building 4886

Per the 2007 CO the FSDF is a DOE responsibility. Groundwater beneath the FSDF exhibits the highest concentrations of trichloroethene (TCE) of any location within Area IV. Prior to aquifer pumping at the FSDF in 1997, the maximum TCE concentrations observed at the site was 4,100 microgram per liter (µg/L). During and following pumping, TCE concentrations decreased, with a 1,600 µg/L concentration reported for 2013.

4.1.1 FSDF Operation History

Operations

The FSDF, also known as the Sodium Burn Pit and Building 4886, was used from 1956 to 1978 to clean metallic components and other materials (pipes, valves, tanks, and instruments) of alkali metals (sodium and potassium/sodium mixtures). Treatment was accomplished by reacting the alkali metals with water using either a pressure washer or placement in a pool of water. The use of the FSDF was ceased when rules under the Resource Conservation Recovery Act (RCRA) precluded treatment and disposal in open unlined facilities. In addition to sodium-contaminated materials, the FSDF received chemical wastes including chlorinated solvents (mostly TCE), polychlorinated biphenyls (PCBs), metals (such as mercury), and radionuclides (primarily Cesium-137 [Cs-137]). The site was also used for the burning of "Santo-wax," an organic compound used as a heat transfer medium in nuclear reactors.

The FSDF consisted of three facilities – (1) an asphalt and concrete pad used for steam cleaning objects, (2) an adjacent concrete submergence pit (pool) (see **Figure 4-2**), and (3) a pond. To the immediate north of the pad and pool, was the upper earth-formed pond, with a second lower earth-formed pond at the north edge of the facility. The facility was operated by steam cleaning sodium-impacted objects on the pad, and then placing the material in the concrete pit for final reaction of residual sodium with water. Following treatment the material was either reused or the debris was placed into one of the earthen ponds, thereby using the ponds for temporary disposal of debris not intended for reuse. As a maintenance activity, material that was left in the ponds was periodically removed after the pond was allowed to dry. The debris was bulldozed out of the pond and disposed of either locally in the western debris area or removed from the site. The submergence pit next to the steam cleaning pad was connected to a pipe from the ESADA facility (Building 4814; Boeing responsibility per the 2007 CO) thus receiving liquid wastes from sodium metal tests conducted in that facility. Being a Boeing responsibility, the ESADA is only mentioned minimally in this section.

Soil and Debris Removal Actions

Following cessation of use, the FSDF area was subject to a series of soil and groundwater investigations and removal actions for surface debris. The soil within and adjacent to the ponds was found to be contaminated by PCBs, mercury, Cs-137, and solvents. Groundwater was found to be contaminated by TCE, 1,1,1-trichloroethane (TCA), metals, and perchlorate.

As soil contamination was discovered, soil removal actions were performed. The first soil cleanup was performed in 1980 when approximately 20 cubic yards of soil were excavated from the Lower Pond to remove the soil with Cs-137.

The next soil removal action was planned in 1991, initiated in early 1992, and completed in June 1993. Soil was excavated to the bedrock interface and all debris found within the excavation removed. In all, over 12,000 cubic yards of contaminated soil and 20,000 pounds of debris were removed from the site. Per DOE rules, soil exhibiting radioactivity above background was managed and disposed of separately from soil that was only chemically contaminated. Soil removal also included two drainages north of the facility that were contaminated. The soil/debris removal action addressed the original source of groundwater contamination.

Based on soil surveys in 1994, no radiation was found above background and the FSDF was no longer considered a radioactive material handling area. Some limited excavations of buried objects occurred in August 1996 within previously non-excavated areas based on the results of a geophysical survey. Soil sampling conducted in 1995, in the vicinity of the FSDF, identified contamination by mercury, TPH, PCBs, and dioxins.

Soil and debris removals at and in the vicinity of the FSDF ponds continued to the year 2000. In all, 14,000 cubic yards of soil were removed from the site. The excavated ponds were covered with an impermeable liner to capture rainfall. Facility operators were required to pump off of the liners any accumulated rainfall. In 2000, the liners were removed and the ponds backfilled with soil from the Area IV borrow pit.

Fill materials primarily consist of silty, fine-grained sand and sandy silt with sandstone gravel and cobbles. The maximum depth of backfill in the area of the former FSDF pond excavation is about 13 feet below current grade based on topographic surveys performed following the excavation. In December 2000 the site was hydroseeded and oak trees were planted. In 2011 the oak trees were between 10 and 15 feet in height.

Groundwater Investigations and Interim Measures

Interim measures to remove TCE and perchlorate from the groundwater were conducted from 1997 to 2000, and again from 2002 to 2003. Groundwater was extracted from bedrock well RD-21 and near-surface groundwater well RS-54 and treated by resin filters for perchlorate.

To measure the downward infiltration of rainwater through the soil overlying the FSDF ponds, two pan lysimeters were installed in 2000. The first was installed in the area of the Lower Pond and the second to the south of the first. The lysimeters were placed about 1 foot above the bedrock interface. The total soil cover above lysimeter 1 is approximately 7 feet and above lysimeter 2 is approximately 11 feet. Four piezometers were installed to measure water at the backfilled soil-bedrock interface. The piezometers were advanced from the surface to 4 to 6 inches into the bedrock.

4.1.2 FSDF Soils, Geology, and Hydrogeology

The former FSDF facility and ponds are on the western edge of the relatively flat terrain of Burro Flats. The land surface drops off approximately 20 feet to the northeast. There are two geologic bedrock units of interest in the FSDF groundwater investigation area – the Chatsworth Formation that underlies the FSDF and the Santa Susana Formation that is immediately to the south of ESADA and the FSDF.

The soils in the FSDF area are derived from weathered Chatsworth bedrock and colluvium. The FSDF area borders the Santa Susana formation that is of a higher elevation and some soil may be derived as colluvium. Backfill material for the FSDF ponds came from the borrow site located in the Santa Susana formation.

The FSDF is underlain by the Upper Burro Flats member of Chatsworth Formation. This sandstone unit includes thin interbeds of fine-grained rock and to the northeast, in the NBZ, the Shale 3 members outcrop. Beds of these units generally strike N70°E and dip 25°NW.

The Santa Susana Formation is predominantly composed of micaceous claystone and siltstone, with a few minor sandstone beds (Dibblee, 1992).

Structurally, the Chatsworth and Santa Susana Formations are separated by the Burro Flats Fault, located immediately south of ESADA. This fault strikes east-west in the study area. Other structural features in the FSDF include a series of deformation bands north and west of the FSDF site and two other structures located east of the FSDF site. Investigations of the Western FSDF Structure Lineament and the Eastern FSDF Lineament Structure by MWH indicate that these structures are not faults (MWH, 2013).

At the FSDF, near-surface groundwater is perched above the Chatsworth Formation groundwater. When present (perched groundwater is typically not present), perched groundwater can be as shallow as 6 feet below ground surface (bgs) at ESADA and 8 to 21 feet bgs near the FSDF. Because it is perched there is a downward vertical gradient between the near-surface and bedrock groundwater.

Depth to bedrock groundwater at FSDF varies greatly from 101 feet bgs to 305 feet bgs. Within the bedrock there is generally a downward vertical gradient at locations on Burro Flats, and an upward vertical gradients at locations on the western slopes of the FSDF (specifically at the RD-33 well cluster). The lateral flow gradient is to the northwest.

Corehole 8 (C-8) was drilled to 400 feet in the FSDF area to obtain data on bedrock properties (see **Figure 4-2**). C-8 is a 400-foot deep, 12.25-inch diameter borehole, cased from ground surface to 65 feet bgs. From 65 feet to 400 feet the corehole is a nominal 5-inch diameter. Nineteen bedrock core samples were collected while drilling C-8 for hydraulic conductivity (K_m) analyses. Laboratory results for K_m ranged between 4.96×10^{-8} centimeters per second (cm/s) and 9.67×10^{-2} cm/s, with a geometric mean of 2.61×10^{-7} cm/s (MWH, 2006a).

The bulk hydraulic conductivity (K_b) of bedrock at the FSDF was determined by 26 rising head and falling head slug tests in four wells equipped with discrete interval monitoring systems. Approximately 90 percent of the tests indicated K_b values in the range of 10^{-5} to 10^{-6} cm/s, and a geometric mean of 5.4×10^{-6} cm/s (MWH, 2006a).

A pump test using RD-54B was conducted to further evaluate bedrock K_b. Groundwater was extracted at a rate of 173 gallons per day (gpd) for 165 days, inducing a 160-foot water level drawdown. Measurements were made in 16 adjacent wells fitted with pressure transducers. The test resulted in a geometric mean K_b value of 6×10^{-7} cm/sec. The data indicate that the bedrock fracture network near the FSDF area does not appreciably enhance the K_b of the Chatsworth Formation (MWH, 2006a).

Down-hole geophysical logging has been conducted on wells RD-22, RD-23, RD-57, and RD-65, and in C-8. The borehole geophysical measurements were used to evaluate the stratigraphy at depth and the inter-well relationships to characterize the three-dimensional geometry of the bedrock. This data and the boring logs were used to evaluate the connectivity of bedrock fractures for the vicinity of the FSDF. The overall findings of the hydrogeological investigation of the FSDF area indicated that the bedrock sandstone is less porous and exhibit fewer fractures than other locations of Area IV and the SSFL.

Extent of Contamination

The results of soil sampling at the FSDF location post-soil removal actions show the location to be nearly free of contaminants. Therefore, this section focuses on current soil vapor and historic groundwater contamination data for the FSDF.

MWH performed a soil vapor investigation across Area IV during the summer of 2014 (MWH, 2014b). Results for key COCs are illustrated in **Appendix A, Figure A-1**. As would be expected, the highest TCE concentration observed for Area IV was 1.6 µg/L for the sample collected at the location of the FSDF (8SV_DG-512). Lesser amounts of TCE were observed at locations adjacent to the FSDF (8SV_DG-506, 8SV_DG-515, 8SV_DG-502, 8SV_DG-503, and 8SV_DG-517). These results are consistent with the knowledge that the FSDF was the source for TCE in groundwater at this location.

The FSDF location has been investigated through installation of six shallow wells and piezometers, eleven deep wells, and the drilling, logging and testing of a 400-foot deep corehole (C-8). The highest concentration of TCE in the Near-surface groundwater has been reported for shallow monitoring well RS-54 installed within the boundaries of the FSDF ponds and adjacent to deep cluster well RD-54A, 54B, and 54C. Although typically dry, a concentration of 1,600 µg/L TCE was reported for a 2013 sample. The FSDF pond is assumed to be the source for the TCE in groundwater at this location. TCE has been detected at lower concentrations at locations on the edges of the FSDF:

- 29 µg/L of TCE was detected in PZ-098, located downgradient of both the FSDF and Building 100, in April 2003

- 140 µg/L of TCE was detected in PZ-099, located about 200 feet north of the FSDF ponds, in April 2003
- 140 µg/L of TCE was detected in PZ-101, located upgradient of the FSDF concrete pool and downgradient of ESADA, in June 2005.

4.1.3 Monitoring Well Network

Groundwater quality at FSDF has been monitored by six shallow wells or piezometers RS-54, PZ-097, PZ-098, PZ-099, PZ-100, and PZ-101 and 11 bedrock wells (RD-22, RD-23, RD-33A, RD-33B, RD-33C, RD-54A, RD-54B, and RD-54C, RD-57, RD-64, and RD-65) (**Figure 4-2**).

Shallow Wells

TCE has been reported for groundwater samples from the near-surface groundwater, although several of the piezometers and shallow wells are either routinely dry (PZ-097, PZ-098, PZ-101) or have been abandoned (PZ-099; abandoned in 2005).

PZ-097

PZ-097, located downgradient of the FSDF, has always been dry and does not provide water quality data.

PZ-098

PZ-098 (37.5 feet deep) was sampled once in April 2003; the TCE concentration was 29 µg/L. It is typically dry. Due to downgradient location of PZ-098 of the FSDF and Building 4100, it is not known whether the detection of TCE is a result of a release from either or both facilities. PZ-098 is too shallow to be an effective monitoring point for bedrock water quality; it is typically either dry or contains insufficient water to sample.

<u>Possible Data Gap Actions for PZ-098:</u>

- The northern portion of the TCE plume is not defined because downgradient piezometer PZ-098 is too shallow to intersect near-surface water
- Install deeper monitoring well capable of collecting Chatsworth Formation groundwater. This new well is discussed at the end of the section.

PZ-099 (Abandoned)

PZ-099 was installed in the downgradient direction from the FSDF. PZ-099 was only sampled one time in April 2003 and TCE was reported at a concentration of 140 µg/L. The well was dry during the RD-54B pump test and the location has provided no additional aquifer characterization data. Well PZ-099 was abandoned in 2006 during the installation of surface water erosion controls at nearby Outfall 005.

PZ-100

PZ-100, potentially lateral and upgradient of the FSDF and downgradient of ESADA, was sampled twice prior to 2011; TCE was not reported for either event. PZ-100 (16.5 feet deep) has been typically dry and is not a reliable monitoring point. Bedrock well RD-21, located downgradient of ESADA and adjacent to PZ-100, exhibits TCE concentrations exceeding 100 µg/L. Packer testing of RD-21 may provide shallow groundwater data in lieu of a point at PZ-100.

PZ-101

Like the other shallow wells at the FSDF, PZ-101 is typically dry. Packer testing of RD-21 may provide shallow groundwater data for the PZ-101 location.

RS-54

RS-54 was installed within the boundaries of the FSDF ponds adjacent to deep cluster well RD-54A, 54B, and 54C. RS-54 (38 feet deep) has typically been dry, although a TCE concentration of 1,600 µg/L was detected in 2013. RS-54 was identified as a pumping well for the FSDF groundwater interim measure (GWIM), but obviously cannot serve in the capacity of a continuously pumped well.

Deep Wells

Twelve deep bedrock wells have been used to monitor water quality at and in the vicinity of the FSDF. The deep bedrock wells are RD-21, RD-22, RD-23, RD-33A, RD-33B, RD-33C, RD-54A, RD-54B, and RD-54C, RD-57, RD-64, and RD-65 (**Figure 4-2**). Well cluster RD-33A, -33B, and -33C, and well RD-57 are downgradient of the FSDF. One significant observation about most bedrock wells is the order-of-magnitude differences in TCE concentrations between pre- and post-2003, when open borehole sampling was replaced by multi-port FLUTe™ systems.

Bedrock Wells

RD-21

RD-21, open from 30 to 175 feet bgs, is located upgradient of the FSDF and near ESADA. It has been sampled multiple times, with and without FLUTe™ multi-port samplers, which complicates interpretation of water quality data. Historic TCE concentrations reported for the open borehole and each RD-21 FLUTe port are shown below:

Pre-FLUTe (30 -175 feet)	89 to 2,900 µg/L
Port 1 (85 - 95 feet)	Not collected
Port 2 (105 -115 feet)	47 to 230 µg/L
Port 3 (125 - 135 feet)	52 to 69 µg/L
Port 4 (145 -155 feet)	54 to 340 µg/L
Port 5 (165 - 175 feet)	56 µg/L
Post-FLUTe (30 - 175 feet)	140 µg/L

Figure 4-3 illustrates TCE concentrations and water elevations measured in the open borehole and with the FLUTe™ sampler system installed over time. Sampling results show that TCE concentrations decreased from approximately 600 µg/L in 2002 to about 60 µg/L in 2003. TCE concentrations gradually increased to a high of 340 µg/L in 2009 in port 4. This is the highest TCE concentration detected from any FLUTe™ port in RD-21. Port 4 is the second deepest port available for sampling; the relatively high concentration of TCE in port 4 indicates that TCE is present in greater concentrations near the bottom of the borehole. The last sample collected from a FLUTe™ prior to removal contained 230 µg/L of TCE in 2010. The February 2014 sample collected from the open borehole exhibited TCE at a concentration of 140 µg/L.

Comparison of groundwater collected from the open borehole, pre-FLUTe™ conditions with sampling of FLUTe™ ports suggest that TCE may be entering the well above the shallowest FLUTe™ port. Open borehole samples contain higher TCE concentrations than most samples collected from the FLUTe™ ports. A plausible interpretation of the distinctly different RD-21 data is that the FLUTe™ sealed the borehole between the conductor casing (set from 0 to 30 feet bgs) and the first FLUTe™ port and, in effect, sealed the open borehole, preventing TCE from migrating vertically within the borehole conduit. When the FLUTe™ was removed, the seal was essentially removed, and the vertical pathway re-established. If TCE is present between the conductor casing and previous FLUTe™ port intervals, TCE may increase over time. Since TCE has only been sampled once since the FLUTe™ was removed, this communication/impact cannot be confirmed without additional investigation (e.g., packer and sampling the interval between these zones).

The general lithologic log for RD-21 shows the following materials and depths:

Material	Port Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Siltstone	None	27 to 30	1,840 to 1,837
Sandstone	1 – 85 to 95	30 to 100	1,837 to 1,767
Shale	2 – 105 to 115	100 to 110	1,767 to 1,757
Sandstone with some siltstone and shale	2 – 105 to 115 3 – 125 to 135 4 – 145 to 155 5 – 165 to 175	110 to 175	1,757 to 1,692

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

Soil removals and use of RD-21 for groundwater pumping had an effect on the TCE concentrations in this area (**Figure 4-3**). However, it should be noted that only FLUTe™ sampling port 1 is screened in the sandstone above the shale bed present from 100 to 110 feet bgs. Port 1 has not been sampled but groundwater collected at this interval could be expected to exhibit higher TCE concentrations than lower ports based on open borehole data and presence of TCE in the fractures. The depth of the groundwater in this well is approximately 100 feet bgs. Water levels in the open borehole have risen into this upper sandstone unit. The effect of the shale unit on water levels is not known. The well is a candidate for additional aquifer testing.

Perchlorate has also been detected in RD-21. Prior to installation of the FLUTe™ in January 2003, perchlorate was reported at concentrations between 3.7 µg/L and 9 µg/L (MCL of 6 µg/L). Results for RD-21 with the FLUTe™ system indicate perchlorate concentrations were between 9.7 µg/L and 12 µg/L. Samples were collected from ports 2 (9.7 µg/L), 3 (9.8 µg/L), 4 (11 µg/L), and 5 (12 µg/L). Groundwater samples collected from the open borehole (30 to 175 feet) in 2013 contained slightly lower perchlorate concentrations – 6.2 µg/L (February 2013), 5.8 µg/L (July 2013), and 4.1 µg/L (February 2014).

Perchlorate data suggest that port 4 (145 to 155 feet) and 5 (165 to 175 feet) are in communication with fractures and bedding planes that transmit perchlorate to a greater degree than shallower ports 2 (105 to 115 feet) and 3 (125 to 135 feet).

Groundwater extraction was performed at FSDF between January 1997 and mid-2002 using RD-21. The groundwater extraction rate from RD-21 averaged about 173 gpd. Observations and conclusions from the groundwater extraction interim measure include:

- TCE concentrations declined during the pumping (**Figure 4-3**)

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock
- Gradual decline in water levels after a recharge event indicates low to moderate bulk permeability of the bedrock (water slowly drains from the bedrock)
- TCE was removed from fractures and bedding planes
- Fractures/bedding planes containing TCE may not be in communication with the well when water levels are lowered
- Following the groundwater pumping and prior to FLUTe™ installation, TCE was detected at lower concentrations indicating that it may have been effectively removed from the fractures and bedding planes
- A slight TCE rebound appears following the aquifer pumping as a result of fractures and bedding planes now being in communication with wells that were not in contact with open borehole during the pumping of the well

The following information comprises the Conceptual Site Model (CSM) for RD-21:

- TCE is present in small, systematic, and interconnected bedrock fractures (solute transport).
- TCE is also present in the porous sandstone matrix (TCE diffusion from factures into the bedrock matrix).
- TCE was removed from the fractures and bedding planes during the groundwater extraction interim measure conducted at RD-21. TCE remains in the sandstone matrix.
- Over time, TCE will continue to diffuse from the bedrock matrix to the fractures and bedding planes. Diffusion of TCE from the sandstone matrix to the fractures will continues as long as a chemical gradient exists between water present in the fractures and the sandstone matrix. A chemical gradient is present due to the fractures containing 'fresh' water from precipitation/ infiltration.
- The chemical gradient between fractures and the bedrock matrix will decrease over time as TCE 'leaks' from the sandstone matrix and the TCE concentration in the matrix approaches non-detected levels.

RD-21 monitors water near ESADA and based on operational history there may be a separate TCE source associated with the ESADA facility. However, due to groundwater flow and pumping at RD-21, separating the ESADA and FSDF groundwater impacts may not be discernable. TCE is present at the lowest port in this well but may be below the MCL and therefore may define the vertical extent of TCE at the ESADA.

<u>Possible Data Gap Actions for RD-21:</u>

- Perform borehole geophysics (oriented acoustic logging) and video logging (optical televiewer) to identify fractures and bedding planes. Geophysics methods will include:

    a) temperature/conductivity
    b) borehole caliper

c) spontaneous potential
d) single point resistance
e) normal resistivity
f) induction
g) acoustical
h) nuclear logs (including gamma-gamma, and neutron)
i) Corehole dynamitic flow meter (CDFM)
j) Ambient, injection, and/or pumping flow condition

- Perform packer testing of RD-21 to identify zones of contamination based on fracture data
- Confirm completion in the Upper Burro Flats member with analysis of water quality type (calcium bicarbonate) as part of RD-50 fault data
- Continue sampling for FSDF area groundwater characterization
- Install Blank FLUTe™ or packer(s) to isolate non-impacted from impacted zones, if present

RD-22

RD-22 is a 440-foot deep bedrock monitoring well located lateral and downgradient from the FSDF and ESADA (**Figure 4-2**). TCE has not been detected at RD-22 either prior to installation of the FLUTe™ or during sampling of the FLUTe™ ports. RD-22 does not appear to be affected by releases of TCE at the FSDF. It should be noted that MWH reported that the RD-22 FLUTe™ ruptured during or shortly after installation. The FLUTe™ system is still installed in this well.

Perchlorate was detected in samples collected from RD-22 in February 2003 from three FLUTe™ ports:

Port 1 (310 to 320 feet)	Sample not collected
Port 2 (330 to 340 feet)	Non-detect (0.8 µg/L)
Port 3 (350 to 360 feet)	17 µg/L
Port 4 (370 to 380 feet)	6.7 µg/L
Port 5 (390 to 400 feet)	2.9 µg/L
Port 6 (410 to 420 feet)	Non-detect (0.8 µg/L DL)
Port 7 (430 to 440 feet)	Non-detect (0.8 µg/L DL)

Perchlorate data indicated that fractures and bedding planes that contain perchlorate are in communication with the well between 350 and 400 feet. Perchlorate was not detected in samples collected from port 2 in January 2013, or port 1 in July 2013 and February 2014.

The general lithologic log for RD-22 shows the following material and depths:

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	None	4 to 125	1,849 to 1,728
Sandstone with some siltstone	None	125 to 130	1,728 to 1,723
Sandstone	None	130 to 155	1,723 to 1,698
Sandstone with some siltstone	None	155 to 180	1,698 to 1,673
Sandstone	1 – 310 to 320	180 to 330	1,673 to 1,523
Shale	2 – 330 to 340	330 to 340	1,523 to 1,513
Sandstone	None	340 to 350	1,513 to 1,503

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Shale	3 – 350 to 360	350 to 360	1,503 to 1,493
Sandstone	4 – 370 to 380	360 to 385	1,493 to 1,468
Shale	5 – 390 to 400	385 to 400	1,468 to 1,453
Sandstone	6 – 410 to 420 7 – 430 to 440	400 to 440	1,453 to 1,413

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

It is presumed that RD-22 was installed to define the vertical and horizontal extent of TCE contamination emanating from the ESADA and FSDF. Based on the simplistic model above and knowing the RD-22 is in communication with wells located at the FSDF, RD-22 is located appropriately and the open interval is of sufficient length to monitor TCE at depth. The following conclusions are used in the CSM for RD-22:

- RD-22 is used to define the vertical and western horizontal extent of the TCE plume
- RD-22 is in communication with other wells at the FSDF as shown by the perchlorate results
- TCE is not present in deeper samples collected from the well

Possible Data Gap Actions for RD-22:

- Review field data including visual, geophysical, and video logs
- Remove FLUTe™ system
- Sample intervals based on determination of fracture zones Monitor the response of TCE concentrations in the fracture zones during and following the GWIM
- Install Blank FLUTe™ or packer(s) to isolate non-impacted from impacted zones, if present

RD-23

RD-23 is a 440-foot deep bedrock monitoring well located downgradient from the FSDF. Historic TCE concentrations reported for the open borehole and each RD-23 FLUTe™ port are shown below:

Pre-FLUTe™ (30 to 440 feet)	38 to 610 µg/L (sampling prior to January 2003)
Port 1 (231 to 241 feet)	26 to 48 µg/L
Port 2 (251 to 261 feet)	29 to 410 µg/L
Port 3 (271 to 281 feet)	28 to 630 µg/L
Port 4 (291 to 301 feet)	Sample not collected
Port 5 (311 to 321 feet)	29 µg/L
Port 6 (331 to 341 feet)	28 µg/L
Port 7 (351 to 361 feet)	37 µg/L
Port 8 (371 to 381 feet)	18 µg/L
Port 9 (391 to 396.5 feet)	58 µg/L

TCE concentrations detected in RD-23 are variable depending on depth of sample. TCE concentrations have generally been increasing since installation of the FLUTe™ with the highest concentration being

630 µg/L in port 3 in 2009. Most recently (February 2014) the highest concentration was 160 µg/L (**Figure 4-4**). It should be noted that FLUTe™ ports 2 and 3 have been the only ports sampled since 2004 and generally reflect the scatter of data points collected prior to the installation of the FLUTe™. Because the FLUTe™ system is still present in RD-23, it is unknown what the TCE concentrations would be if collected from an open borehole. MWH (2006a) reported that the RD-23 FLUTe™ ruptured during the pumping of RD-54B.

Of interest in RD-23 is a marked increase in TCE concentrations between September 1992 (78 µg/L) and March 1993 (540 µg/L) and the highest open borehole TCE detection in the well occurring in February 2000 at a concentration of 610 µg/L (**Figure 4-4**). Water elevations remained relatively stable over the TCE sampling period. In review of previous data, TCE concentrations fluctuated, generally mirroring annual precipitation. The highest TCE concentration was detected following the highest annual precipitation year. This was followed by decreasing TCE concentrations with decreasing annual precipitation (1993, 1994, 1995, 1996, and 1997). In 1998 an above average precipitation year occurred with a corresponding increase in TCE concentrations, albeit delayed. TCE concentrations in 2001 and 2002 appear to correspond to TCE concentrations detected in 1997 during a similar annual water year. RD-23 water level fluctuations in response to precipitation events are minimal and may be explained by the presence of siltstone (9 to 30 feet bgs) and shale (210 to 225 feet bgs) or higher storage capacity for the bedrock in this area.

An alternative explanation for higher TCE concentrations detected in the open borehole versus the TCE concentrations detected in the FLUTe™ ports immediately after FLUTe™ installation is that the FLUTe™ sealed the open borehole between the conductor casing (set from 0 to 30 feet bgs) and the first FLUTe™ port. If TCE is present in this interval, the FLUTe™ prevented TCE from entering the well from this zone.

Perchlorate was sampled in May 1998, February 2003, and February 2014 and has not been detected in the RD-23.

The general lithologic log for RD-23 shows the following materials and depths:

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	None	4 to 9	1,833 to 1,828
Siltstone	None	9 to 30	1,828 to 1,807
Sandstone	None	30 to 60	1,807 to 1,777
Sandstone with some siltstone	None	60 to 65	1,777 to 1,772
Sandstone	None	65 to 115	1,772 to 1,722
Sandstone with some siltstone	None	115 to 140	1,722 to 1,697
Siltstone	None	140 to 160	1,697 to 1,677
Sandstone (possible fracture at 209 to 210)	None	160 to 210	1,677 to 1,627
Shale	None	210 to 225	1,677 to 1,612
Sandstone	1 – 231 to 241 2 – 251 to 261 3 – 271 to 281 4 – 291 to 301 5 – 311 to 321 6 – 331 to 341 7 – 351 to 361 8 – 371 to 381	225 to 380	1,612 to 1,457
Sandstone with some shale	None	380 to 385	1,457 to 1,452
Sandstone	9 - 391 to 396.5	385 to 415	1,452 to 1,422

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Shale	None	415 to 420	1,422 to 1,417
Sandstone	None	420 to 440	1,417 to 1,397

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

Lithologic information and the hydraulic relationship to surrounding wells suggest that this well is a candidate for groundwater extraction during the proposed FSDF GWIM. Groundwater levels and TCE concentrations suggest that the optimal extraction zone is above 280 feet bgs, therefore the borehole below 280 feet bgs should be sealed (with packers) before extraction is initiated.

The following assumptions are used in the CSM for RD-23:

- RD-23 is in communication with other wells at the FSDF (RD-54B pumping test)
- RD-23 water levels do not directly respond to increased annual precipitation
- TCE increases with increased annual precipitation
- RD-23 may intercept fractures and bedding planes that contained higher TCE concentrations and flow into the well during higher precipitation years

<u>Possible Data Gap Actions for RD-23:</u>

- Review field data including visual, geophysical, and video logs
- Remove FLUTe™ system
- If necessary, perform borehole geophysics and video logging to clearly identify fractures and bedding planes
- Isolate the perched zone from the bedrock aquifer during sampling
- Evaluate the possibility of removal of groundwater from highest sandstone unit during GWIM at this location (above 280 feet bgs)
- Install Blank FLUTe™ or packer(s) to isolate non-impacted from impacted zones, if present

RD-33

The RD-33 well cluster was installed in the Northern Buffer Zone (NBZ) downgradient of the FSDF (**Figure 4-2**). It consists of three wells – RD-33A, RD-33B, and RD-33C.

RD-33A – RD-33A is a 320-foot deep bedrock well, cased and sealed from the surface to 100 feet bgs. Historic TCE concentrations reported for the open borehole and in each RD-33A FLUTe™ port are shown below:

Pre-FLUTe™ (100 to 320 feet)	2.4 to 14 µg/L (prior to January 2003)
Port 1 (211 to 221 feet)	Non-detect (0.26 µg/L)
Port 2 (231 to 241 feet)	0.1 to 0.44 µg/L

Port 3 (251 to 261 feet)	0.16 to 0.28 μg/L
Port 4 (271 to 281 feet)	0.23 to 0.66 μg/L
Port 5 (291 to 301 feet)	0.9 μg/L
Port 6 (311 to 321 feet)	Non-detect (0.26 μg/L)

TCE concentrations prior to FLUTe™ installation in 2003 ranged between 2.4 μg/L and 14 μg/L. Following installation of the FLUTe™ on January 9, 2003, the TCE concentrations were reported below 0.9 μg/L. The decrease in TCE concentrations is believed to be a result of FLUTe™ sampling and the post-2003 results may not characterize the extent of TCE concentrations migrating into well RD-33A. TCE concentrations were below the laboratory reporting limit in the February 2014 sample.

Perchlorate was reported at a concentration of 4 μg/L prior to January 2003, and at 1.2 μg/L in port 3 in 2012.

The general lithologic log for RD-33A shows the following material and depths:

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Siltstone	None	0 to 3	1,793 to 1,790
Sandstone	None	3 to 140	1,790 to 1,653
Sandstone with some claystone	None	140 to 145	1,653 to 1,648
Sandstone	None	145 to 155	1,648 to 1,638
Sandstone with some interbedded claystone	None	155 to 160	1,638 to 1,633
Sandstone	None	160 to 170	1,633 to 1,623
Sandstone with some claystone	None	170 to 180	1,623 to 1,613
Sandstone	None	180 to 185	1,613 to 1,608
Sandstone with some interbedded claystone	None	185 to 190	1,608 to 1,603
Sandstone	1 – 211 to 221 2 – 231 to 241 3 – 251 to 261	190 to 275	1,603 to 1,518
Sandstone with some claystone	None	275 to 276	1,518 to 1,517
Sandstone	4 – 271 to 281 5 – 291 to 301	276 to 315	1,517 to 1,478
Sandstone with some clay	6 – 311 to 321	315 to 320	1,478 to 1,473

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

This well is an important point in the well network as it monitors downgradient of the FSDF and helps define the vertical and horizontal extent of TCE contamination to the west of the FSDF.

The following comprises the CSM for RD-33A:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock (less response than most)
- Gradual decline in water levels after recharge event indicates low to moderate bulk permeability of the bedrock (water slowly drains from the bedrock)
- TCE was detected in RD-33A prior to FLUTe™ sampling
- RD-33A is in communication with the FSDF TCE plume

- The FLUTe™ ports are not placed to monitor fractures and bedding planes that are transporting TCE from the FSDF to the well
- TCE concentrations will not increase following removal of the RD-33A FLUTe™ and commencement of open borehole sampling

Possible Data Gap Actions for RD-33A:

- Remove FLUTeTM system
- Continue sampling as a downgradient monitoring point.

RD-33B - RD-33B is a 415-foot deep bedrock well, cased and sealed from the surface to 360 feet bgs, and open to 415 feet. The borehole was advanced to a total depth of 678 feet bgs and then cemented back to 415 feet bgs during well completion. It does not have a FLUTe™ system. TCE has been reported in RD-33B twice; at a concentration of 0.76 µg/L in December 1991 and at a concentration of 0.18 µg/L in August 2002. These TCE detections are close to the detection limit and are not believed to represent an impact of TCE in the deeper groundwater monitored by this well.

Perchlorate has been sampled for seven times and was not detected.

The general lithologic log for RD-33B shows the following materials and depths:

Material	Depth [1] (ft bgs)	Elevation (ft MSL)
Sandstone	2 to 175	1,792 to 1,619
Sandstone with some claystone	175 to 180	1,619 to 1,614
Sandstone	180 to 282	1,614 to 1,512
Sandstone with fracture (2 gallons per minute [gpm])	282 to 283	1,512 to 1,511
Sandstone	283 to 300	1,511 to 1,494
Sandstone with some interlayers of clayey sandstone	300 to 310	1,494 to 1,484
Sandstone	310 to 335	1,484 to 1,459
Sandstone with some claystone	335 to 380	1,459 to 1,414
Sandstone	380 to 455	1,414 to 1,339
Claystone with some interbedded sandstone	455 to 475	1,339 to 1,319
Sandstone with some claystone interlayers	475 to 495	1,319 to 1,299
Sandstone with claystone	495 to 501	1,299 to 1,293
Fracture (75 to 100 gpm)	501 to 502	1,293 to 1,292
Sandstone with claystone	502 to 508	1,292 to 1,286
Sandstone with interbedded claystone	508 to 518	1,286 to 1,276
Sandstone	518 to 521	1,276 to 1,273
Fracture	521	1,273
Sandstone	521 to 605	1,273 to 1,189
Sandstone with some fine gravel	605 to 610	1,189 to 1,184
Sandstone	610 to 620	1,184 to 1,174
Sandstone with claystone interlayers	620 to 630	1,174 to 1,164
Sandstone	630 to 645	1,164 to 1,149
Fracture	645	1,149
Sandstone with claystone interlayers	645 to 660	1,149 to 1,134
Sandstone	660 to 678	1,133 to 1,116

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface
.. The lithologic log presents the total depth of the boring at 678 feet bgs. The borehole was cemented back to 415 feet bgs during well completion. The depth of the borehole is sufficient to detect TCE in this lower zone.

The following information comprises the CSM for RD-33B:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock (less response than most)
- Gradual decline in water levels after recharge events indicates low to moderate bulk permeability of the bedrock (water slowly drains from the bedrock)
- TCE is not present at RD-33B
- RD-33B defines the vertical extent of TCE northwest of the FSDF and ESADA
- TCE migrates in fractures (pathways) above 360 feet (1,433 feet MSL) based on RD-33A data

Possible Data Gap Actions for RD-33B:

- Continue sampling as a downgradient monitoring point.

RD-33C – RD-33C is a 520-foot deep well, cased and sealed from the surface to 480 feet bgs and open to 520 feet. TCE and perchlorate have never been detected in RD-33C.

The lithologic log for RD-33C shows the following material and depths:

Material	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	3 to 25	1,791 to 1,769
Sandstone with water bearing facture	25 to 302	1,769 to 1,492
Fracture (water bearing)	302	1,492
Sandstone	302 to 310	1,492 to 1,484
Sandstone with some claystone beds	310 to 340	1,484 to 1,454
Sandstone with some coarse sand and very fine gravel	340 to 350	1,454 to 1,444
Sandstone with interbedded claystone	350 to 375	1,444 to 1,419
Sandstone	375 to 422	1,419 to 1,372
Fracture (water bearing)	422	1,372
Sandstone	422 to 499	1,372 to 1,295
Fracture (water bearing)	499	1,295
Sandstone	499 to 520	1,295 to 1,274

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

Depth of the borehole is sufficient to detect TCE in this lower zone.

The following information comprises the CSM using data collected from RD-33C:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock (less response than most)
- Gradual decline in water levels after recharge events indicates low to moderate bulk permeability of the bedrock (water slowly drains from the bedrock)
- TCE has not been detected in RD-33C

Possible Data Gap Actions for RD-33C:

- None recommended at this time.

RD-50

RD-50 is a 195-foot deep bedrock well that may be installed within the Santa Susana Formation. It is located upgradient of the FSDF (and upgradient of ESADA). TCE has been reported 11 times for the well, with the highest detection at 2.2 µg/L collected from FLUTe™ port 5 in February 2003 (**Figure 4-5**). TCE concentrations detected in the open borehole and in each RD-50 ports are shown below:

Pre-FLUTe™ (18.5 to 195 feet)	0.61µg/L
Port 1 (106 to 116 feet)	Not collected
Port 2 (126 to 136 feet)	0.1 to 0.68 µg/L
Port 3 (146 to 156 feet)	0.69 µg/L
Port 4 (166 to 176 feet)	1.5 µg/L
Port 5 (186 to 195.3 feet)	2.2 µg/L

TCE has not been detected above the MCL in this well since sampling commenced in 1993. Differences in TCE concentrations detected from sample ports 2, 3, 4, and 5 are not significant and indicate that TCE is probably not present in significant concentrations at deeper zones upgradient of these facilities.

Perchlorate has been reported from port 2 of this well at concentrations between 0.81 and 1.8 µg/L (MCL 6 µg/L). Perchlorate has been reported to be non-detect from the lower elevation ports.

The general lithologic log for RD-50 shows the following material and depths:

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	1 – 106 to 116 2 – 126 to 136	10 to 145	1,905 to 1,770
First water in sandstone	3 – 146 to 156	145	1,770
Sandstone	3 – 146 to 156	145 to 160	1,770 to 1,755
Water production increases with depth in sandstone	None	160	1,755
Sandstone	4 – 166 to 176 5 – 186 to 195.3	160 to 195	1,755 to 1,720

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

The following information comprises the CSM for RD-50:

- TCE detected in RD-50 from 2003 through 2009 are slightly above detection limit
- TCE concentrations will not increase following removal of the RD-50 FLUTe™ and commencement of open borehole sampling
- This well did not respond to RD-21 or RD-54B pumping
- RD-50 relationship with the Burro Flats fault is not known
- The TCE impacted groundwater at the ESADA is bounded on the south by the Burro Flats fault

Possible Data Gap Actions for RD-50:

- Remove the FLUTe™ system
- Perform borehole geophysics and video logging to identify fractures and bedding planes
- Monitor RD-50 response during FSDF GWIM
- Confirm Lower Burro Flats member and water quality type (calcium bicarbonate)

RD-54 Well Cluster

The RD-54 well cluster consists of three deep wells – RD-54A, RD-54B, and RD-54C. All three wells were installed in the center of the former FSDF pond area, adjacent to RS-54 (**Figure 4-2**).

RD-54A – RD-54A is a 278-foot deep bedrock well. It is cased and sealed from the surface to 119 feet bgs. Historic TCE concentrations reported for samples collected from the open borehole and from each RD-54A port are shown below:

Pre-FLUTe™ (119 to 278 feet)	66 to 580 µg/L (prior to January 2003)
Port 1 (150.5 to 160.5 feet)	Sample not collected
Port 2 (170.5 to 180.5 feet)	2.1 to 73 µg/L
Port 3 (190.5 to 200.5 feet)	6.9 µg/L
Port 4 (210.5 to 220.5 feet)	9.5 µg/L
Port 5 (230.5 to 240.5 feet)	9.2 µg/L
Port 6 (250.5 to 260.5 feet)	6.7 µg/L
Port 7 (270.5 to 278 feet)	5.1 µg/L
Post-FLUTe™ (119 to 278 feet)	1.3 to 2.3 µg/L (after January 2013)

The FLUTe™ was installed in January 2003 and TCE concentrations exhibited a marked decrease compared to pre-FLUTe™ conditions; however, the shallowest interval (port) was not sampled. The well has been sampled twice since the FLUTe™ was removed in January 2013. TCE concentrations were 1.3 µg/L in January 2013 and 2.3 µg/L in February 2014.

RD-54A has an interesting TCE-time profile (**Figure 4-6**). In general, following a very wet 1993 water year, TCE concentrations were reported between 70 µg/L and 200 µg/L. An increase in TCE concentrations corresponded with decreased annual precipitation over a 4-year period (1996, 1997, 1998, and 1999). Annual precipitation increased in 2000 and 2001 while TCE concentrations decreased.

Similar to RD-23, an explanation for higher TCE concentrations detected in the open borehole versus the TCE concentrations detected in the FLUTe™ ports may be the result of the FLUTe™ acting a seal between the conductor casing (set from 0 to 119 feet bgs) and the first FLUTe™ port. If TCE is present in this interval, the FLUTe™ prevented TCE from entering the well from this zone.

Perchlorate has been reported in RD-54A FLUTe™ samples. Perchlorate concentrations in samples collected from ports in February 2003, immediately following installation of the FLUTe™s, were:

Port 1 (150.5 to 160.5 feet)	Non-detect (0.28 µg/L)

Port 2 (170.5 to 180.5 feet) Non-detect (0.8 µg/L)
Port 3 (190.5 to 200.5 feet) 56 µg/L
Port 4 (210.5 to 220.5 feet) 35 µg/L
Port 5 (230.5 to 240.5 feet) 27 µg/L
Port 6 (250.5 to 260.5 feet) 24 µg/L
Port 7 (270.5 to 280.5 feet) Non-detect (0.8 µg/L)

From the perchlorate data it can be concluded that fractures and bedding planes that contain perchlorate are in communication with the well between 190.5 and 260.5 feet. Perchlorate was not detected in the open borehole in groundwater samples collected February 2013 and 2014.

The general lithologic log for RD-54A shows the following materials and depths:

Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	None	0 to 12	1,842 to 1,830
Claystone	None	12 to 14	1,830 to 1,828
Sandstone	None	14 to 75	1,828 to 1,767
Sandstone - clayey	None	75 to 90	1,767 to 1,752
Sandstone	1 – 150.5 to 160.5 2 – 170.5 to 180.5 3 – 190.5 to 200.5 4 – 210.5 to 220.5 5 – 230.5 to 240.5	90 to 237	1,752 to 1,605
Sandstone with fracture	5 – 230.5 to 240.5	237	1,605
Sandstone	5 – 230.5 to 240.5 6 – 250.5 to 260.5 7 – 270.5 to 280.5	237 to 278	1,605 to 1,564

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-54A is located in the center of the FSDF and TCE has been detected along its total depth. RD-54B and RD-54C at this location define the vertical extent of TCE contamination at the location. The graphic relationship between well depths and sample ports in this area is illustrated in **Figure 4-7**.

RD-54A water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of claystone (12 to 14 feet bgs) and sandstone - clayey (75 to 90 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the CSM for RD-54A:

- RD-54A is in communication with other wells at the FSDF based on RD-54B pumping test
- RD-54A water levels do not significantly respond to increased or decreased annual precipitation
- TCE increased with decreased annual precipitation; a relationship that is the reverse of that observed in RD-23. This may be due to the depth of the open borehole at RD-54A
- TCE concentrations have decreased two orders of magnitude in the groundwater contained in the fractures and bedding planes that conduct groundwater into RD-54A

<u>Possible Data Gap Actions for RD-54A:</u>

- Perform a packer test of RD-54A to determine which fracture zones are contributing TCE to the well
- Evaluate RD-54A as an extraction well pumping during the proposed FSDF GWIM targeting the highest sandstone unit
- Continue to sample for contamination trends.

RD-54B – RD-54B is a 437-foot deep well at the RD-54 cluster. RD-54B is cased and sealed from the surface to 379 feet bgs, and then open to 437 feet. TCE has been reported four times in RD-54B at concentrations between 1 µg/L and 9.9 µg/L (in 1993 and 2002, respectively). TCE has not routinely been detected in this well and was not detected in February 2014. Perchlorate has been sampled for five times and has not been detected.

The general lithologic log for RD-54B shows the following materials and depths:

Material	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	0 to 158	1,843 to 1,643
Siltstone	158 to 164	1,643 to 1,679
Sandstone	164 to 206	1,679 to 1,637
Fracture	205 to 206	1,638 to 1,637
Silty Sandstone	206 to 218	1,637 to 1,625
Sandstone	218 to 247	1,625 to 1,596
No cuttings returned, no water in return	247 to 278	1,596 to 1,565
Sandstone	278 to 384	1,565 to 1,459
Sandstone (small increase in clay content)	384 to 394	1,459 to 1,449
Sandstone	394 to 404	1,449 to 1,439
Sandstone (with clay noted)	404 to 418	1,439 to 1,425
Sandstone	418 to 437	1,425 to 1,406

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-54B is located within the FSDF and defines the vertical extent of TCE contamination. RD-54B water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of siltstone (158 to 164 feet bgs) and sandstone - clayey (384 to 394 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the CSM for RD-54B:

- TCE has not been detected in RD-54B since 2002
- RD-54B is in communication with C-8, RD-22, RD-23, RD-54A, RD-64, and RD-65
- RD-54B currently defines the vertical extent of TCE at the FSDF
- TCE migrates in fractures (pathways) above 379 feet (1,463 feet MSL)

<u>Possible Data Gap Actions for RD-54B:</u>

- Continue to sample for contamination trends.

RD-54C – The available well completion information for RD-54C is conflicting. The RD-54C boring log shows a total depth of the borehole as 620 feet bgs. The schematic diagram of monitoring well RD-54C shows a total depth of 520 feet bgs and the database shows a total depth of 638 feet bgs. It is unknown if the borehole was advanced to 638 feet bgs and then cemented to a shallower depth as was done in other boreholes at SSFL. RD-54C is cased and sealed from the surface to 557 feet bgs.

TCE has been detected in RD-54C seven times with a maximum concentration of 1.1 µg/L in a 2006 sample. TCE has not been detected above laboratory reporting limits since 2006, including a sample collected in February 2014. Perchlorate has been sampled for five times and was not detected in this well.

The general lithologic and video camera log for RD-54C shows the following materials and depths:

Material	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	0 to 20	1,844 to 1,824
Claystone	20 to 21	1,824 to 1,823
Sandstone	21 to 24	1,823 to 1,820
Seepage	24 to 25	1,820 to 1,819
Sandstone	25 to 28	1,819 to 1,816
Sandstone with siltstone interbed	28 to 29	1,816 to 1,815
Sandstone	29 to 40	1,815 to 1,804
Fracture (closed)	40 to 42	1,804 to 1,802
Sandstone	42 to 56	1,802 to 1,788
Fracture (closed)	56 to 58	1,788 to 1,786
Sandstone	58 to 183	1,786 to 1,661
Fracture zone with minor seepage at 179.5 feet bgs	183 to 186	1,661 to 1,658
Sandstone	186 to 201	1,658 to 1,643
Fracture (closed)	201 to 202	1,643 to 1,642
Sandstone	202 to 216	1,642 to 1,628
Sandstone with clay content increasing	216 to 218	1,628 to 1,626
Bedding plane with minor seepage	218	1,626
Sandstone with clay content increasing	218 to 234	1,626 to 1,610
Sandstone	234 to 278	1,610 to 1,566
Sandstone with clay content increasing	278 to 290	1,566 to 1,554
Sandstone	290 to 296	1,554 to 1,548
Fracture	296	1,548
Sandstone	296 to 301	1,548 to 1,543
Facture	301 to 304	1,543 to 1,540
Sandstone	304 to 327	1,540 to 1,517
Fracture (filled)	327	1,517
Sandstone	327 to 332	1,517 to 1,512
Sandstone with some claystone interbeds	332 to 340	1,512 to 1,504
Sandstone	340 to 405	1,504 to 1,439
Fracture	405	1,439
Sandstone	405 to 426	1,439 to 1,418
Fracture	426	1,418
Sandstone	426 to 429	1,418 to 1,415
Fracture (vertical)	429	1,415
Sandstone	429 to 478	1,415 to 1,366
Sandstone with clay content increasing	478 to 498	1,366 to 1,346
Sandstone	498 to 500	1,346 to 1,344
Silty Sandstone	500 to 516	1,344 to 1,328
Fracture	516	1,328

Material	Depth (ft bgs)	Elevation (ft MSL)
Silty Sandstone	516 to 520	1,328 to 1,324
Sandstone	520 to 583	1,324 to 1,261
Fracture	583	1,261
Sandstone	583 to 596	1,261 to 1,248
Water (1 to 2 gpm)	596	1,248
Sandstone	596 to 620	1,248 to 1,224

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-54C is located within the TCE plume and defines the vertical extent of TCE contamination.

RD-54C water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of claystone (20 to 21 feet bgs) and clayey sandstone (218 to 234 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the CSM for RD-54C:

- TCE has not been detected in RD-54C since 2006
- RD-54C does not appear to be in communication with RD-54A; however, based on the historic presence of TCE in the well it is assumed to be in communication with the upper groundwater zones
- RD-54C confirms the vertical extent of TCE at FSDF with complementary data from RD-54B
- TCE present at lower zones has been diluted since 2006 and is not present above DLs in 2014

<u>Possible Data Gap Actions for RD-54C:</u>

- Continue to sample for plume vertical depth evaluation
- Monitor response in well during the proposed FSDF GWIM
- Confirm total depth of borehole

RD-57

RD-57 is a 419-foot deep bedrock well located in the NBZ downgradient of the FSDF. RD-57 is cased and sealed between 0 and 19.5 feet bgs, and is an open borehole from 19.5 to 419 feet. TCE was reported in RD-57 once in 2000, at a concentration of 1.9 µg/L. TCE has not been reported above its detection limit since 2000, including the sample collected in February 2014. A FLUTe™ system was installed in September 2003 and has not been removed. It does not appear that FLUTe™ sampling has biased reported TCE concentrations in this well. However, the open borehole is quite long (from 19.5 to 419 feet bgs) and TCE impacted water, if present in fractures located above the FLUTe™ (the 228 to 238-foot interval), may not have been sampled. Selected interval sampling may be necessary to confirm that TCE has not impacted shallower zones at this location.

Perchlorate has been sampled from the open borehole and the FLUTe™ ports and has not been detected above laboratory detection limits.

The general lithologic and video camera log for RD-57 shows the following materials and depths:

Material	Port Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	None	3 to 87	1,771 to 1,687
Sandstone with fracture zone	None	87 to 94	1,687 to 1,680
Sandstone	None	94 to 101	1,680 to 1,673
Sandstone with fracture zone	None	101 to 124	1,673 to 1,650
Sandstone	None	124 to 152	1,650 to 1,622
Sandstone with fracture zone	None	152 to 155	1,622 to 1,619
Sandstone	None	155 to 156	1,619 to 1,618
Sandstone – slightly clayey	None	156 to 160	1,618 to 1,614
Sandstone	None	160 to 204	1,614 to 1,570
Sandstone – clayey	None	204 to 206	1,570 to 1,568
Sandstone	None	206 to 207	1,568 to 1,567
Sandstone with fracture zone	None	207 to 214	1,567 to 1,560
Sandstone	1 – 228 to 238	214 to 236	1,560 to 1,538
Sandstone – clayey	None	236 to 240	1,538 to 1,534
Sandstone	2 – 248 to 258 3 – 268 to 278	240 to 270	1,534 to 1,504
Sandstone with fracture zone	3 – 268 to 278	270 to 273	1,504 to 1,501
Sandstone	3 – 268 to 278	273 to 281	1,501 to 1,493
Sandstone with closed fractures	None	281 to 284	1,493 to 1,490
Sandstone	None	284 to 286	1,490 to 1,488
Sandstone with closed fractures	4 – 288 to 298	286 to 297	1,488 to 1,477
Sandstone	5 – 308 to 318 6 – 328 to 338	297 to 336	1,477 to 1,438
Sandstone with fracture	6 – 328 to 338	336 to 337	1,438 to 1,437
Sandstone	6 – 328 to 338	337 to 343	1,437 to 1,431
Sandstone with fracture	None	343 to 344	1,431 to 1,430
Sandstone	7 – 348 to 358	344 to 349	1,430 to 1,425
Sandstone with fracture zone (filled and steep)	7 – 348 to 358	349 to 357	1,425 to 1,417
Sandstone	7 – 348 to 358	357 to 363	1,417 to 1,411
Sandstone with fracture zone (filled)	None	363 to 368	1,411 to 1,406
Sandstone	8 – 368 to 378	368 to 386	1,406 to 1,388
Sandstone – clayey	9 – 388 to 398	386 to 400	1,388 to 1,374
Sandstone	10 – 408 to 418	400 to 410	1,374 to 1,364
Sandstone with sandy Claystone layers	10 – 408 to 418	410 to 415	1,364 to 1,359
Sandstone	10 – 408 to 418	410 to 419	1,359 to 1,355

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-57 water levels fluctuations in response to precipitation events are minimal and may be explained by the presence of clayey sandstone (204 to 206 and 236 to 240 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the CSM using data collected from RD-57:

- TCE has not been detected in RD-57 since 2000
- RD-57 defines the horizontal and vertical extent of TCE northwest of the FSDF

- TCE may be present in fractures above the FLUTe™ sampling ports selected interval sampling may be required to adequately monitor for TCE in groundwater in this area

Possible Data Gap Actions for RD-57:

- Review field data including visual, geophysical, and video logs
- Remove the FLUTe™ system to allow access to upper portion of well
- Sample depth intervals based on field log observations of fracture zones
- If appropriate, seal or otherwise abandon the deeper zone
- Install Blank FLUTeTM or packers to isolate non-impacted from impacted zones, if necessary.
- Include sampling for plume extent definition

RD-64

RD-64 is a 398-foot deep bedrock well installed immediately west and lateral (downgradient) of the FSDF. Historic TCE concentrations reported for the open borehole and in each RD-64 port is shown below:

Pre-FLUTe™ (20 to 230 feet)	8.9 to 680 µg/L (prior to April 2002)
Port 1 (170.5 to 180.5 feet)	Not collected
Port 2 (190.5 to 200.5 feet)	Not collected
Port 3 (210.5 to 220.5 feet)	Not collected
Port 4 (230.5 to 240.5 feet)	60 to 300 µg/L
Port 5 (250.5 to 260.5 feet)	Not collected
Port 6 (270.5 to 280.5 feet)	35 to 180 µg/L
Port 7 (290.5 to 300.5 feet)	27 to 280 µg/L
Port 8 (310.5 to 320.5 feet)	30 to 110 µg/L
Port 9 (330.5 to 340.5 feet)	27 µg/L
Port 10 (350.5 to 360.5 feet)	39 µg/L
Port 11 (370.5 to 380.5 feet)	31 µg/L
Port 12 (390.5 to 400.5 feet)	24 µg/L

RD-64 has an unusual and somewhat uncharacteristic TCE time trend versus other wells at the FSDF. TCE concentrations rose relatively quickly from February 1995 to the highest TCE concentration of 680 µg/L reported for May 2001 (**Figure 4-8**). This is approximately 7 months following the completion of the RD-21 aquifer pumping test. Following installation of the FLUTe™ system in April 2002, TCE concentrations in the FLUTe™ ports range between 24 µg/L and 300 µg/L. Because the FLUTe™ system remains in the well it is unclear if sampling an open borehole will result in higher TCE concentrations (as seen in RD-07; see Section 4.5). MWH (2006a) reported that the RD-64 FLUTe™ ruptured during or shortly after installation.

After review of annual precipitation data, a correlation between TCE concentration and annual precipitation is not evident.

Possible explanations for this unusual TCE trend are:

- The TCE source area was removed resulting in no TCE-impacted water moving down into the groundwater system decreasing TCE concentrations after May 2001
- The TCE plume moved across this well via natural groundwater gradient and movement
- Groundwater and TCE were influenced by pumping of RD-21
- This is the amount of time for the TCE chemical gradient to occur across the length of the open borehole (20 to 230 feet)
- TCE was introduced to lower zones as a result of drilling (pathway from upper zones to lower zones via well core hole, a poor seal, and/or conductor casing not extending entirely through the weathered Chatsworth Formation)
- TCE was introduced to lower zones via surrounding wells
- Failure of the FLUTe™ and isolation zone seals to prevent TCE from migrating to deeper zones

Figure 4-9 shows chloroethene concentrations in RD-64. The presence of *cis*-1,2-Dichloroethene (*cis*-1,2-DCE) indicates that dechlorination may be occurring in this well; potential dechlorination will be further evaluated with future data. Vinyl chloride has been detected above the MCL in this well.

Perchlorate has not been detected in samples collected from this well.

The general lithologic log for RD-64 shows the following materials and depths:

Material	Port Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone (weathered)	None	5 to 21	1,852 to 1,836
Sandstone	None	21 to 45	1,836 to 1,812
Sandston with fracture	None	45	1,812
Sandstone	None	45 to 50	1,812 to 1,807
Sandstone – coarse sand	None	50 to 70	1,807 to 1,787
Sandstone	None	70 to 160	1,787 to 1,697
Sandstone with coarse sand	None	160 to 166	1,697 to 1,691
Sandstone with fracture zone	1 – 170.5 to 180.5	166 to 173	1,691 to 1,684
Sandstone	1 – 170.5 to 180.5 2 – 190.5 to 200.5 3 – 210.5 to 220.5 4 – 230.5 to 260.5 5 – 250.5 to 260.5	173 to 264	1,684 to 1,593
Sandstone with fracture (possible)	None	264	1,593
Sandstone	6 – 270.5 to 280.5 7 – 290.5 to 280.5 8 – 310.5 to 320.5 9 – 330.5 to 340.5 10 – 350.5 to 360.5 11 – 370.5 to 380.5 12 – 390.5 to 400.5	264 to 398	1,593 to 1,459

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-64 water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of low-permeability sediments, not identified in the boring log, between the well screen and ground surface, or higher storage capacity of the bedrock in this area.

Lithologic information and the hydraulic connection to surrounding wells suggest that the well is a candidate for groundwater extraction during the GWIM. Groundwater levels and TCE concentrations suggest that the optimal extraction zone is above 230 feet bgs.

The following comprises the CSM for RD-64:

- RD-64 is in communication with other wells at the FSDF based on the RD-54B pumping test results
- RD-64 water levels do not significantly respond to increased or decreased annual precipitation
- TCE concentration trends do not correlate with annual precipitation changes
- TCE may be present in fractures above the FLUTe™ sampling ports; open borehole or selected interval sampling may be required to detect TCE present in groundwater in this area
- TCE diffusion (chemical gradient) from the rock matrix is the most likely source into groundwater
- Fractures and bedding planes that contained higher TCE concentrations are not connected to water sampled in RD-64 due to the FLUTe™

<u>Possible Data Gap Actions for RD-64:</u>

- Remove the FLUTe™ system
- Perform borehole geophysics and video and compare with C-8 logging to identify fractures and bedding planes
- Sample selected intervals to evaluate the vertical extent of the TCE plume
- Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary

RD-65

RD-65 is a 397-foot deep bedrock well installed downgradient of the FSDF and RD-23. The borehole is cased and sealed from the surface to 19-feet bgs. Historic TCE concentrations detected in the open borehole and in each RD-65 port are provided below:

Pre-FLUTe™ (19 to 397 feet)	360 to 960 µg/L (prior to October 2002)
Port 1 (167 to 177 feet)	Not collected
Port 2 (187 to 197 feet)	Not collected
Port 3 (207 to 217 feet)	Not collected
Port 4 (227 to 237 feet)	11 to 58 µg/L
Port 5 (247 to 257 feet)	8.4 to 220 µg/L
Port 6 (267 to 277 feet)	3.8 to 130 µg/L
Port 7 (287 to 297 feet)	9.6 µg/L
Port 8 (307 to 317 feet)	4.6 µg/L

Port 9 (327 to 337 feet)	7.8 µg/L
Port 10 (347 to 357 feet)	5.8 µg/L
Port 11 (367 to 377 feet)	7.9 µg/L
Port 12 (387 to 397 feet)	Not collected
Post-FLUTe™ (19 to 397 feet)	5 to 68 µg/L (after February 2013)

RD-65 had a concentration of 69 µg/L TCE in the February 2014 sample.

Figure 4-10 shows TCE concentrations in RD-65. TCE concentrations generally remain stable from well installation in 1995 through 2002, which includes the period of pumping of RD-21. There was a decrease in TCE concentrations following installation of the FLUTe™ system. Prior to FLUTe™ installation, chloroethene concentrations may have shown dechlorination trends. Following installation of the FLUTe™ and selected port sampling, TCE was detected at well below previous TCE concentrations from samples collected from the open borehole. *Cis*-1,2-DCE and *trans*-1,2-dichlorethene (*trans*-1,2-DCE) were also detected in this well. The FLUTe™ system was removed in February 2013 and samples collected from the open borehole contained slightly higher concentrations of TCE compared to *cis*-1,2-DCE. TCE concentrations in samples from the open borehole were comparable to TCE concentrations detected from the FLUTe™ since 2006. It is believed that dechlorination is occurring in RD-65.

Perchlorate concentrations collected from RD-65 ports in February 2003 and immediately following installation of the FLUTe™ are:

Pre-FLUTe™ (19 to 397 feet)	Non-detect (4 µg/L)
Port 1 (167 to 177 feet)	Not collected
Port 2 (187 to 197 feet)	Not collected
Port 3 (207 to 217 feet)	Not collected
Port 4 (227 to 237 feet)	Not collected
Port 5 (247 to 257 feet)	6.2 µg/L
Port 6 (267 to 277 feet)	Non-detect (0.8 µg/L)
Port 7 (287 to 297 feet)	Non-detect (0.8 µg/L)
Port 8 (307 to 317 feet)	1.6 µg/L
Port 9 (327 to 337 feet)	1.8 µg/L
Port 10 (347 to 357 feet)	2.7 µg/L
Port 11 (367 to 377 feet)	3.8 µg/L
Port 12 (387 to 397 feet)	Non-detect (0.8 µg/L)
Post-FLUTe™ (19 to 397 feet)	Non-detect (0.0088 µg/L)

From the perchlorate data it can be concluded that fractures and bedding planes that contain perchlorate are in communication with the well at 247 to 257 feet and 307 to 377 feet. Perchlorate was not detected in samples collected from the open borehole in February of 2014.

The general lithologic and video camera log for RD-65 shows the following materials and depths:

RD-65 Boring Material	Port/Interval (ft bgs)	Depth (ft bgs)	Elevation (ft MSL)
Sandstone	None	5 to 45	1,814 to 1,774
Sandstone – coarse sand	None	45 to 47	1,774 to 1,772
Sandstone	None	47 to 59	1,772 to 1,760
Sandstone with fracture	None	59	1,760
Sandstone	None	59 to 63	1,760 to 1,756
Sandstone – coarse sand	None	63 to 71	1,756 to 1,748
Sandstone	None	71 to 74	1,748 to 1,745
Sandstone with fracture	None	74	1,745
Sandstone	None	74 to 102	1,745 to 1,717
Sandstone with fracture	None	102	1,717
Sandstone	None	102 to 104	1,717 to 1,715
Sandstone with coarse sand	None	104 to 112	1,715 to 1,707
Sandstone	None	112 to 158	1,707 to 1,661
Sandstone with coarse sand with fractures	None	158 to 159	1,661 to 1,660
Sandstone	None	159 to 163	1,660 to 1,656
Sandstone with fracture	None	163 to 164	1,656 to 1,655
Sandstone	1 – 167 to 177	164 to 171	1,655 to 1,648
Sandstone with mudstone and fractures	1 – 167 to 177	171 to 172	1,648 to 1,647
Sandstone	1 – 167 to 177 2 – 187 to 197	172 to 207	1,647 to 1,612
Sandstone with silty interbed grades to mudstone	3 – 207 to 217	207 to 208	1,612 to 1,611
Sandstone with fracture zone	3 – 207 to 217	208 to 210	1,611 to 1,609
Sandstone	3 – 207 to 217 4 – 227 to 237	210 to 230	1,609 to 1,589
Sandstone with fracture	4 – 227 to 237	230	1,589
Sandstone	4 – 227 to 237 5 – 247 to 257	230 to 250	1,589 to 1,569
Sandstone with fracture	5 – 247 to 257	250	1,569
Sandstone	5 – 247 to 257 6 – 267 to 277	250 to 276	1,569 to 1,543
Sandstone with fracture	6 – 267 to 277	276 to 277	1,543 to 1,542
Sandstone	6 – 267 to 277	277 to 285	1,542 to 1,534
Sandstone with fracture	None	285	1,534
Sandstone	7 – 287 to 297	285 to 310	1,534 to 1,509
Sandstone with fracture zone	8 – 307 to 317	310 to 319	1,509 to 1,500
Sandstone	9 – 327 to 337	319 to 335	1,500 to 1,484
Sandstone with fracture	9 – 327 to 337	335	1,484
Sandstone	9 – 327 to 337	335 to 340	1,484 to 1,479
Sandstone with fracture	None	340	1,479
Sandstone	10 – 347 to 357 11 – 367 to 377	340 to 383	1,479 to 1,436
Sandstone with fine to coarse grained	12 – 387 to 397	383 to 397	1,436 to 1,422

Notes:
ft MSL – feet mean sea level
ft bgs – feet below ground surface

RD-65 water level fluctuation in response to precipitation events are considered minimal and may be explained by the presence of low-permeability sandstones with mudstone between well screen and ground surface at 171 to 172 and 207 to 208 feet bgs or higher storage capacity for the bedrock in this area.

The following information comprises the CSM for RD-65:

- RD-65 is in communication with other wells at the FSDF based on RD-54B pumping test
- RD-65 water levels do not significantly respond to increased or decreased annual precipitation
- No TCE trend and annual precipitation changes are apparent
- TCE may be present in fractures above the FLUTe™ sampling ports and open borehole or selected interval sampling may be required to detect TCE present in groundwater at this elevation
- Groundwater with relatively higher concentrations of TCE is no longer present in fractures and bedding planes sampled in RD-65

Possible Data Gap Actions for RD-65:

- Perform geophysical and video logging of well
- Perform a packer test to collect groundwater from the perched groundwater zone
- Continue sampling to monitor for plume trends

Possible Data Gap Actions for FSDF:

On August 12, 2015 a meeting was held and attended by DOE, DTSC, and CDM Smith to review data and address DTSC comments on the work plan. During this meeting, the geologic map of the FSDF (IT, 2002) was discussed and compared to the TCE plume emulating from the FSDF. Three general trends were reported as a result of this geologically mapping of the excavated and exposed Chatsworth Formation at the FSDF; N20°E, N60°W, and east-west (IT, 2002).

Using current depth to groundwater in Chatsworth Formation monitoring wells, groundwater would be expected to move to the northwest. Instead, groundwater is moving to the northeast based on the elongation of the TCE from the FSDF source area(s) to the RD-65. The TCE plume is believed to reflect groundwater movement along the northeast striking fractures shown on Figure xx-x and collaborates fractured media groundwater movement assumptions.

To test this thesis, two additional Chatsworth Formation monitoring wells have been proposed. The first well will confirm the presence/absence of TCE along the northeast fractures at what is believed the TCE plume's northern extent. The second well will confirm the presence/absence of TCE northwest of the FSDF area and demonstrate preferentially movement along the northeast fractures.

The following information was used to determine the depth of the new Chatsworth Formation monitoring well located near PZ-098.

- Current purposed location (See Figure 9-1)
- Elevation at purposed location (1,800 feet above MSL)
- Strike and dip of sandstone beds identified at the FSDF (strike N 70°E, dip of 30° to the northwest)
- Groundwater interval of interest is 1,450 feet above MSL (using RD-65 TCE concentrations present within and above Port 6 –1,542 below MSL and dip of beds)

CDM Smith

The new monitoring well will be drilled to a total depth of 350 feet at this proposed location. This well will fill the following data gap.

- Provide TCE and perchlorate concentration data northeast of the FSDF
- Bound the plume's northeastern extent
- Provide groundwater elevation data in the Chatsworth Formation
- Confirm current FSDF understanding that the TCE is preferentially migrating to the northeast of the FSDF through northeast fractures mapped at the FSDF
- Provide water level response during GWIM pumping and hydraulic connectivity to the FSDF

The second Chatsworth Formation monitoring well would be installed northwest RD-65. This new well will require field locating due the difficult terrain (large sandstone outcrops, alluvial deposits, and vegetation) present at this location.

The following information was used to determine the depth of the new monitoring well.

- Current purposed location (See Figure 9-1)
- Elevation at purposed location (1,835 feet above MSL)
- Strike and dip of sandstone beds identified at the FSDF (strike N 70°E, dip of 30° to the northwest)
- Groundwater interval of interest is 1,390 feet above MSL (RD-65 TCE concentrations present within and above Port 6 –1,542 below MSL and dip of beds)

The new monitoring well will be drilled to a total depth of 445 feet at this proposed location. This well will fill the following data gap.

- Provide TCE and perchlorate concentration data north of the FSDF
- Bound the plume's northern extent
- Provide groundwater elevation data in the Chatsworth Formation
- Provide water level response during GWIM pumping

4.1.4 Corehole 8

C-8 is a 400-foot deep, 12.25-inch diameter borehole, cased from ground surface to 65 feet bgs. It offers the opportunity to observe shallower bedrock conditions as adjacent monitoring well RD-54A is cased off from the surface to 119 feet bgs. Because C-8 was drilled at the FSDF location, it becomes a potential for use in understanding the fracture network where TCE may be harbored. C-8 is currently equipped with the FLUTe multi-port system. Drilling information, pore water and groundwater data suggest that Near-surface groundwater has not been isolated from the deeper Chatsworth Formation groundwater. Isolation failure may be the result of conductor casing not being extended deep enough into the unweathered Chatsworth Formation, the borehole remaining open between completion of drilling and installation of the FLUTe system, and/or the failure of the FLUTe to seal the open borehole between the conductor casing and bottom of the corehole.

C-8 is also being considered as an extraction well for the FSDF GWIM should the fracture network transport TCE to its location.

Possible Data Gap Actions for C-8:

- Remove the FLUTe™ system
- Video log the upper 65 to 200 feet of corehole to identify visual changes in bedrock fracture conditions from its original installation and logging
- Packer test the corehole to identify potential intervals with TCE to see if C-8 is a candidate location for a GWIM pumping well
- Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary

4.1.5 FSDF Conceptual Site Model

The information and data collected in the previous investigations and presented above have been used to develop a CSM for the presence and migration of TCE through the Near-surface and Chatsworth Formation groundwater at the FSDF area. The TCE now found in the FSDF groundwater was most likely originally discharged to the ground (e.g., drum storage) or to the former treatment ponds. Through various removal actions, the original source of TCE to groundwater, contaminated soil and sediment has been removed down to bedrock. The area has been covered with local fill soil.

The current source of TCE to the groundwater is TCE retained in the upper (weathered) bedrock. The Near-surface groundwater is perched in the partially weathered rock and alluvium (fill), and is derived from precipitation. As the precipitation infiltrates downward it can come in contact with existing contaminated Near-surface groundwater and the contaminated weathered rock where TCE diffuses from the rock matrix into the water.

Various tests and studies performed at the FSDF show that the vertical migration of water from the Near-surface to the bedrock system is hindered by the low bulk hydraulic conductivity of the Chatsworth Formation and general lack of a bedrock fracture network near the FSDF. Alluvial soils (fill) and/or weathered Chatsworth Formation, therefore, act as a water storage reservoir following precipitation events. The lateral extent of the TCE–contaminated groundwater stored in the alluvial soils (fill) changes as water levels rise (the plume expands outward) and fall (the plume contracts) in this zone. Alluvial soils (fill) in the area are thin and occur as fingers between bedrock outcrops. Near-surface groundwater in the FSDF area is laterally discontinuous and has limited areal extent. The plume's horizontal extent is controlled by presence alluvium soils (fill) and groundwater elevation. The plume's horizontal extent most likely extends from the source area(s) to where the alluvial soils (fill) pinch-out and/or contact with low K_b bedrock formation.

The Near-surface groundwater is separated from the Chatsworth Formation groundwater by a vadose (unsaturated) zone. Contaminated groundwater can migrate vertically "leak" from the Near-surface system to the bedrock system, although, as mentioned above, migration of TCE from the perched zone to the lower bedrock zone is believed to be constricted by the low bulk conductivity.

The source of the perchlorate may have been located south of the former concrete pool and north of H Street. A 20-foot by 50-foot area of soil was excavated to bedrock to remove perchlorate contamination in the 2000 Interim measure. This location is both upgradient of RD-22 (where perchlorate was found and TCE was not) and along strike from RD-54A. The source of perchlorate in the RD-54A location is uncertain and may have been disposed in the former ponds. In 2014, the only detection of perchlorate in the FSDF area was in RD-21, located near interim action excavation.

4.1.6 FSDF Groundwater Interim Measure (GWIM)

Boeing submitted to DTSC the *Work Plan (revision 2) Groundwater Interim Measures* (July 2008) and *Addendum 2 of the Work Plan for Groundwater Interim Measures* (February 2009) addressing facility wide groundwater interim measures for SSFL. The documents included the potential for a GWIM at the FSDF. Following public comments on the SSFL GWIM work plan, DTSC approved the SSFL GWIM work plan for implementation in March 2013.

The purpose of the SSFL GWIM is to collect data on aquifer properties, remove contaminant mass, and possibly control plume migration for locations within SSFL that exceed 1,000 µg/L of TCE in groundwater. Within Area IV of SSFL, this definition applies to the FSDF where historical groundwater concentrations of TCE have exceeded the 1,000 µg/L level. The scope of the GWIM for the FSDF, as stated in the approved 2013 GWIM Work Plan, was to pump groundwater from shallow monitoring well RS-54 and convey the extracted groundwater via pipeline into Area III. The Area IV pipeline would connect to a Boeing extracted groundwater piping system to the central groundwater extraction treatment system (GETS) located in the central SSFL.

In December 2013, DOE submitted to DTSC a conceptual work plan for the GWIM to be performed at the FSDF (CDM Smith, 2013). The scope of the GWIM included an aquifer pump test, extended aquifer pumping, and treatment of extracted groundwater. The GWIM work plan evaluated on-site treatment of groundwater instead of conveying the water beyond the boundaries of Area IV of the SSFL. This conceptual planning document provided the scope and requirements for the on-site treatment and local release of extracted groundwater. Upon further evaluation, it was determined that RS-54 could not provide extracted water for the GWIM at a sustainable rate. DTSC provided comments on the Conceptual Work Plan (CDM Smith, 2013), which will be addressed in a Detailed Work Plan for implementation of the GWIM.

4.2 Building 4100 Trench

In accordance with the 2007 CO, the Building 4100 Trench is a DOE responsibility. The Building 4100 Trench groundwater investigation area (**Figure 4-11**) is a small (less than 1-acre) area located about 250 feet east of Building 4100. A much larger (4.4-acre) area was investigated during the RFI (MWH, 2008).

4.2.1 Operation History

The Building 4100 Trench (also known as [aka] Building 100 Trench) was used from 1960 through 1966 for burning and disposal of building debris. According to CH2MHill (2008) there are no facility records of the types of materials burned or placed at the site. The site consisted of three elongated trenches (60 to 100 feet long, 20 to 40 feet wide, and 2 to 6 feet deep). The overall area measured approximately 100 feet by 100 feet. The trenches were filled and partially paved over in 1971. In 1988 Rocketdyne surveyed the trench area for gamma readings. The survey concluded that the area complied with unrestricted release criteria. Soil and soil vapor samples were collected 1999 through

2001. In 2003, 330 cubic yards of material (scrap metal, asbestos) were excavated and disposed of off-site. Soil samples collected following debris removal demonstrated no contamination. The trenches were backfilled with DTSC-approved material from an onsite borrow area (CH2MHill, 2008).

4.2.2 Soil, Geology, and Hydrogeology

Alluvial soils are less than 11 feet thick throughout the B4100 groundwater investigation area, and weathered bedrock is estimated to be about 30 feet thick. The ELV fine-grained member of Sandstone 2 subcrops out beneath the trenches (see **Figure 4-11**) and dips to the northwest intersecting RD-20 at a depth of about 26 to 28 feet bgs as indicated by thick "claystone" beds at that depth (Groundwater Resources, 1995).

During the excavation of debris, no groundwater was noted in the trench, but Near-surface groundwater is found at a depth of about 23 feet bgs in PZ-103 located 300 feet south of the trenches. However, PZ-103 is screened in a different geologic unit (Upper Burrow Flats Member) and groundwater found there may not be continuous into the Building 4100 Trench area.

4.2.3 Extent of Contamination

During the RFI, VOCs were not detected in soil or soil vapor samples. Semi-volatile organic compounds (SVOCs) and TPH were reported at concentrations in soils at less than their respective risk-based screening levels (RBSLs). The metals lead, barium, selenium, copper and zinc were reported above background. Dioxins were also reported above background (CH2MHill, 2008).

MWH (2014b) collected three soil vapor samples (5CSV_DG-530, 5CSV_DG-531, and 5CSV_DG-572) in the vicinity of the former trench and all results were non-detect for key COCs (**Appendix Figure A-2**).

Monitoring well data demonstrates no impacted groundwater.

4.2.4 Monitoring Well Network

Bedrock well RD-20 was installed in July 1989 at the location of the former trench. RD-20 is a 127-foot deep bedrock corehole, cased from surface to 30 feet bgs. This well has been sampled 25 times since installation with no consistent detections of site-related COCs.

<u>Possible Data Gap Actions for Building 4100 Trench:</u>

No additional groundwater characterization is required at the Building 4100 Trench groundwater investigation area. RD-20 can be used to provide a water level measuring point for this location of Area IV.

4.3 Building 56 Landfill

In accordance with the 2007 CO, the Building 56 Landfill is a DOE responsibility. The Building 56 Landfill groundwater investigation area includes a 4-acre rock, soil, and construction debris landfill located south and west of the basement excavation of Building 4056, and the location of the excavation. The basement excavation is the source of much of the landfilled rock and soil. The groundwater investigation area (see **Figure 4-12**) includes the landfill area, the basement excavation and associated groundwater monitoring wells RS-16, PZ-124, RD-07, and RD-74. TCE was present in RD-07 at concentrations of 52 μg/L in 2013 and 57 μg/L in 2014. It is the only well with observed groundwater within the investigation area.

4.3.1 Operation History

Use of the site as a landfill originated in the 1960s. Materials deposited included asphalt, concrete, and scrap metal generated during the initial construction phases of Building 4056, located east of the landfill. The excavation created through the removal of bedrock for the basement of Building 4056 is a circular vertical pit extending approximately 65 feet into the bedrock. The Southern Debris Area has also been defined south of the landfilled soil and rock. Per the Group 8 RFI Report (MWH, 2007) continued use of the landfill for disposal of building debris continued to the late 1970s.

The landfilled materials, including those in the Southern Debris Area, were placed in topographic lows, filling valleys in the topography resulting in a relatively flat surface. In the mid-1970s drums of waste (including grease, oils, alcohols, sodium, sodium reaction products, phosphoric acid, asbestos rags, and rope) were stored in the middle part of the landfill. The drums were removed in the early 1980s. Drums were also noted at the base of a ravine along the western edge of the Southern Debris Area.

4.3.2 Soils, Geology, and Hydrogeology

Natural alluvial soils are about 8 feet thick throughout the landfill area. Fill soil in the northern landfill area range in thickness from less than 1 foot to 25 feet thick. In the Southern Debris Area, fill soil ranges between 1 foot and 14 feet thick. A mound of soil, created for a ramp used during excavation of the Building 4056 basement, is located on the east side of the excavation. Some metal debris was observed in the bottom of the excavation when the pit was dewatered in 1999 as part of the effort to lower the groundwater in the vicinity of Building 4059.

The Building 4056 Landfill groundwater investigation area sits on the Upper Burrow Flats member of the Chatsworth Formation (**Figure 2-2**). The ELV fine-grained member of Sandstone 2 is believed to intersect RD-07 at a depth of about 240 to 260 feet bgs. Harding Lawson Associates (1995) conducted focused geologic mapping in the groundwater investigation area and determined that beds strike at N45°E and dip 35 degrees to the northwest. Two predominant fracture sets were mapped – one striking northeast and dipping to the southwest and the other striking north-northwest and dipping to the northeast. Both of these sets of fractures cut across bedding planes; however, acoustic televiewer logs of well RD-07 indicate that some fractures are parallel and co-incident with bedding planes (Harding Lawson Associates, 1995).

Perched Near-surface groundwater has been observed in the past at RS-16 (**Figure 2-2**) located about 60 feet west of the Building 4056 excavation and adjacent to deep well RD-07. Natural gamma geophysical logs of RD-07 indicate a relatively clay-rich stratigraphic unit at a depth of 15 to 25 feet (Harding Lawson Associates, 1995). The Near-surface groundwater is likely perched on this finer-grained material. Historically, water levels in RS-16 have been up to 60 feet higher than in RD-07 (MWH, 2009a) indicating that the Near-surface groundwater is not hydraulically connected to the Chatsworth Formation groundwater. However, the Near-surface groundwater is hydraulically connected to the surface water in the excavation; RS-16 was dry during the 6-year period that the excavation was actively dewatered (MWH, 2007). When the adjacent Building 4056 (aka B056) excavation was dewatered in 1999, lowering the water surface elevation in the excavation by 49 feet, RS-16 went dry. Near-surface groundwater is only sporadically found in PZ-124; in many years the well is dry.

The regional direction of groundwater flow is to the northwest as shown on **Figure 2-3**. When pumping of the RD-25, and RD-28 also started in 1999 as part of the effort to lower the water table to dewater the basement of Building 4059, a response (lowering of water levels) was observed in RD-07, indicating a hydraulic connection between RD-07 and one or both of those wells (Groundwater Resource Consultants [GRC], 1999a). Dewatering of the Building 4056 pit did not impact water levels in RD-07, but did impact water levels in RD-74 (GRC, 1999b).

Although there are strong downward vertical gradients between the Near-surface groundwater and the Chatsworth Formation groundwater, there are no data to indicate the vertical gradients within the Chatsworth Formation. Packer testing of individual fracture zones indicates that the fractures are less conductive with depth (Harding Lawson Associates, 1995).

4.3.3 Extent of Contamination

Groundwater

See RD-07 discussion below.

Environmental Protection Agency (EPA) sampled the surface water in the Building 4056 pit in March 2011. There were no concentrations of man-made radionuclides indicative of contamination from site operations in the analysis of surface water (HGL, 2012). A low concentration of toluene at 0.37 µg/L J (i.e., an estimated concentration below the quantitation limit) was reported in surface water.

Soils

A total of 205 soil samples were collected from five Chemical Use Areas at Building 56 Landfill during the RFI. Ninety-five soil vapor samples were collected during the RFI. VOCs and perchlorate detected in the five chemical use areas are discussed below.

Building 56 Landfill (Chemical Use Area 1):

Thirty-seven soil samples were collected from the Building 56 Landfill. Acetone was reported for three samples ranging from 1,520 to 5,000 µg/kg. Methylene chloride was reported in one sample at 23 µg/kg. One acetone and the methylene chloride detections are considered a likely result of mobile laboratory contamination. VOCs were not detected in any of the other 33 soil samples collected from the landfill.

Thirty-six soil vapor samples were collected from this area and analyzed for VOCs. Methane was detected in two soil vapor samples at a 7 and 12 feet bgs at a concentration of 10 µg/L. VOCs were not detected in any of the 35 other soil vapor samples.

Southern Debris Area (Chemical Use Area 2a):

Twenty-three soil samples were collected analyzed for VOCs from this area. Trichlorofluoromethane (Freon 11) was reported at 900 µg/kg in one soil sample and acetone as reported in four samples at concentrations ranging between 10 and 41µg/kg; there were no other VOCs detected in soil.

The area was sampled and analyzed 16 times for VOCs in soil vapor. Methane was reported for 10 soil vapor samples from 7 locations with concentrations ranging between 10 and 17 µg/L. No other VOCs were reported in soil vapor samples from this area.

Roadside Debris Area (Chemical Use Area 2b):

This area was not sampled and analyzed for VOCs or perchlorate.

Building 056 Excavation (Chemical Use Area 3a):

Seven soil samples were analyzed for this area; VOCs and perchlorate were not reported for any of the samples.

Building 056 Excavation Debris Area (Chemical Use Area 3b):

This area was not sampled and analyzed for VOCs.

MWH performed a soil vapor investigation across Area IV during the summer 2014 (MWH, 2014b). VOCs were not reported for MWH soil vapor sample 8SV-DG-545 (**Appendix Figure A-1**).

4.3.4 Monitoring Well Network

RD-07

RD-07, the first well installed with Area IV in January 1986, is a 300-foot deep bedrock borehole. The well is cased from ground surface to 25 feet bgs. As shown in **Figure 4-13**, TCE was reported at about 20 to 30 μg/L when the well was first sampled in 1986. TCE concentrations for the well have fluctuated ranging from 30 μg/L in the early 1990s to over 80 μg/L in 2000 and 2002 with an isolated detection of130 μg/L in 1987. During this sampling period (pre-2002), low concentrations of TCE breakdown product *cis*-1,2-DCE were also increasing slowly to 5.6 μg/L (**Figure 4-14**).

In 2002, a FLUTe™ multi-port sampling system was installed in the open borehole of RD-07. The system had thirteen 10-foot long ports spaced evenly along the length of the borehole starting at a depth of 50 to 60 feet. A 10-foot long "blank" (where the borehole was sealed from sampling) was inserted between each port. The system was removed in January of 2013. During the period that the FLUTe™ system was in place, concentrations of TCE in groundwater from individual ports was lower than it had been from the open borehole samples. The highest concentrations were from port 4 (110 to 120 feet bgs) and port 5 (130 to 140 feet bgs). The concentration in port 5 was 27 μg/L; in port 4 it was slightly lower at 24 μg/L.

A comparison of the depths of ports 4 and 5 with interpreted borehole acoustic televiewer images (Harding Lawson Associates, 1995) from borehole RD-07 show that "bedding/fractures" were found in both those intervals. From a depth of 136 feet to about 138 feet (port 5, where the highest TCE concentrations were found) a fracture with an aperture of about 0.5 feet was noted. Other ports were screened across fractures; however, bedding planes were not noted with the other screened fractures.

From about 2005 to 2010, only port 3 (90 feet to 100 feet bgs) was sampled. Concentrations of TCE through that time were below the MCL of 5 μg/L. Between about 2010 and 2012, concentrations in port 3 increased to over 20 μg/L. Over that same time period (2003 to 2013), the concentration of *cis*-1,2-DCE measured in port 3 groundwater was much higher (as high as 73 μg/L in 2007) than the TCE, indicating that the degradation of the TCE may be a significant factor in groundwater in that zone of the Chatsworth Formation. Concentrations of *cis*-1,2-DCE in groundwater from port 3 were decreasing by the time the FLUTe™ system was removed in 2013 (**Figure 4-14**).

Subsequent to the removal of the FLUTe™ multi-port, concentrations of TCE in the borehole have been measured at 57 μg/L, and concentrations of *cis*-1, 2-DCE have decreased to about 3.9 μg/L in early 2014 (**Figure 4-14**).

RD74

RD-74 is a 101 feet deep bedrock corehole well with casing from the surface to 30 feet bgs. It was installed in January 1999, which was the last time it was sampled. According to MWH (2007), the well is installed near a drainage and water levels may be influenced by additional surface input when the drainage has flowing water. With less than average rainfall in recent years, RD-74 has been dry.

RS-16

RS-16 is a 20.5 feet deep well installed into the alluvium above bedrock. It has a well screen between 16.5 and 20.5 feet bgs. It was sampled once following installation. It exhibited groundwater in 2004 and 2005 that were during years of above-average rainfall; but it has been dry since.

PZ-124

PZ-124 was drilled to 31 feet into the weathered bedrock, and has a well screen set at 11.3 to 31 feet bgs. It was installed in March of 2003. It was sampled once following installation and has been dry since.

4.3.5 Conceptual Site Model

No source for TCE has been identified at the Building 56 Landfill, including the Building 4056 excavation and the Southern Debris Area. Numerous soil and soil vapor samples have been collected and no TCE has been detected (MWH, 2007) in those samples.

The TCE has historically been detected only in samples from one Chatsworth Formation well, RD-07. The association of higher concentrations of TCE and bedding features and fractures indicated that the contaminant-containing fractures are bedding plane fractures. Therefore, the source is suspected to be located upgradient and along geologic strike from RD-07. Based on the 2013 groundwater level data, groundwater could be expected to flow from the TCE-contaminated RD-91 (groundwater at about 1,740 feet MSL in April) located at the Building 4009 Leach Field (a Boeing responsibility), toward RD-07 (groundwater at about 1,728). RD-91 is located approximately along strike from RD-07 approximately 450 feet to the southwest with a TCE concentration of 200 µg/L. Flow along bedding plane fractures from RD-091 to RD-07 may have been accelerated during the period that RD-25 and RD-28 were pumped, lowering the water level in RD-07.

Although data from RD-07 port 3 indicated that some dechlorination of TCE has occurred in that zone, the oxidation reduction potential (ORP) and dissolved oxygen (DO) content reported in 2013 in RD-07 and RD-91 samples were not conducive to reductive dechlorination. TCE concentrations can be expected to attenuate somewhat as groundwater flows through the fractures due to diffusion into the rock matrix.

<u>Possible Data Gap Actions for B56 Landfill:</u>

The Building 56 Landfill is identified in the 2007 CO as a DOE responsibility. However the source may not be at the landfill but, rather, in an area that is a Boeing responsibility (Building 4100/4009). Future investigation of the area should be shared.

- RD-07 should be geophysically logged to identify water bearing and transmissive fractures.
- VOC concentrations in groundwater in individual fractures are not known and data are necessary for extent of groundwater impact. The fractures in RD-07 should be individually sampled for VOCs to determine which are contributing to the present VOC contamination. Identification of the most contaminated fractures will allow a focused approach to remediation.
- The downgradient extent of contamination is not defined because the downgradient monitoring well, RD-74 (101 feet deep) is too shallow to intersect the bedding plane fractures previously identified as most contaminated. This data gap can be filled through the installation of a new monitoring well that is deep enough to intersect the same fractures formerly monitored by RD-07 ports 4 and 5, or fractures identified as most contaminated during the testing described

above. The well will be located near PZ-124 to define the downgradient extent of TCE in this area.

- The relationship of groundwater contamination observed at RD-91 and potential for migration to RD-07 needs evaluation.

The following information was used to determine the depth of the new Chatsworth Formation monitoring well.

- Current purposed location (See Figure 9-1)
- Elevation at purposed location (1,760 feet above MSL)
- Strike and dip of sandstone beds identified at B56 Landfill (strike N 45 °E, dip of 35° to the northwest)
- Groundwater interval of interest is 1,490 feet above MSL (RD-07 TCE concentrations present within and above Port 5 –1,983 feet above MSL and dip of beds in this area)

The new monitoring well will be drilled to a total depth of 270 feet at this proposed location. This well will fill the following data gap.

- Provide TCE and perchlorate concentration data north of the B56 Landfill
- Bound the plume's northern extent
- Provide groundwater elevation data in the Chatsworth Formation

4.4 Buildings 4057/4059/4626

Per the 2007 CO, Building 4059 is a DOE responsibility. The buildings comprising this study area (4057, 4059, and 4626) were part of DOE ETEC's former operations. PCE-contaminated groundwater has been identified in the vicinity of former Buildings 4059 and 4626, and existing building 4057. Building 4059 was part of the SNAP facility in the western part of Area IV. Existing Building 4057 supported the liquid metals testing program, while Building 4626 used for equipment storage and has exhibited PCE soil contamination. The buildings, monitoring wells, potential PCE contamination source areas in the Building 4057/4059/4626 groundwater investigation area are depicted in **Figure 4-15.**

4.4.1 Operation History

Building 4059 was constructed between 1961 and 1963 and was used to test SNAP reactors from 1961 to 1964 and again from 1968 to 1969 when a leak in the reactor core was found. From 1973 to 1978 the building was used for the Large Leak Test Sodium Test program. In 1964, a French drain was constructed around the three external sides below the foundations to collect and remove any infiltrating groundwater into the test cells of the reaction vault. Sump (S-2) received water from a French drain and maintained water levels in the sump within 3 feet of the bottom of the sump (CH2M Hill, 2008).

Operational history of the French drain system is fragmented. The following information was reported in the *Results of Enhanced Dewatering, Building 059* (GRC, 1999a):

- Foundation boring data in 1961 suggests that the water table was below the basement level of Building 4059 when it was initially constructed.
- A review of data and reports achieved in GRC files did not reveal when groundwater seepage into Building 5049 was initially recognized.
- It appears that degraded groundwater was initially confirmed in Building 4059 in 1978.

GRC further suspects that groundwater levels in the vicinity of Building 4059 commenced rising in the late 1960s in response to historic water imports to SSFL in conjunction with a lack of water supply. This resulted in a net historic rise in groundwater levels of approximately 50 feet in portions of Area IV, as evidenced in WS-07 (GRC, 1999a) located 2,500 feet east Building 4059. It is not clear when sump S-2 pumping began; however, it is reported that during periods of high seasonal precipitation as much 300 gpd was pumped (CH2M Hill, 2008).

In 1983, radioactive isotope-contaminated water was detected in seepage found in the below-grade vault of the south test cell in Building 4059. Radioactivity measurements in the water were less than maximum concentration permissible (MCP) limits in effect at the time and countermeasures were established to pump out the water and prevent leaching from impacted building basement concrete. No radioactive contamination was detected in groundwater out of the building footprint (CH2MHill, 2008). The water was pumped out and the vault leaks were sealed.

In 1987, water was present in the north test cell floor of the reactor vault floor. Two radionuclides (Eu-152 and Na-22) were detected above their respected MCP limits. Following this discovery, Rockwell began a decontamination and decommissioning program to remove the remaining radioactivity.

In 1989, EPA reported tritium in water sampled from the French drain to be above background, but below the MCL at the time.

From 1986 through 1992, water collected in the drainage system was found to be contaminated with PCE, TCE, and their degradation products as well as tritium (CH2M Hill, 2008). Water from the French drain was temporarily stored in a holding tank, screened for radioactivity, and then discharged through carbon treatment to the storm drain. Non-radioactive water from the French drain was also transported to an air stripping tower in Area II for treatment prior to disposal. In an effort to further lower the water table in the Building 4059 area, pumping of nearby monitoring well RD-24 began in early 1995. Additional dewatering by pumping monitoring wells RD-25 and RD-28, and the Building 4056 excavation started in mid-1999.

The SNAP facilities included 14 above-ground storage tanks, four underground storage tanks, and a reaction products tank (RPT). None of the tanks were reported to have contained PCE or other solvents; however, the contents of two tanks located along the perimeter of Building 4059 were not known (CH2M Hill, 2008).

Other buildings in the groundwater investigation area where chemicals were used or stored included:

- Building 4057 – used as a Liquid Metals Engineering Center (LMEC) Laboratory. A flammable materials storage cabinet was located outside the north wall of the building. The cabinet was used for storing alcohol, paint, TCA, oil, and ethylene glycol monoethyl ether.

- Building 4038 – used for SNAP, LMEC, and administration offices. An unknown quantity of acetone was released in 1989 and 2 gallons of hydraulic oil spilled into an open trench in 2000.
- Building 4358 – used for chemical storage and for Sodium Component Testing Laboratory (SCTL) support. Later it was used for Sodium Component Testing Installation (SCTI) and the Kalina program support. The building was moved from the SNAP area in 1978.
- Building 4360 – used for storage of acids, bases, and combustible liquids used for SCTI.
- Building 4459 – contained a large diesel generator and was used to store non-radiological supplies and flammables. When Building 4059 was demolished, Building 4459 was used to store radioactive waste containers.
- Building 4626 – used for equipment storage; chemical use in this building is unknown. Soil samples collected on the south side of the building were found to be contaminated with VOCs, including PCE at a concentration of 37µg/kg at a depth of 9 feet.

Building 4059, the French drain, and storage tanks were removed in 2003 and 2004. The resulting excavation was backfilled with approximately 5,000 to 8,000 cubic yards of material from an Area IV borrow pit (CH2M Hill, 2008). Monitoring wells RD-25 and RD-28 were abandoned in April 2004 as part of the building demolition. Other buildings in this area have been removed, including 4626 (2004), 4459 (2003), 4358 (2003), 4360 (1999), and 4459 (2003). Buildings 4038 and 4057 remain.

4.4.2 Soils, Geology, and Hydrogeology

Natural soils are up to 12 feet thick. The bottom of Building 4059 was constructed into the top of the Chatsworth Formation; the backfill of the excavation is up to 60 feet deep.

Near-surface groundwater is present at Building 4057 where piezometer PZ-109 is installed into the weathered Chatsworth Formation. The extent of Near-surface groundwater to the southwest of PZ-109, in the area of Building 4626, is not known. Based on data from piezometers located mostly northeast of PZ-109, the direction of groundwater flow in the Near-surface groundwater fluctuates from southwest to northeast. The Near-surface groundwater at PZ-109 has been reported to be continuous with the Chatsworth Formation groundwater (CH2M Hill, 2008). There is a strong downward vertical gradient between the Near-surface groundwater and the Chatsworth Formation groundwater near PZ-109.

Groundwater at the Building 4059 investigation area was historically monitored by four Chatsworth Formation wells – RD-24, RD-25, RD-28, and RD-96. Two of the wells – RD-25 and RD-28 – were abandoned in 2004 during building demolition. Historical groundwater data for RD-25 and RD-28 and current data for RD-24 indicate that Building 4059 was not a source of PCE contamination.

Under static conditions, as currently exist in the investigation area, groundwater flow in the Chatsworth Formation is toward the west-northwest. However, from about 1986 to 2004 pumping from the French drain sump and various monitoring wells was used to lower the water table around Building 4059. There are no water level data in the Chatsworth Formation prior to 1989, but pumping of the sump in 1986 lowered the groundwater to below the building foundation and probably caused a localized cone of depression in the potentiometric surface around the building. Similarly, when pumping starting at RD-24, and later at RD-25 and RD-28, the potentiometric level dropped. When pumping of RD-25 and RD-28 started in July 1999, an abrupt drop in water levels was observed in

RD-07, located about 350 feet southwest of RD-25, indicating strong hydraulic connectivity between RD-07 and RD-25 and RD-28 (GRC, 1999a).

4.4.3 Extent of Contamination

The primary contaminant in the Building 4057/4059/4626 area is PCE; other VOCs, including breakdown products of PCE (TCE and *cis*-1,2-DCE) have been reported at lower concentrations in the same set of wells. Because two of the wells, RD-25 and RD-28, were removed in 2004, and PZ-109 was installed in 2001, there is a 3-year period when all four wells were available to monitor the plume. The distribution of PCE based on data from 2001 is depicted on **Figure 4-16**. At that time the northern area of PCE-impacted groundwater, as defined by concentrations exceeding the MCL of 5 µg/L, extended from PZ-109 (240 µg/L) northwest to RD-25 (about 11 µg/L). The concentration of PCE in the Near-surface groundwater at PZ-109 (280 J µg/L in 2001) was the highest concentration that has been reported in the investigation area. More recently (February 2014), the concentration of PCE in PZ-109 was 48 µg/L. In 2001 PCE was detected in both RD-24 and RD-28 at concentrations below 1 µg/L. PCE has not been detected in the most downgradient monitoring well, RD-96.

During the RFI, VOCs were sampled and analyzed at eleven locations at Building 4059, 4057, and 4626. Soil and soil vapor results are discussed below.

Building 4059

Soil samples were collected from three locations surrounding the previous SNAP excavation area (Building 4059). VOCs were detected in the soil samples but less than RBSLs. Soil vapor samples were collected from two locations; one surrounding the previous SNAP excavation area and one southwest of former Building 4059 and one in the excavation backfill. VOCs in soil vapor were not detected in the native soil location but exceeded the Ecological RBSLs for toluene in the backfilled soil.

Building 4057

Soil samples for VOC analysis were collected at two locations; near southwest corner of building and northwest corner of building. VOCs were reported for both locations with PCE reported above the Residential RBSLs. Soil vapor samples were collected from four locations along the southern perimeter of the building. VOCs were reported above RBSLs for PCE, benzene, and toluene.

Building 4626

Soil samples were collected from five locations; one at the centroid of the former building and four at the eastern perimeter of the former building. PCE was reported in soil above the Residential RBSLs at two locations along the eastern perimeter of the building. Soil vapor was collected from two locations; one at the centroid and one at the eastern perimeter of the former building. PCE was reported above the Residential RBSLs in the eastern perimeter soil vapor sample. MWH collected 10 soil vapor samples from this part of Area IV in 2014 (5CSV_DG-543, 5CSV_DG-545, 5CSV_DG-549, 5CSV_DG-551, 5CSV_DG-554, 5CSV_DG-557, 5CSV_DG-559, 5CSV_DG-561, 5CSV_DG-563, and 5CSV_DG-570) and all samples were non-detect for key Area IV COCs (**Appendix Figure A-2**).

There are many factors that would result in reporting of VOCs in soil samples and not in soil gas samples. One is the possibility of highly localized contamination; VOC contamination is not that extensive. Soil gas and soil samples would need to be collected from identical locations to see detections in both the samples. Another is the age of the soil samples versus recent soil gas samples. Just looking at the physicochemical properties of a volatile chemical in an aerated, arid environment, sandy soil, one would expect continued and rapid decreases in VOC concentrations.

4.4.4 Conceptual Site Model

The source of PCE that has been detected in the Near-surface and Chatsworth Formation groundwater is suspected to be contaminated soil near Building 4626 and, potentially, Building 4057. Building 4059 does not appear to be a significant source for PCE given the response of PCE concentrations in wells RD-25 and RD-28 during groundwater pumping. PCE was reported at increasing concentrations with depth in soil on the south side of Building 4626 and in soil vapor on the east side of Building 4057. PCE in the soil dissolves into infiltrating precipitation and migrates to the Near-surface groundwater. Under downward vertical hydraulic gradients, PCE-contaminated groundwater moves to the fractures of the Chatsworth Formation. In the Chatsworth Formation, some PCE diffused into the rock matrix, potentially becoming a future source of low-level contamination. The remainder flows downgradient through fractures in the rock. As the hydraulic gradients changed due to dewatering efforts in the period from about 1983 to 2004, the flow path of contaminated groundwater would also have changed.

The change of PCE concentration with time in PZ-109, RD-24, RD-25, and RD-28 is shown in **Figure 4-17** along with the time periods when groundwater pumping occurred using wells RD-24, RD-25 and RD-28. Pumping from the French drain sump started prior to the installation of the Chatsworth Formation wells; therefore, the impact of the start of that pumping is not shown on this figure. Water levels would have dropped within the radius of influence of the pumping wells: first in RD-24, then in RD-25 and RD-28, correspond to the start of pumping in these wells. Conversely there was an abrupt rise in water levels at the end of pumping in 2004. The French drain was also removed at that time, so the groundwater flow system returned to static conditions.

The changing concentration of PCE in these same wells provides insight into the impact of pumping and the changing groundwater flow regime on contaminant migration. Monitoring well RD-25 is located most directly downgradient of the Buildings 4626 and 4057 source area. From 1989, when monitoring started in the Chatsworth Formation monitoring wells, until about 1995 when pumping started at RD-24, concentrations of PCE gradually increased in RD-25 indicating that the northern edge of the PCE plume was passing through that area. During that same time period PCE was detected at fairly stable, low concentrations of about 1 µg/L at RD-28 located on the far side of the French drain from the source area. It is possible that during this time the French drain was diverting contaminated groundwater that would have reached RD-28 had the drain not been there. Also during the 1989 through 1995 time period, PCE was not detected at RD-24, located north-northeast (cross gradient) of the source area.

With the start of pumping at RD-24, the direction of groundwater flow may have shifted northward. Prior to the start of pumping in RD-24, concentrations of PCE in RD-25 increased from <5 µg/L in 1989 to a high of 43 µg/L in 1995. With the start of pumping in RD-24 concentrations of PCE in RD-25 declined to between 6 and 12 µg/L in 2001 and 2002. PCE concentrations appeared to increase in RD-25 (27 µg/L) following cessation of pumping although the concentration in the final sample (collected in 2004) was less than 1 µg/L.

PCE was detected in RD-24 during pumping (<1 to <3 µg/L) but concentrations returned to non-detect following pumping and was non-detect in the February 2014 sampling of the well. Concentrations of PCE in RD-28 decreased from 1.5 µg/L to less than 1 µg/L during pumping and were non-detect at the time the well was removed. This decrease in concentration may have been due to the increase in uncontaminated water drawn into the well with the start of pumping.

In the time since 2004, when RD-25 and RD-28 were removed and pumping stopped in RD-24, PCE concentrations in RD-24 have decreased to non-detect. PZ-109 has been only sampled three times with PCE concentrations of 273 µg/L in 2001, 60 µg/L in 2012, and 48 µg/L in 2014. The source for the PCE appears to be in the vicinity of Buildings 4057 and 4626. The decrease in PCE concentrations in PZ-109 is likely due to the depletion of any remaining source over the 15-year period, some diffusion of the PCE into the weathered rock matrix, and potentially, some reductive dechlorination of PCE into its breakdown products, TCE and *cis*-1,2-DCE. Both of these breakdown products have been detected in PZ-109. The groundwater in 2013 was compatible for reductive dechlorination (an ORP value of -246 EV and a DO concentration of 0.88 µg/L) in January of that year (MWH, 2014a).

<u>Possible Data Gap Actions for Buildings 4057/4059/4626</u>

Since the abandonment of RD-25 and RD-28, discussions on whether to replace the wells have occurred between DOE and DTSC. Justification for replacing the wells would be based on filling data gaps at this area and completion of the RFI report. At this time, RD-25 and RD-28 replacement wells are not recommended based on the following lines of evidence:

- Building 4059 demolition and surrounding area soil excavation and backfill was completed in 2004. All groundwater pumping activities have been terminated and static "non-pumping" water levels are present at this area.
- Soil and soil vapor supports that the source of PCE is contaminated soil near Building 4626 and, potentially, Building 4057.
- Historic PCE detections in groundwater supports that source of PCE is located at Building 4626 and, potentially, Building 4057. As hydraulic gradients changed from dewatering using the French drain and then pumping RD-24, RD-25 and RD-28, so did the flow path of contaminated groundwater. PCE was not detected in RD-24 prior to pumping or shortly following termination of pumping of the well. PCE concentration increased from 2 µg/L in 1989 to a maximum concentration of 42 µg/L in 1995 in RD-25 while operation of the French drain dewatering system occurred. PCE concentrations detected in RD-25 ranged between 4.2 µg/L and 27 µg/L during pumping of this well. In 2004, following termination of all dewatering activities at the area, PCE was detected at 0.48 J µg/L. PCE concentrations in RD-28 were detected between 0.22 J µg/L and 1.5µg/L from 1989 through 2002. PCE was not detected in 2003 or 2004.
- In RD-24, following termination of French drain dewatering and well pumping, PCE was reported (estimated) in five groundwater samples ranging between 0.1 J µg/L and 0.67 J µg/L and was not detected in seven groundwater samples including samples collected in 2008, 2009, 2010, or 2014. PCE was reported (estimated) in RD-25 at 0.48 J µg/L in 2004. Two groundwater samples were collected in 2003 and one sample in 2004 for RD-28. PCE was not reported in these samples. PCE concentrations in these wells following termination of dewatering activities confirm that PCE was being drawn to the well during dewatering activities. Once dewatering was terminated, PCE concentrations decreased to near or below pre-pumping PCE concentrations. Since all dewatering or pumping activities have been terminated and no future pumping is planned for this area, current water levels reflect a non-pumping condition and water levels should remain at their current elevations.

The fact that there is no PCE source near RD-25 and RD-28, PCE concentrations in groundwater increased during dewatering activities, and subsequently decreased following dewatering, all conclude that replacement of RD-25 or RD-28 is not warranted. However, the vertical and northern extent of PCE is not bound at this area. For this reason, a new Chatsworth Formation monitoring well will be installed between RD-25 and RD-28.

The following information was used to determine the depth of the new Chatsworth Formation monitoring well.

- Proposed location (See Figure 9-1)
- Elevation at purposed location (1,810 feet above MSL)
- Strike and dip of sandstone beds based on surface exposure of ELV Member south of Building 4038 (strike N 62 °E, dip of 30° to the northwest)
- Groundwater interval of interest is above 1,636 feet above MSL (RD-25 PCE concentrations present during pumping – total depth of RD-25 was 175 feet bgs)

The new monitoring well will be drilled to a total depth of 175 feet at this proposed location. This well will fill the following data gap.

- Provide PCE concentration data north of Building 4057/4059/4626
- Bound the plume's northern extent
- Provide groundwater elevation data in the Chatsworth Formation

4.5 Hazardous Materials Storage Area Building 4457

In accordance with the 2007 CO, the Hazardous Materials Storage Area Building 4457 is a DOE responsibility. A relatively small area (2 to 3 acres) of TCE-contaminated groundwater comprises the HMSA perched groundwater investigation area (**Figure 4-18**). This area is adjacent to the Building 4057/4059/4626 investigation area to the west. Groundwater quality in this area has historically been monitored through sampling of piezometers (PZ-041, PZ-108, PZ-109, PZ-120, PZ-121, and PZ-122) screened in the weathered bedrock. PZ-108 and PZ-120 are the impacted wells, and PZ-041, PZ-109, PZ-121, and PZ-122 define the edge of the plume. Shallow well RS-27 is dry and has not been sampled since 1995 providing minimal monitoring data. Chatsworth Formation monitoring wells RD-24 and RD-29 provide bedrock aquifer data. The monitoring points, current and former buildings, and TCE plume as defined by the MCL and 2014 analytical data are shown on **Figure 4-18**.

4.5.1 Operation History

Table 4-1 presents an inventory of the buildings found in the HMSA including the operations conducted in the buildings and chemicals that were potentially used or spilled there. As of late 2013, only Building 4024 remained standing; all others had been demolished. All surface and underground tanks have been removed.

The operational history of activities within the HMSA groundwater investigation area, as described in the RFI (CH2MHill, 2008), is summarized below. DOE conducted a variety of operations in the numerous buildings that make up the HMSA groundwater investigation area. The buildings included 4005, 4024, 4025, 4026, 4226, 4334, 4335, 4355, 4356, 4357, 4358, 4359, 4361, 4392, 4426, 4457, 4478, 4615, 4625, 4656, 4826, 4925, 4926, 4927, and 4928. The area also included 51 above-ground storage tanks, 14 underground storage tanks, and 3 sumps. Building 4005 had an associated leach field (AI-Z8).

The RCRA Program identified one former building, Building 4457, as an area of concern. In the 1960s, Building 4457 was used for testing of sodium-lubricated bearings for large sodium pumps. Later, the building was used for storage of a variety of chemicals including waste oils, acids, bases, solvents, petroleum hydrocarbon oils, and other lubricants. The building also included a 1,000-gallon sulfuric acid storage tank and two sumps.

Various SNAP operations, including testing of prototype reactors, were conducted in Buildings 4024 and 4025. Building 4026 housed a facility for testing components of sodium-cooled graphite moderated reactors. Building 4026 later became a sodium component test laboratory. SCTI operations were conducted in Building 4355 (the control room), 4356 (steam generation), and 4457 (testing of lubricated bearings for sodium pumps). DOE operated the Kalina program, to expand non-nuclear power technologies, in Buildings 4334 (the control building) and 4335 (containing the turbine).

Most of the 65 aboveground and underground tanks were used for storage of various forms of sodium or ammonia, fuels and lubricants, sulfuric acid and acid rinse waters, and sodium hydroxide and caustic rinse waters. None of the inventoried tanks contained solvents, although a "drain tank" in Building 4361 was listed as "unknown" size and contents.

CH2MHill (2008) reported five documented spills: two of sulfuric acid (1 gallon in Building 4355 and 25 gallons in the SCTI area), one of sodium hydroxide (3 to 5 gallons in Building 4355), one of sodium hydroxide (15 gallons in the Kalina area), and one of ammonia (3,900 pounds in the Kalina area). No solvent spills were documented.

4.5.2 Soils

One to 11 feet of soils derived from the weathering of the Chatsworth Formation underlies the HMSA. These soils consist of fine-grained silty sands, sandy silts, lean clays, and poorly graded sands (MWH, 2008).

Table 4-1 History of Operations within the HMSA Area

HMSA Building	Operations Conducted	Chemicals Known/Potentially Used or Released
4005	Testing non-nuclear thermodynamic characteristics of coolants for organic moderated reactor experiments and Piqua reactors Fabrication of enriched carbide fuel Pilot plant for molten salt combustion Included change rooms, chemistry labs, storage Building had a leach field	Polyphenols Benzene produced by coal gasification Chlorinated waste Sodium carbonate Chromium was detected in clean salt bin Tar/water mixtures have been released
4024	Testing of prototype reactors	No chemical uses reported
4025	Nuclear reactor remote handling Warehouse storage	No chemical uses reported
4026	Testing components of sodium-cooled graphite moderated reactors Included a below-grade drain tank	Hydraulic line broke releasing fluid to ground (1999) Ammonia and glycol released from pipe (1997) DeWorals sodium, Dowanol, sodium, and hydrocarbons were generated and disposed off-site
4226	Housed a motor generator and used for storage of drummed non-radiological hazardous	Petroleum spills

Table 4-1 History of Operations within the HMSA Area

HMSA Building	Operations Conducted	Chemicals Known/Potentially Used or Released
	materials	PCB-containing hydraulic oil used
4334	Control room, general chemical storage	Stored aqueous and anhydrous ammonia, turbine lubrication oil, compressor oil, greases, and other lubricants Leaks of anhydrous ammonia
4335	Housed turbine for Kalina facility	No chemical uses identified
4355	Control room, offices, small chemistry laboratory, and record storage Cooling tower and emergency generator	No chemical uses reported
4356	Sodium tank cleaning, steam generation from sodium heat source, water treatment, X-ray operations Testing small steam engines	Sulfuric acid, sodium hydroxide, hydrazine, and morpholine were used Cadmium and chromium were stored Recorded sodium leak; 200-300 gallons of 20 percent sulfuric acid spilled (1988) Six to eight gallons of sulfuric acid spilled (unknown)
4357	Supply storage for SCTI Pump bearing test facility	Propellants for rockets mixed and processed
4358	Chemical storage and storage for SCTL and Kalina Storage of Space Shuttle Main Engine (SSME) stability bombs	Igniters containing ammonium, magnesium, potassium perchlorate Drums of lube oil
4359	SCTI compressor building and storage	Oil staining from a transformer
4361	SCTI hazardous material storage Chemicals stored in underground storage tanks (USTs) with containment pit	Chlorine stored in drums
4392	Electrical equipment building for Kalina and SCTI	No chemical use
4426	Uninterruptible power supply	No chemical uses reported
4457	Proof and performance testing of sodium lubricated bearings	Waste oils stored Sulfuric acid (1,000-gallon tank) Acids, bases, TPH oils, solvents, and lubricants were stored in subsurface sumps
4478	Office support trailer	No known chemical uses
4615	Combustion test facility (non-radiological)	No known chemical uses
4625	Non-nuclear component storage building	No chemical uses reported
4656	Cooling stacks	Cooling tower periodically treated with chlorine Sulfuric acid and sodium hydroxide used to regenerate resins Hydrazine and morpholine to control oxygen and pH
4826	Expansion of Building 4026 Testing components in sodium environment	No chemical uses reported
4925	Mechanical equipment slab	No known chemical uses
4926	Sodium Reactor Mock-up Equipment Area	No known chemical uses
4927	Nitrogen tank storage area	Nitrogen
4928	Cooling Tower for Building 4026	No known chemical uses

Notes:

HMSA – Hazardous Materials Storage Area

SCTI – Sodium Component Testing Installation

SSME – Space Shuttle Main Engine

SCTL – Sodium Component Testing Laboratory

UST – underground storage tank

4.5.3 Soils, Geology, and Hydrogeology

Bedrock in the HMSA consists predominantly of the Upper Burro Flats member of the Upper Chatsworth Formation. This member consists of fine- and medium-grained sandstone with minor interbeds of shale and siltstone. Immediately east of the HMSA, the ELV fine-grained member of Sandstone 2 that contains at least 50 percent fine-grained rock (shale and siltstone) is found at surface or subcropping beneath the surface alluvial soils. The ELV fine-grained member of Sandstone 2and Upper Burro Flats Members strike N70˚E and dip 25 degrees to the northwest. This structural configuration brings the ELV fine-grained member of Sandstone 2 beneath the HMSA at depths ranging from 0 feet on the east to about 260 feet bgs on the western edge of the HMSA. The Near-surface aquifer well, RS-27, located within the subcrop area, is likely screened within the weathered ELV fine-grained member of Sandstone 2. RD-29, an Upper Chatsworth Aquifer well also located in the ELV fine-grained member of Sandstone 2 subcrop area, is an open borehole beneath the ELV fine-grained member of Sandstone 2, in the Lower Burro Flats member.

Near-surface groundwater in the HMSA is discontinuous and perched above the Chatsworth Formation groundwater (MWH, 2008). The ELV fine-grained member of Sandstone 2 may be providing a barrier to the downward infiltration of precipitation, causing the water to perch, particularly in the eastern portions of the HMSA. On the eastern edge of the HMSA, RS-27, screened in the weathered ELV fine-grained member of Sandstone 2 at a depth of about 10 feet bgs is frequently dry. The other Near-surface groundwater monitoring points, PZ-108, PZ-109, PZ-120, and PZ-121, are screened at the depths of 26 to 36 feet bgs. PZ-121, located on the northwestern side of the HMSA, was dry in 2014. Groundwater flow direction in the Near-surface groundwater varies considerably. As discussed below, groundwater elevations in PZ-108 have been higher than those in PZ-120 over much of the last 14 years indicating a general southwesterly component to the flow direction. However, at least once during that same period the water levels in PZ-109 (southwest of PZ-120) were also higher than PZ-108 indicating a northeasterly flow direction from PZ-109 to PZ-120.

Chatsworth Formation monitoring wells have not been installed in the central part of the HMSA. Monitoring well RD-24, open from 30 to 150 feet bgs in the Upper Burro Flats Member of the Chatsworth Formation, is located on the western side of the HMSA. Monitoring well RD-29, open from 30 to 150 feet bgs in the Lower Burro Flats Member, is located on the eastern side of the HMSA. RD-93 is located about 200 feet northwest of PZ-121; generally north of the HMSA. Water levels in RD-24 are about 20 feet lower than those in the closest Near-surface groundwater piezometer (PZ-109). Similarly, water levels in RD-93 (open from 20 to 60 feet bgs) are about 20 feet lower than those in PZ-121. Water levels in RD-29 are less than a foot lower than those in adjacent well RS-27, although there is only a small set of data that can be compared as RS-27 is dry much of the time. Water in the Lower Burrow Flats member may be semi-confined beneath the ELV fine-grained member of Sandstone 2.

The HMSA is also located on a groundwater divide in the Chatsworth Formation aquifer, with groundwater flowing radially outward, predominantly to the east, southeast, southwest, and west (**Figure 4-19**).

4.5.4 Extent of Contamination

Since monitoring began in 2001, TCE has been detected at concentrations greater than the MCL (5 μg/L) in the Near-surface groundwater in piezometers PZ-108 (79 μg/L in 2014), PZ-120 (90 μg/L in 2014), and PZ-109 (5.5 μg/L in 2013, 2.8 μg/L in 2014). The TCE reported for PZ-109 may be the result of degradation of PCE, and not a connection with the HMSA impacted area. Lower concentrations, below the MCL, have been detected in PZ-122 (0.84 J µg/L in 2014); TCE has not been detected in PZ-121. The extent of TCE contamination is, therefore, fairly well-defined in the Near-surface groundwater of the HMSA (**Figure 4-18**). Concentrations in PZ-108 have decreased since they were first measured (about 160 µg/L in 2001) to between 57 µg/L and 79 µg/L from 2001 through February 2014 (**Figure 4-20**). From 2001 through 2014 concentrations of TCE in PZ-120 have generally increased from less than the MCL to 90 µg/L in February 2014 (**Figure 4-21**). This may be the result of a slow migration of contamination to the southwest.

TCE was detected at concentrations below the MCL in Chatsworth Formation monitoring well RD-29 (3.3 µg/L in 2014) and RD-93 (0.16 µg/L in 2014), and has not been detected in RD-24. Concentrations of TCE have ranged from less than 1 µg/L to 3.3 µg/L in the period from 1989 through 2014; contamination in the Chatsworth Formation is very stable and below the MCL.

Other VOCs, including 1,2-dichloroethenes, acetone, and *cis*-1,2-DCE, have been found in the HMSA groundwater at concentrations below MCLs.

MWH (2014b) collected 21 soil vapor samples from this part of Area IV (5ASV_DG-529, 5ASV_DG-537, 5ASV_DG-540, 5ASV_DG-543 and 5BSV_DG-525, 5BSV_DG-526, 5BSV_DG-530, 5BSV_DG-531, 5BSV_DG-532, 5BSV_DG-534, 5BSV_DG-536, 5BSV_DG-538, 5BSV_DG-543, 5BSV_DG-552, 5BSV_DG-555, 5BSV_DG-557, 5BSV_DG-560, 5BSV_DG-561, 5BSV_DG-562, 5BSV_DG-563, 5BSV_DG-566). TCE was reported for three of the samples (5BSV_DG-526, 5BSV_DG-530, and 5BSV_DG-560), and PCE and benzene for four (5BSV_DG-526, 5BSV_DG-530, 5BSV_DG-560, and 5BSV_DG-562) (**Appendix Figure A-3 and Figure A-4**).

4.5.5 Conceptual Site Model

The source of the TCE found in the HMSA groundwater has not been definitively determined, but based on the history of building usage and features, is most likely to be spills, discharge, or other leakage associated with operations in one of the following buildings:

- Building 4457, where solvents were once stored and where two sumps were located. Spilled solvents in the sumps could have leaked from the sumps to the surrounding soil through cracks in the concrete. Soil vapor sampling conducted during the RFI identified VOCs, including TCE, in soil near Building 4457 (CH2MHill, 2008).

- Building 4026, where small components of sodium cooled reactors were tested and where a floor drain and tank were located. Building 4026 is also located between PZ-108 and PZ-120 where the highest concentrations of TCE have been consistently found. Associated Building 4426, located southwest of PZ-120, was the location of non-radioactive hazardous material storage. Soil vapors collected during the RFI contained VOCs, but these did not include TCE (CH2MHill, 2008).

- Building 4357, where sodium storage tanks were cleaned. There was no reported use of solvents in this building; however, soil vapor sampling at this building during the RFI found that soil vapors contained VOCs; TCE was not identified in soil vapors (CH2MHill, 2008). PZ-120, where the highest concentrations of TCE were detected in 2014, is located southwest of this former building location.

VOCs can be present as vapors in soil pore spaces when there is a nearby source in the soil or when groundwater is sufficiently contaminated that VOCs volatilize from the water and migrate upward into the unsaturated soil pore spaces. Therefore, the presence of VOCs in soil vapors near these three buildings confirms that they are likely sources of VOCs in soil and groundwater.

TCE present in soil from leaks or spills at these source areas would dissolve into precipitation infiltrating through the soil and migrate to the perched Near-surface groundwater. Once in the groundwater, dissolved TCE will migrate with groundwater flow. There is not a clear direction of groundwater flow in this discontinuous, perched groundwater; however, between April 2004 and February 2014 groundwater levels typically were higher in PZ-108 than in PZ-120 indicating that groundwater flow within the relatively porous media of the perched water table was from northeast to southwest. Concentrations of TCE increased in PZ-120 over that time period (from near the MCL or 5 µg/L in April 2004 to 90 µg/L in February 2014). This distribution of the contamination indicates a source area northeast of PZ-120.

The relatively large potentiometric head difference (about 20 feet) between the Near-surface groundwater (higher) and the Chatsworth Formation groundwater (lower) over much of the HMSA indicates a downward vertical gradient. TCE-contaminated perched water leaking through the low-permeability layer will infiltrate through the underlying weathered and competent rock and into the Chatsworth Formation through fractures in the competent rock. The HMSA is located on a groundwater divide for the bedrock aquifer (Chatsworth Formation) with low horizontal groundwater gradients. In the Chatsworth Formation, TCE-contaminated groundwater can be expected to migrate slowly in multiple directions, but primarily to the east, southeast, south, southwest, and west. TCE will also diffuse from the groundwater in the fractures into the rock matrix, decreasing the concentration of TCE in fractures and generally slowing the migration of the plume front.

<u>Possible Data Gap Actions for HMSA:</u>

For the Hazardous Materials Storage Area Building 4457, the following actions include:

- The HMSA TCE plume is well delineated in the Near-surface groundwater. Although it appears that the area of highest concentration is moving to the southwest over the past 14 years, the migration is relatively slow and further migration can be monitored at PZ-109. Continued annual monitoring at PZ-109, as well as PZ-108, PZ-120, PZ-121, PZ-122, and RS-27, is recommended.

- The Chatsworth Formation groundwater is monitored by two wells, RD-29 and RD-24, both of which are open hole wells in the upper 120 feet of the Chatsworth Formation, i.e., immediately below the weathered bedrock. The stable low-level contamination found in RD-29, located south of the HMSA, and absence of TCE in RD-24, located west of the plume, indicate that there is not significant migration of TCE from the near-surface groundwater into the Chatsworth Formation. Continued annual monitoring of these two wells and Chatsworth Formation monitoring well RD-93 and RD-95 is recommended.

- Install of new Chatsworth Formation well between PZ-108 and PZ-120 will define the vertical extent of TCE in the source area.

- This area of relatively low level, but persistent, TCE-contaminated groundwater is candidate for a groundwater interim measure through dewatering of the contaminated Near-surface groundwater via pumping of PZ-120. Water could be pumped and treated with the unit that will be on site during the FSDF GWIM. Water level and quality of near-surface water would need to be monitored following the dewatering effort.

- The following information was used to determine the depth of the new Chatsworth Formation monitoring well.
- Proposed location is shown on Figure 9-1
- Elevation at purposed location (1,810 feet above MSL)
- Strike and dip of sandstone beds identified at B56 Landfill and assumed to be present at HMSA (strike N 67 °E, dip of 30° to the northwest)
- Groundwater interval of interest is first available water present in the Chatsworth Formation and expected to be above 1,660 above MSL

The new monitoring well will be drilled to a total depth of 150 feet at this proposed location. This well will fill the following data gap.

- Provide TCE concentration data in the central portion of the plume
- Bound the plume's vertical extent
- Provide groundwater elevation data in the Chatsworth Formation

4.6 Tritium Plume

4.6.1 Operation History

The Tritium Plume is a DOE responsibility; the 2007 CO identifies Building 4010 in this area as a DOE responsibility. A plume of bedrock groundwater containing tritium, the radioactive isotope of the element hydrogen, is found in the north central portion of Area IV (**Figure 4-22**). The location coincides with an area where several reactor experiments occurred during the 1960s and early 1970s. Reactor buildings in this area are/were Building 4059 (SNAP8 Development Reactor Facility, operational 1968-1969; demolished in 2004), Building 4019 (SNAP Flight System Critical Facility, criticality tests 1964-1965; existing), Building 4010 (SNAP Reactor Experimental Test Facility, operational 1959-1960, 1963-1965; demolished 1978), Building 4024 (SNAP Environmental Test Facility, operational 1961-1962, 1965-1966; existing), Building 4028 (Shield Test Irradiation Facility, operational 1964-1974; demolished 1989). Buildings 4010 and 4028 had leach fields (AI-Z7 and AI-Z6, respectively).

Tritium in groundwater in Area IV was discovered by EPA in 1989 when EPA staff sampled water collected from the Building 4059 French drain (see Section 4.4 for a discussion of Building 4059). EPA reported a value of 1,890 ± 538 picocuries per liter (pCi/L) for tritium. Until that time, the physicists managing the nuclear program had stated that there was no radioactive contamination in groundwater (1989 Annual Site Environmental Report [ASER]) (Rocketdyne, 1989). The suspected source for the tritium was the absorption of neutrons captured in lithium in the concrete containment walls of the reactor building (Rocketdyne, 1990).

The 1991 ASER states that the tritium in groundwater issue 'has been thoroughly investigated,' although monitoring wells had yet to be installed in the tritium plume area and tritium was just being added as a groundwater analyte (Rocketdyne, 1992). The next reporting of tritium in groundwater in the 1992 ASER was for well RD-28 (420 to 1,025 pCi/L) at Building 4059 and well RD-34A (1,800 to 7,069 pCi/L) at the Radioactive Materials Handling Facility (RMHF) (Rocketdyne, 1993). The ASER authors ascribe RD-34A tritium to neutron activated lithium in concrete from Building 4010 (demolished in 1978).

Further sampling of tritium in groundwater during the 1990s identified detectable tritium in wells RD-23 (672 pCi/L), RD-21 (560 pCi/L), and RS-54 (1,099 pCi/L) at the FSDF, and repeated detections in RD-28 and RD-34A. Continued sampling of these wells during the 1990s confirmed the presence of tritium at these locations.

The true tritium groundwater impact was not known until 2004/2005 as part of the installation of bedrock monitoring wells RD-87, RD-88, RD-89, RD-90, RD-93, and RD-94 in the area of the former reactor research buildings.

Tritium Plume

As previously stated, Chatsworth Formation wells RD-87, RD-88, RD-89, RD-90, RD-93, and RD-94 were installed in the area of the removed reactor research buildings. Groundwater sampling of those wells indicated tritium above the regulatory criteria present in this area. Overtime physicists attempted to identify the potential source(s) for the tritium plume; however, they have concluded that the size of reactors and length of operation could not have resulted in the mass of tritium observed in groundwater in 2005. Although the plume has been termed the Building 4010 plume, the source may not be entirely related to Building 4010. It is possible that all the reactor buildings contributed some tritium to groundwater in Area IV.

The extent of tritium in the bedrock matrix was investigated in 2007 when two bedrock coreholes were drilled; SB-Trit-01 near RD-93 and SB-Trit-02 near RD-95. Corehole SB-Trit-01 was drilled to 127.5 feet bgs with core retrieved in about 5-foot lengths. The cores were subsampled and pore water extracted from the rock matrix analyzed for the presence of tritium. Although tritium was observed throughout the corehole, the highest concentrations were observed between 39.5 and 72.5 feet bgs. This zone started at the groundwater surface. SB-Trit-002 was drilled to 219.5 feet bgs. The highest impacted zone was from 40.5 to 180 feet bgs. The average of the tritium concentrations in the bedrock coreholes corresponded with the groundwater collected from the adjacent monitoring wells.

SB-Trit-01 is located at the former Building 4010 location. Tritium was detected in rock core collected above the table ranging from 200 to 7,000 pCi/L. Rock core samples collected below the water table ranged between 66,000 and 931,258 pCi/L. RD-93 also located within the former Building 4010 footprint had a similar profile with rock cores from the vadose zone ranging from about 90 to 246,921 pCi/L. Interestingly, tritium activity decreases below the water table and presumably due to dissolution with non-impacted groundwater. Tritium in rock core collected below the water table range from 13,120 to 113,601 pCi/L.

Vadose zone data from SB-Trit-01 and RD-93 confirm the greatest impacted area has been identified. Tritium at these activities cannot be present in the vadose zone except by percolation and migration of tritium from a near tritium source. Variation of water table elevations and presumably the contamination of non-saturated fractures and pore water present in the rock matrix is unlikely due to the tritium activity levels and narrow water level elevation fluxuation documented on the RD-93 hydrograph.

Reduced tritium activity in vadose zone was most likely the result of half-life decay, percolation and flushing of fractures with atmospheric precipitation (low tritium activity), and dissolution with atmospheric precipitation in both fractures and within the rock matrix.

Although Building 4010 is suspected as one tritium source area, an additional area will be addressed as a possible tritium source. The RMHF 4614 Hold Up Pond is located approximately 200 feet north-northeast of RD-93. The former holding pond was reported to have a 30,000 gallon capacity and received RMHF runoff from about 1959 to 2006. The pond and asphalt liner were removed and replaced by a plastic tank in 2006. A soil boring is recommended to be advanced at this location to confirm or eliminate this area as an additional tritium source.

Tritium concentrations in the wells ranged from non-detect to 119,000 pCi/L (**Table 4-2**). This data indicated a much greater tritium groundwater issue than was earlier believed.

Table 4-2 Tritium Groundwater Data for Tritium Plume Area

Monitoring Well	Boeing 2004/2005	EPA 09/2010	EPA 04/2011	Boeing 02/2014
RD-34A	1,050	966	342	530
RD-34B	<180	191	187	NS
RD-87	14,800	7,630	5,600	4100
RD-88	86,800	44,800	4,040	Dry
RD-89	77	Not collected	Not collected	Not collected
RD-90	83,800	41,000	54,900	40,000
RD-93	28,400	8,200	9,130	5,300
RD-94	12,300	9,550	5,000	7,200
RD-95	119,000	59,700	49,900	28,000
SP-T02A	Not installed	Not installed	Not installed	2,500
SP-T02B	Not installed	Not installed	Not installed	1,400
SP-T02C	Not installed	Not installed	Not installed	Not detected
SP-T02D	Not installed	Not installed	Not installed	1,100

Units - Picocuries per liter

4.6.2 Extent of Tritium Plume

Figure 4-22 illustrates the extent of the tritium plume. There are monitoring wells that define the upgradient, lateral, and downgradient concentrations. The SP-T02 seep cluster monitors its downgradient extent. The plume extent is adequately characterized.

4.6.3 Tritium Conceptual Model

Tritium is naturally created in the atmosphere or as part of nuclear reactions by adding a neutron to the nucleus of a hydrogen atom (atomic weight of 3). Like non-radioactive hydrogen, the tritium atom readily reacts with oxygen to form tritiated water (water with one hydrogen atom and one tritium isotope). When released into the environment, the tritiated water will behave in the same manner as water. It will percolate through surficial soils down to the bedrock, move with water into bedrock cracks, and then diffuse into the bedrock matrix. The tritium core data illustrates the diffusion of tritium into the bedrock. Tritium will continue to move with the groundwater flow in fractures downward and laterally from the location of release.

Numerous former reactors were located in this area. Tritium impacts from any one of these reactors including Building 4059 may have occurred. It is also possible that tritium could have migrated with groundwater form another source area (Building 4010) during nearby groundwater pumping. It is important to note that the tritium sources, the former reactors have been removed, and the soil tested largely non-detect for tritium. The resulting groundwater impacts will continue to be monitored.

The important property of tritium for fate and transport considerations is its half-life of 12.3 years. Every 12.3 years the concentration of tritium is reduced by one-half. Assuming that the last tritium was produced/released in 1974 with the closure of the Shield Test Radiation Facility (Building 4028), there have been three half-lives for the tritium released at SSFL.

Figure 4-23 illustrates the decay rate for tritium at SSFL as demonstrated in RD-90. The graph illustrates the rate of diminishing concentrations resulting from both its decay rate and diffusion into the bedrock.

<u>Possible Data Gap Activities for Tritium:</u>

Future tritium investigations that are DOE responsibilities are discussed below. To address these data gaps the following activities will be conducted:

- Advance soil boring to confirm or eliminate possible tritium source at RMHF 4614 Hold Up Pond (Tritium Plume). Total depth of soil present at the RMHF Hold Up Pond is assumed to be approximately 20 feet. Soil samples will be collected and screened for radioactivity using field portable instruments. Radioactivity scanning will be used to select up to two soil samples for testing at a laboratory. The boring will be advanced to hollow stem auger refusal. It is assumed that the hollow stem will advance the boring an additional 3 feet into the weathered Chatsworth Formation. If water is available at the bottom of the borehole, a grab water sample will be collected using a bailer. Following collection of the water sample, if available, the soil boring will be abandoned.
- Continue monitoring of tritium in groundwater at RD-96 and RD-97 at 2-year intervals (downgradient of former Building 4059).
- Continue to monitor Tritium Plume wells RD-87, RD-88, RD-89, RD-90, RD-93, RD-94, RD-95, and SP-T02A, SP-T02B, SP-T02C, and SP-T02D at 2-year intervals (Tritium Plume).
- Continue monitoring RD-34A, RD-34B, and RD34C at 2-year intervals (RMHF).
- Continue to monitor off-site wells RD-59A, RD-59B, and RD-59C at 5-year intervals (Off-Site Wells).

4.7 Radioactive Materials Handling Facility

Per the 2007 CO, the RMHF is a DOE responsibility. The RMHF (still in existence) was used for the processing, packaging, and shipping of radioactive materials used and generated in the various nuclear testing facilities within Area IV. The focus of the groundwater investigation at the RMHF is the RMHF leach field (AI-Z5) described below. Other operations at the RMHF do not appear to have impacted groundwater below or adjacent to the facility.

4.7.1 RMHF Operation History

Figure 4-24 illustrates existing features of the RMHF area. The area of interest is the location of the former leach field located north of the RMHF near its eastern edge and the area of grou`ndwater impacted by TCE and Strontium-90 (Sr-90). The leach field was constructed in 1959 for disposal of sanitary wastewater. The leach field was taken out of service for sanitary purposes in late 1961 when the central wastewater treatment facility was installed in Area III; however, it may have still been used for disposal of other liquid wastes generated at the RMHF after that time.

A pipeline directed sanitary effluent from RMHF Buildings 4021 to 4022 to the leach field. This pipeline was also connected to a liquid waste holdup tank in the yard of the RMHF (Rockwell 1982a). The intention of the tank was to hold radioactive liquids until their decay met discharge standards. The tank apparently received liquid containing TCE and Sr-90 wastes with a 28.8-year half-life. At an unknown time (the decontamination report speculates 1963 [Rockwell, 1982b]), liquids from the holdup tank containing Sr-90 wastes were released into the leach field. The release period of wastes with TCE into the leach field is unknown.

Radioactive contamination at the leach field site was discovered in 1975 during routine monitoring in the vicinity of the RMHF when vegetation was observed to be contaminated by radioactivity. In 1978, contaminated soil from the leach field was removed to bedrock and radioactivity that was observed in accessible bedrock was removed by hydraulic hammering the bedrock. During removal of the leach field, concentrations of up to 115,000 picocuries per gram (pCi/g)[1] of Sr-90 were observed in the excavated materials. The environmental report on the removal of the leach field states that after excavation, on average 300 pCi/g of Sr-90 and traces of Cs-137 remained in bedrock cracks.

The environmental report on the removal action states that three bedrock cracks exhibiting radioactive contamination were mapped prior to sealing. The cracks averaged 1.5 inches wide and were 7, 12, and 19 feet in length (Rockwell, 1982b). The environmental report states that several small areas continued to show that radioactive material had penetrated deeper into loosely cemented fractures and uncemented cracks. Removal of rock was performed by the hydraulic hammer and resulted in mining out holes up to 10 feet deep, the assumed depth that the equipment could effectively reach. Following removal of what bedrock material could be excavated, the bedrock was sealed with a bituminous asphalt mastic material and the site backfilled with 10 feet of soil.

4.7.2 Groundwater Monitoring

Monitoring well RD-27 is the only well within the RMHF boundaries. It has not exhibited contamination during its periods of sampling. The other wells associated with the RMHF are in the drainage below the RMHF site.

Groundwater monitoring of Sr-90 activity concentrations has been conducted at several wells near and potentially downgradient of the former RMHF leach field beginning in 1994 in the RD-34 well cluster and more recently in RS-28 and RD-30 (**Figure 4-24**). Activity concentrations have been below the MCL for Sr-90 (8 pCi/L) in all wells, with the exception of RD-98, which is located at the western end of the former RMHF leach field and was drilled in 2008.

---

[1] This is nearly one-half life ago (28.8 years). Concentration today would be expected to be nearly half the concentrations in 1978.

RD-98

Monitoring well RD-98 was drilled at the leach field site in June 2008 (Cabrerra, 2008). Investigative derived waste from the drilling fluids showed 80 pCi/L of Sr-90. RD-98 is an open-hole bedrock boring, cased 0 to 20 feet bgs, with a depth of 65 feet. When sampled first in 2008 and 2009, Sr-90 was below its MCL of 8 pCi/L. However, groundwater surface elevation levels were low at that time. As water levels in the well rose in subsequent years, Sr-90 was detected with concentrations increasing with higher water levels. (**Figure 4-25**, a plot of Sr-90 activity and groundwater elevation in RD-98 over time). The highest concentration of Sr-90 in RD-98, reported by EPA in 2011 (Hydrogeologic, Inc. [HGL] 2012a), was 183 pCi/L also corresponding with the highest groundwater elevation level. With the ongoing drought in southern California, the water table has been dropping along with Sr-90 concentrations. This indicates that remaining Sr-90 at the leach field site is shallow and has not migrated deeply into the bedrock.

RD-98 exhibited 5.6 μg/L TCE when sampled in 2014. It exhibited 10 μg/L when sampled following its installation in 2008.

The nearest downgradient monitoring wells to RD-98 are the collocated wells RS-28 and RD-30. When RS-28 was sampled last in 2008, Sr-90 was non-detect in the well sample. The well casing was then capped and the well not resampled until 2014. The 2014 results show detectable Sr-90 and shallow impacted groundwater may extend to that location. It is suspected that groundwater flow from RD-98 is westward based on observations of TCE in the area. However, an additional monitoring point is needed for groundwater flow control. A new monitoring point is planned north of RD-98 to serve this purpose.

RS-28

Well RS-28 is a 19-foot well installed into weathered bedrock. It was sampled for TCE and Sr-90 periodically until 2008 when it was capped by Boeing. The well was not opened for EPA's groundwater sampling in 2010 and 2011. DOE directed Boeing to reopen the well for the first quarter 2014 sampling event. Sr-90 concentrations were below the detection limit (DL) in well RS-28 when sampled in 2008, but had a value of 2.5 pCi/L in the dissolved phase in 2014.

RD-30

Well RD-30 is a 75-foot deep bedrock well cased and sealed from 0 to 30 feet bgs. It was sampled for TCE and Sr-90 periodically until 2008 when it was capped by Boeing. The well was not opened for EPA's groundwater sampling in 2010 and 2011. DOE directed Boeing to reopen the well for the first quarter 2014 sampling event. Sr-90 concentrations were below the detection limit for all sampling events.

RD-34 Cluster

The RD-34 cluster consists of three co-located wells; RD-34A, RD-34B, and RD-34C. RD-34A is a 320-foot deep bedrock well cased and sealed from 0 to 100 feet bgs. RD-34B is a 415-foot bedrock well cased and sealed from 0 to 360 feet bgs. RD-34C is a 520-foot deep bedrock well cased and sealed from 0 to 480 feet. SR-90 has not been detected in this well cluster and it serves primarily to monitor TCE in groundwater in the vicinity of the RMHF leach field. TCE has been consistently observed in RD-34A, but at concentrations less than its MCL. The first quarter 2014 TCE result was 0.98 μg/L.

RD-34B

RD-34B is a 415-foot deep bedrock well cased and sealed from 0 to 360 feet bgs. RD-34B was last sampled in 2011 with a concentration of 0.7 µg/L TCE being reported. RD-34B has an obstruction at 167 feet bgs preventing access to the screened interval of the well (360 to 415 feet bgs).

RD-34C

RD-34C is a 520-foot deep bedrock well cased and sealed from 0 to 480 feet bgs. TCE has never been reported for RD-34C.

RD-63

Well RD-63, installed in 1994 as an extraction well for TCE[2], is a 230-foot open bedrock borehole, cased and sealed from 0 to 20 feet bgs. The well was pumped periodically for about 10 years, ending in 2005. Drawdown of up to 30 feet was observed in well RD-30 and 6 to 9 feet in RD-19, located to the northeast of RD-98. Previous pumping of well RD-63 may have had a significant impact on hydraulic gradients and groundwater flow directions in the vicinity of the RMHF leach field and may have resulted in preferential migration of TCE contamination in the direction of RD-63 during pumping.

Pumping of RD-63 was initiated in October 1994 and continued periodically until 2005 based on ASER descriptions of that time period. In all, 3.9 million gallons were pumped from the well. The specific objectives of the groundwater extraction for RD-63 are not stated in the documents of the pumping period, but it is assumed that it was in response to the TCE concentrations in RS-28, RD-30, and RD-34A, which were between 47 to 85 µg/L for RS-28, 34 to 44 µg/L for RD-30, and 42 to 82 µg/L for RD-34A for the years prior to the pumping of RD-63. During pumping, TCE in RD-63 ranged 6.2 to 15 µg/L, and was 4.3 µg/L when the pumping ceased. Following pumping, TCE concentrations in RD-63 have ranged from 5.7 to 11 µg/L, and was 6.1 µg/L in February 2014.

A larger change in TCE concentrations was observed in RS-28, RD-30, and RD-34A during and following RD-63 pumping. RS-28 TCE concentrations decreased from 59 to 15 µg/L during pumping, and have hovered around 15 µg/L since. RD-30 TCE concentrations decreased from 34 µg/L to 5.4 µg/L during pumping, and have been between 8.4 and 11 µg/L since pumping. TCE concentrations in RD-34A decreased from 82 µg/L to <1 µg/L during pumping, and have been less than 1.5 µg/L since (non-detect in February 2014).

RD-19

Well RD-19 is a 135-foot deep bedrock well installed upgradient of RD-98. It is screened from 0 to 30 feet bgs. Its response to the pumping of RD-63 indicates that it is hydraulically connected with the RD-98 area.

4.7.3 RMHF Leach Field Conceptual Model

Contamination of the site with Sr-90 originated with discharge of water to the RMHF former leach field. Characterization of the leach field by borings prior to remediation indicated that the highest activity concentrations in leach field gravel and soils were within about 10 feet of the surface and originated from the distribution box and leach lines (Carroll et al., 1982). Materials contaminated with Sr-90 that could be practically excavated were removed during remediation and were replaced with clean fill.

[2] 1995 ASER

Several cracks or fractures were identified during remediation as containing Sr-90 contamination that extended to greater depths. The total Sr-90 activity remaining below the excavated zone was estimated to be about 0.05 Curies, although there is significant uncertainty in this calculated estimate (Tuttle, 1978). Elevated Sr-90 activity was observed in the cracks and the adjoining rock, with estimated specific activity of 200 to 1,000 pCi/g. The vadose zone below the RMHF former leach field is the principal remaining source of Sr-90 at this location, with contamination existing in the fracture zones and the sandstone matrix of the Upper Burro Flats Member. Sr-90 is released to groundwater by recharge from downward percolating infiltration or by direct contact with contaminated rock when the water table rises by as much as 25 feet (**Figure 4-25)**.

Shallow soils contaminated with Sr-90 in the area of the RMHF former leach field may be secondary, minor sources of Sr-90 to groundwater via recharge by infiltration from the surface. Soil samples collected by EPA with Sr-90 activity above the DL, ranging from 0.489 to 14.3 pCi/g, were obtained at nine locations at and to the west of the RMHF former leach field (HGL, 2012a). One soil sample from the slope to the north of the RMHF had a Sr-90 activity of 28.1 pCi/g (Boeing, 2006). The source of the Sr-90 contamination in these soils is not clear, but their spatial distribution suggests that material or runoff from remediation operations at the RMHF former leach field may have inadvertently spread this contamination. Records indicate that the leach field was excavated during the rainy season with intense rain storms, and that there were difficulties controlling surface water flow through the excavation site.

The wells shown in **Figure 4-26** and the shallow groundwater flow system in this area are located in the Upper Burro Flats Member of the Chatsworth Formation. Groundwater flow occurs primarily in fractures within the relatively low-permeability sandstone rock matrix. Finer-grained beds within the Upper Burro Flats Member may result in horizontal anisotropy in permeability and reduce vertical groundwater flow. The ELV fine-grained member of Sandstone 2 at the base of the Upper Burro Flats Member constitutes a major aquitard that isolates the shallow groundwater flow system from the underlying sandstone aquifers in the Chatsworth Formation.

The shallow horizontal groundwater hydraulic gradient in the area of the RMHF former leach field is generally to the northwest. However, several east-west or east-southeast/west-northwest striking contaminated cracks or weathered fractures observed in the bedrock during excavation of the former leach field (Carroll et al., 1982) may impart anisotropic permeability in the fractured sandstone resulting in more westerly groundwater flow at the RMHF relative to the more regional hydraulic gradient. Lineaments on aerial photography, observations at the Sodium Reactor Experiment (SRE) site, and the east-west alignment of the surface water drainage to the north of the RMHF former leach field also suggest the presence of east-west oriented fractures in the bedrock in this vicinity (**Figure 4-26**). Water-level differences in the RD-34 well cluster suggest a small downward vertical hydraulic gradient in the shallower part of the Upper Burro Flats Member and a moderate upward hydraulic gradient between the lower and upper strata of the Upper Burro Flats Member.

Groundwater levels vary significantly in wells near the RMHF former leach field, with shallower wells showing greater variability than deeper wells. Increased head roughly correlates with monthly precipitation totals, particularly in the wettest months in which precipitation totals exceed about 6 inches. Well RD-98 with water level differences of about 23 feet between 2008 and 2014 shows somewhat less variability than well RD-34A with about 28 feet maximum difference in water levels over the same period. These patterns indicate that recharge is occurring to the shallow bedrock groundwater system in response to large precipitation events.

Recharge to the shallow groundwater flow system occurs by infiltration in outcrops of the Upper Burro Flats Member and overlying unconsolidated soils. During operation of the RMHF leach field, significantly enhanced percolation occurred from water discharged to the leach field. Following remediation of the former leach field, recharge in the major bedrock fractures may have been reduced in this area, although the effectiveness of the emulsified asphalt in reducing downward percolation is difficult to assess. In addition, the asphalt sealing may have reduced effectiveness over time due to microbial degradation of the asphalt. Downward percolation of water occurs primarily within fractures in the sandstone bedrock of the vadose zone, but is modulated by imbibition of liquid water into the unsaturated rock matrix from fractures. Enhanced recharge occurs at the bottom of the surface drainage channel to the north of the former leach field during larger precipitation events that result in surface water flow.

4.7.4 Contaminant Transport Processes

Sr-90 is moderately to highly soluble in groundwater relative to many other radionuclides and its transport is governed by several processes, including advection, dispersion, radioactive decay, diffusion, sorption, and potentially colloid-facilitated transport. Advective transport in the saturated zone of the Upper Burro Flats Member is primarily in the fracture network of the sandstone. Groundwater contamination by Sr-90 is spread in the longitudinal and transverse directions by hydrodynamic dispersion within fractures and at fracture intersections. Radioactive decay reduces the activity and mass of Sr-90 in the groundwater system in a predictable way with a half-life of 28.8 years.

Diffusion of dissolved Sr-90 from the groundwater in fractures into the sandstone rock matrix retards transport relative to advective transport in the fracture network. Diffusive mass transfer between the fractures and the rock matrix is a function of groundwater specific discharge, fracture aperture, fracture spacing, matrix diffusion coefficient, matrix porosity, and sorption coefficient in the matrix. In general, the effectiveness of matrix diffusion as a retardation mechanism in groundwater transport increases with transport distance and time from the source. Sorption onto the rock matrix also enhances diffusive mass transfer into the matrix and increases effective retardation for Sr-90 in the groundwater system.

Strontium is a moderately sorbing solute in most geologic media and achieves an equilibrium distribution between aqueous and solid phases. A compilation of measurements of sorption coefficient for 63 soils indicates a median value of 15 milliliters per gram (mL/g) and a highly skewed distribution that extends to very large values for some samples (EPA, 1999). Sr-90 is subject to sorption via mineral surface complexation and ion exchange with some clay minerals; both of these reversible processes likely contribute to sorption and retardation of Sr-90 in sandstone of the Upper Burro Flats Member. Even moderate sorption of Sr-90 in the rock matrix results in significant retardation in transport in the groundwater system, assuming matrix diffusion provides access to the sorptive capacity of the sandstone matrix.

Colloid-facilitated transport occurs when a contaminant is carried by colloids at a rate faster than it would be by groundwater alone. Such enhanced groundwater migration has been observed in natural systems for highly sorbing radionuclides, such as plutonium (e.g., Kersting et al., 1999). Groundwater colloids are particles smaller than 10 microns and may consist of various minerals or organic macromolecules. Potentially important processes for colloid-facilitated transport include sorption of Sr-90 onto colloids, advective transport of colloids, sorption and cation exchange on the sandstone matrix, filtration of colloids, and retardation of colloids. The concentration of natural colloids in groundwater can be readily measured and would provide one measure of the potential for colloid-facilitated transport. However, evaluating sorption of Sr-90 onto colloids and filtration/retardation of colloids in the groundwater flow system are more difficult and costly measurements. The sorption coefficient for colloids may be large relative to aquifer material due to the large surface area to mass ratio of colloidal particles. In equilibrium, sorption onto colloids is in balance with sorption (or cation exchange) onto the aquifer medium. Slow desorption kinetics from colloids may lead to non-equilibrium chemical conditions and enhanced colloid-facilitated contaminant transport, particularly over short transport distances and time scales (Turner et al., 2006). Colloids are subject to mechanical filtration, which may permanently remove them from groundwater, and to retardation by electrostatic attachment to mineral surfaces in the sandstone.

The potential for significant colloid-facilitated transport of Sr-90 is related to the concentration of groundwater colloids, the sorption coefficient onto colloids, desorption kinetic rates, colloid velocities, and colloid retardation. Although extensive research on colloid-facilitated transport processes has been conducted, predicting such transport at the field scale remains uncertain because of the complex interaction among these factors. However, the general conclusion is that the greatest potential for colloid-facilitated transport of radionuclides is for highly sorbing elements, such as plutonium, americium, and cesium. Sr-90 has a low potential for significant colloid-facilitated transport relative to these more highly sorbing species. For example, the groundwater transport modeling for the safety assessment of Yucca Mountain included colloid-facilitated transport of plutonium, americium, thorium, protactinium, and cesium, but not strontium (Zyvoloski, et al., 2003).

4.7.5 Projected Future Migration of Sr-90

Future groundwater migration of Sr-90 in the area of the RMHF former leach field will be limited by the location of the primary source in the vadose zone, diffusion into the sandstone rock matrix, sorption of Sr-90 in the matrix, and radioactive decay. Rise in the water table associated with high precipitation appears to leach Sr-90 from the vadose zone, but subsequent fall in the water table reduces the rate of release to the groundwater system resulting in lower Sr-90 activity concentrations in well RD-98. Sr-90 that is released to groundwater is subject to retardation by matrix diffusion and sorption along transport pathways in fractures downgradient of the RMHF former leach field. The apparent retention of Sr-90 in the vadose zone below the former leach field demonstrates the effectiveness of these processes in retarding Sr-90 migration. Radioactive decay of Sr-90 in the source zone and in the groundwater system reduces activity concentrations with a 28.8-year half-life. Colloid-facilitated transport of Sr-90 is unlikely to have a significant impact on migration in groundwater. Overall, Sr-90 contamination in the groundwater is projected to present limited risk beyond a local area near the RMHF former leach field or for periods beyond several half-lives of Sr-90 (i.e., greater than about 100 years).

Groundwater migration of Sr-90 could be assessed and/or mitigated at various levels of effort, ranging from monitoring alone to active measures aimed at reducing Sr-90 concentrations in groundwater.

Monitoring for Sr-90 concentrations is already conducted at wells RD-30, RS-28, RD-63, and the RD-34 cluster to the west of RD-98 and the RMHF former leach field. These monitoring locations are consistent with the conceptual model that groundwater flow occurs preferentially in a westerly direction due to fractures oriented in that direction. An additional well could be added to the monitoring system to the northwest of RD-98, which would assess potential migration of Sr-90 in the direction of the hydraulic gradient, independent of the apparent fracture orientations. Monitoring would also continue at well RD-98 to assess the contaminant concentrations directly beneath the source.

<u>Possible Data Gap Activities for the RMHF:</u>

Future work at the RMHF Leach field groundwater investigation area is a DOE responsibility. Sr-90 is moderately soluble in water compared with other radionuclides. The downgradient extent of Sr-90 and TCE has not been delineated and the direction of groundwater flow is not well defined. The groundwater surface elevation map indicates that groundwater flow in the area is to the northwest. However, the migration of TCE indicates flow in the area is to the west. To address these data gaps the following activities will be conducted:

- An additional monitoring well northwest of RD-98 will be installed to provide groundwater flow control
- The new well will be sampled for VOCs and Sr-90
- Continue sampling RD-98, RS-28, RD-30, RD 34A, and RD-63 for TCE and Sr-90 on an annual basis
- Collect and sample water from above the obstruction in well RD-34B. Detailed investigation of RD-34B shows the obstruction at 167 feet bgs and prevention of access to the screened interval of the well (360 to 415 feet bgs). A modification of the Site-Wide Quality Sampling Plan will be required to address this pumping interval configuration.

The following information was used to determine the depth of the new Chatsworth Formation monitoring well.

- Current purposed location (See Figure 9-1)
- Elevation at purposed location (1,830 feet above MSL)
- Strike and dip of sandstone beds are locally variable, but typically strike N70°E and dip 25° - 35° to the northwest (does not consider effect of SRE/RHMF lineament)
- Groundwater interval of interest is 1,645 (RD-98 TCE contamination detected in open borehole of 1,744 below MSL and dip of beds)

The new monitoring well will be drilled to a total depth of 185 feet at this proposed location. This well will fill the following data gap.

- Provide TCE and Sr-90 concentration data and bound the plume's northern extent
- Evaluate the presences/absence of the SRE/RHMF lineament
- Provide groundwater elevation data in the Chatsworth Formation

4.8 Old Conservation Yard

The OCY is a DOE responsibility per the 2007 CO. The OCY groundwater investigation area is approximately 10 acres located along a ridge in the northernmost part of Area IV. Several separate former storage areas and debris disposal areas are included in the OCY investigation area (**Figure 4-27**). Groundwater is monitored by one Chatsworth Formation monitoring well, RD-14, and a 700-foot deep former water supply well, WS-07. Historically, TCE has been detected in both wells. PZ-151, located on the easternmost edge of Area IV, about 450 feet from RD-14 and outside of the OCY, was installed to monitor a TCE plume in the National Aeronautics and Space Administration (NASA)-administered Area III.

4.8.1 Operation History

The OCY was used from 1952 to 1977 to store salvageable materials (metal parts and equipment) from Area IV operations. Typically the materials were stored in drums (MWH, 2006b). In 1987 the stored materials were moved to the NCY and the OCY was then used for storage by the Plant Services (MWH, 2006b). From 1986 to the late 1990s the OCY was used by the SSFL transportation department as a storage area for trailers and containers. All buildings and most other features have been removed from the groundwater investigation area.

The former storage areas and other features that could have been sources of contamination are shown on **Figure 4-27** and include:

- Former Rocketdyne Conservation Yard – used for storage of salvageable materials and drums of unknown contents. Chlorinated solvents were detected in soil vapor in 1997, but have not been found in soil. Some SVOCs were detected in the surface soil of the southwest corner of the yard. No metals-contaminated soil was detected (MWH, 2006b). Cs-137 contaminated soil was found in a 400-square-foot area in the southwest corner of the Rocketdyne Conservation Yard in 1988 (Rockwell, 1990); the contamination was remediated in 1989.

- Former Atomic International (AI) Conservation Yard – used for storage of salvageable materials and drums of unknown contents. Most of the yard is covered with asphalt-aggregate material. 2-butanone (11 μg/kg) was detected in shallow soil (MWH, 2006b).

- Former Northern Storage Area – used for storage of equipment and materials; some storage was likely in drums (MWH, 2006b). No VOCs were detected in soil or soil vapor.

- Former Container Storage Area – Containers were stored on an asphalt road after the fuel farm was constructed in 1977. The area is divided by a north-south running drainage ditch. The area is also located near the former SRE Pond drainage pipeline. No VOCs were detected in this area.

- Former Aboveground Storage Tanks (ASTs) 732 and 731 and Earthen Berms – Between 1952 and 1977 the area was used for storage of drums of unknown contents. In 1981, two 1.5-million-gallon ASTs were constructed for storage of diesel fuel. The ASTs were removed in 1999 and the berm was leveled over the area in 2002. No VOCs were detected in soil (MWH, 2006b).

- Former Building 320 Fueling Area – used to transfer diesel fuel from trucks to the ASTs 731 and 732, the fueling area included a UST, UT-28 (closed in 1994). The area also includes a concrete ditch and diesel pipeline. Methylene chloride, toluene, and acetone have been found in soil (MWH, 2006b).

- SRE Pond Discharge Pipeline – diverted water from the SRE Pond to Silvernale Reservoir. During the RFI, acetone was detected in soil beneath the pipeline although it was not considered site-related contaminant (MWH, 2006b).
- Former Telephone Pole Storage Area – used for wooden telephone pole storage. During the RFI, some poles were observed to have been charred; all poles were removed in 2000. Soil samples were not analyzed for VOCs during the RFI (MWH, 2006b).
- Northern Debris Area – used as a construction debris (metal, wood roofing material, and asbestos-containing material) disposal area. The debris was burned prior to disposal. No VOCs were found in soils.
- Southern Debris Area – Similar to the Northern Disposal Area, construction debris was disposed in this area. One 55-gallon drum of unknown contents was found. No VOCs were found in the soil.
- North Slope Debris Areas A and B – This debris area was found after the 2005 Topanga Fire. The debris, located in a steep natural drainage, included metal, crushed drums, 5-gallon drums, and graphite cylinders. 4-isoproyltoluene (1.9 µg/kg) was found in soil during the RFI (MWH, 2006b).
- Several transformer areas – Soil samples were not analyzed for VOCs.
- Topographic Low Spot and Downslope Discharge Area – the area collects surface run-off from other debris and storage areas in OCY. Soil samples were not analyzed for VOCs.

4.8.2 Soil, Geology, and Hydrogeology

Unconsolidated materials in the OCY groundwater investigation include native soil and fill placed in various building excavations during demolition. Native soils are relatively thin and are estimated to be up to 10 feet thick.

There is no near-surface or perched groundwater in the OCY, although there may be perched groundwater at some times in PZ-151, located at the eastern edge of Area IV about 450 feet east of RD-14. The two existing OCY monitoring points, RD-14 and WS-07, are screened in different depths and different geologic units. RD-14 is open from 30 to 125 feet in the Upper Burro Flats Member of the Chatsworth Formation.

WS-07 is a deep (700 feet) well installed in 1954. WS-07 is open across the lower part of the Lower Burro Flats Member, completely across the SPA fine-grained member of Sandstone 2 and the upper part Silvernale Member. From 1955 to 1959 the well supplied between 0.31 and 4.35 million gallons of water a year. Water levels in WS-07 are generally higher than those in RD-14 indicating a northerly component to groundwater flow; however, the high potentiometric surface in WS-07 may be due to confinement by the ELV fine-grained member of Sandstone 2.

MWH (2014b) collected three soil vapor samples in the southern part of the OCY (6SV_DG-543, 6SV_DG-544, 6SV_DG-551). Benzene at 0.00871 µg /L was the only VOC reported (DG-551, **Appendix Figure A-5**).

4.8.3 Extent of Contamination

TCE was detected in RD-14 when the well was first sampled in 1989; the highest detected concentration was 13 µg /L in 1990. From 1992 to 2010, the concentration of TCE in RD-14 was below the MCL of 5 µg/L. Following a single report of 5.9 µg/L in 2011, concentrations have decreased to below DLs (first quarter of 2014). The concentration of *cis*-1,2-DCE, the anaerobic dechlorination daughter product of TCE, peaked at a concentration of 2.6 µg/L in early 1992, shortly after the peak TCE concentration.

Water supply well WS-07 was first sampled in August of 1985 and TCE was detected at a concentration of 1.2 µg/L, below the MCL of 5 µg/L. This was the highest concentration of TCE that was detected in the 17 samples collected between August of 1985 and March of 1992.

4.8.4 Conceptual Site Model

Very low levels of some VOCs have been detected in the soil and soil vapor of limited areas of the OCY. The low concentrations found in soil vapor and soil measured prior to 2014 are not indicative of a continuing source of groundwater contamination. This lack of a source is supported by the fact that concentrations of TCE in both wells decreased through time. In RD-14, the presence of *cis*-1,2-DCE indicates the potential anaerobic dechlorination of the TCE.

The TCE found in the wells was likely the result of a spill or leak in the soil at the OCY. The TCE would have dissolved in, and migrated through, the soils and weathered bedrock, with infiltrating precipitation until it reached the water table within fractures of the bedrock. The presence of an actively pumping well (WS-07) may have pulled TCE-contaminated groundwater downward in the OCY or laterally from areas beyond the OCY. When the pumping stopped in 1959, the groundwater would have returned to static conditions with an upward vertical gradient and northward horizontal gradient.

<u>Possible Data Gap Activities for OCY:</u>

- No further investigation or monitoring is warranted at the OCY groundwater investigation area as concentrations of contaminants are below MCLs and, with one spurious exception, have been for many years.
- Water levels should be measured at RD-14 to be used with data from other site wells in producing accurate potentiometric surface maps.

4.9 Metals Clarifier Laboratory Building 4065/ DOE Leach Fields 3

The Metals Clarifier Laboratory Building 4065 and DOE Leach fields 3 are DOE responsibilities. DOE Leach fields 3 RFI site includes four leach fields, associated with Buildings 4353 (AI-Z15), 4363 (AI-Z14), 4373 (AI-Z13), and 4383 (AI-Z10). They are combined as one groundwater investigation area due to the overlap of the monitoring well network. The Metals Clarifier/DOE Leach fields 3 groundwater investigation area is approximately 20 acres in the central part of Area IV that includes the former location of the Building 4065 Metals Laboratory Clarifier and several former buildings in the DOE Leach fields 3 RFI site where TCE may have been used and released to the environment. There are no monitoring wells open in the consolidated Chatsworth Formation in the Metals Clarifier /DOE Leach fields 3 groundwater investigation area; however, there are four piezometers, PZ-005, PZ-103, PZ-104, and PZ-105, located immediately downgradient of the metals clarifier (PZ-005) and the potential leach field source areas (PZ-104 and PZ-105) (**Figure 4-28**) that are screened in the weathered bedrock.

4.9.1 Operation History

Constructed in 1963, Building 4065 was used as a vacuum test facility until 1972. From 1973 until it was demolished in 1999, the building was used as the Chemical and Metallographic Analysis Laboratory. During the RFI, Building 4065 was identified as an Area of Concern (AOC). Chemical usage was reported to be compressed gases, solvents (including acetone, 1,1,1-TCA, and TCE), acids, bases and metals, and kerosene. Metals preparations were conducted under large fume hoods. The fume hoods channeled fluids to a 3-stage clarifier located on the south side of the building via below-grade pipes within a concrete trench. The clarifier was approximately 4 by 12 feet long and 6 feet deep; discharge was piped underground to a Sewage Treatment Plant in Area III.

Other buildings where chemicals may have been used include:

- Building 4062 was used for non-nuclear reactor qualification testing, storage, and instrument calibration.
- Building 4066 was an instrument repair and calibration and testing of non-nuclear material.

The facilities included one AST used for liquid nitrogen, two ASTs were used for water, and two USTs were used for generator petroleum fuel storage. Soil sampling and analyses conducted during the RFI did not identify any impacted soils associated with these fuel tanks.

All of the buildings have been demolished and removed and all ASTs and USTs have been removed. The clarifier was removed in 2000 (CH2M Hill, 2008).

DOE Leach fields 3 RFI site includes four leach fields, associated with Buildings 4353 (AI-Z15), 4363 (AI-Z14), 4373 (AI-Z13), and 4383 (AI-Z10) (**Figure 4-28**). For the purposes of the RFI each of these leach fields were considered to be an AOC. The RFI site also included 31 former and existing buildings, 12 ASTs, and 9 USTs. The facilities located in the site supported the SNAP and SRE programs from the 1950s through the 1970s, and development and testing of large sodium pumps during the mid-1970s through 2001. Two of the USTs used for fuel oil were removed (one in 1986 and the other in 1999); evidence of a fuel oil leak was found in soil at tank UT12 (UT-55), and metals contamination was found in soil at UT-72. A third fuel oil tank (UT-75) was removed in 2001; no contamination was associated with this tank. No spills of TCE were documented in the RFI, although ethanol (1995) and isopropanol or denatured ethanol (1982) spills occurred at Building 4462.

The buildings associated with the leach fields included the following:

- Building 4353 – Used for sodium mass transfer studies, in the 1960s, and later as a research and development laboratory and general storage. No VOCs were reported to have been used in the building. The leach field, located east of the building, received sanitary wastes (CH2M Hill, 2008). No VOCs were found in soil vapor samples collected in 1993 or in soil samples collected in 2001.
- Building 4363 – Used as a metallurgical research and development laboratory for post-test examination of SRE components. The building was the Mechanical Component Development and Counting Building, also used for sodium systems in support of SRE (1957-1963). From 1963 until it was demolished in 2001, the building was primarily used for storage. No VOCs

were detected in the two soil vapor samples and no soil samples were collected in the RFI. The building was connected to a leach field located southwest of PZ-105. The leach field received sanitary wastes from a 1,500-gallon septic tank.

- Building 4373 – High-energy rocket fuels were manufactured in this building from 1954 to 1956. From 1957 to 1963 it was used for conducting SNAP reactor criticality tests. In 1960 the building was used for a sodium heat transfer facility and after 1964 the building was used for storage of heat transfer equipment. Solvents were used in the building; however, no VOCs were detected in soil vapor, and no soil samples were collected during the RFI. Building 4373 leach field, located south of the building, and received sanitary wastes from a septic tank (CH2M Hill, 2008).

- Building 4383 – From sometime after 1963 to the early 1980s, the building was used as "Instrumentation Building" and "Assembly and Testing Building." It also was the Liquid Metal Engineering Center Assembly and Testing and Construction Staging building. Solvents were used in Building 4383, but no VOCs were detected in two soil vapor samples and no soil samples were analyzed for VOCs during the RFI (CH2M Hill, 2008).

Other buildings where solvents were reported to have been used include:

- Building 4020 – The Rockwell International Hot Lab, used for examination and preparation of irradiated nuclear reactor fuel and for decladding, cleaning, and reprocessing/repackaging of nuclear fuel from 1959 through 1987. Chemical uses within the Hot Lab included solvents, SVOCs, PCBs, and metals. Building 4020 also had a leach field (AI-Z12). Piezometer PZ-103 is situated between Buildings 4020 and 4055; it has exhibited low concentrations (<5 µg/L) of TCE.

- Building 4055 – Used as the Nuclear Materials Development Facility and included chemistry laboratories. Solvents were used in this building and benzene and toluene were detected in soil vapor. Although no TCE was detected in soil samples, the DLs for TCE were high in the soil samples and could have masked the presence of TCE and other VOCs. Fuel oil tank UT-55 was located at this building.

- Building 4374 – From 1956 to 1999 the building was used for testing non-nuclear liquid metal heat transfer loops. Solvents were used, but no VOCs were detected in the one soil vapor and one soil samples that were collected for the RFI (CH2M Hill, 2008).

- Building 4462 – Building 4462 is the Sodium Pump Test Facility. No solvents were reported to have been used in Building 4462. VOCs were detected in one soil sample collected during the RFI, but concentrations were below the RFI screening criteria.

- Building 4463 – used as a sodium cleaning and handling facility.

All the buildings were connected to a sewer system in 1961 and the leach fields were removed between 2000 and 2002. All buildings except Buildings 4055, 4462, and 4463 have been removed.

4.9.2 Soil, Geology, and Hydrogeology

Soil thickness in the Metals Clarifier/DOE Leach fields 3 groundwater investigation area is estimated to be up to 20 feet in depth. The majority of the groundwater investigation area is within the Lower Burrow Flats Member of the Chatsworth Formation, although the far southeast corner of the investigation area is underlain by the fine-grained SPA fine-grained member of Sandstone 2 and Silvernale Member of the Chatsworth Formation. The strata in this area strike about N70˚E and dip about 25 degrees northwest. This configuration brings the fine-grained SPA fine-grained member of Sandstone 2 dipping beneath the site, at a depth of about 55 feet in the area of PZ-105.

All four piezometers (PZ-005, PZ-103, PZ-104, and PZ105) in the groundwater investigation area are screened in the near-surface groundwater within the weathered bedrock. The potentiometric surface within that aquifer shown on **Figure 2-29** is drawn from July 2013 data from these three piezometers as well as PZ-103, located just northeast of the Rockwell International I Hot Laboratory (RIHL). The groundwater flow directions indicated by the potentiometric surface is southeast (in the northern part of the investigation area), east (in the central part of the investigation area), and northeast (in the southern part of the investigation area). The more regionally drawn (site-wide) potentiometric surface map of the near-surface groundwater presented in the 2009 Groundwater RI (MWH, 2009) indicates a more southeasterly groundwater flow direction in the southern part of the investigation area. There are no monitoring wells installed in the unweathered Chatsworth Formation in the investigation area. However, a comparison on the 2009 site-wide potentiometric surface maps for the near-surface groundwater and the unweathered Chatsworth Formation groundwater indicates a downward vertical gradient.

4.9.3 Extent of Contamination

Relatively low concentrations (at or less than 12 µg/L) of TCE have been detected in PZ-005, PZ-104, and PZ-105 since 2000 (PZ-005) and 2002 (PZ-104 and PZ-105) when they were installed. Piezometers PZ-005 and PZ-104 were sampled and analyzed for VOCs once or twice in the years immediately following their installation, and again once or twice in 2013 and 2104. PZ-105 was sampled twice following installation in 2002 and the seven more times between 2008 and 2014. The analytical results for TCE are plotted on **Figure 4-28**. In each case the concentrations of TCE have decreased in the years since sampling first started. As of early 2014 concentrations at PZ-005 and PZ-104 are below the MCL of 5 µg/L; the concentration in PZ-105 was 8.7 µg/L in early 2014.

In all, MWH collected 24 soil vapor samples within this groundwater investigation area (**Appendix Figure A-2 and A-6**). Soil vapor samples were collected from 5CSV_DG-505, 5CSV_DG-507, 5CSV_DG-508, 5CSV_DG-516, 5CSV_DG-518, 5CSV_DG-528, 5CSV_DG-535, 5CSV_DG-543, 5CSV_DG-545, and 5DSV_DG-502, 5DSV_DG-510, 5DSV_DG-511, 5DSV_DG-512, 5DSV_DG-513, 5DSV_DG-515, 5DSV_DG-516, 5DSV_DG-519, 5DSV_DG-526, 5DSV_DG-530, 5DSV_DG-531, 5DSV_DG-532, 5DSV_DG-536, 5DSV_DG-539, 5DSV_DG-544. The only reported VOCs are those described below.

MWH (2104b) collected a soil vapor sample at the location of former Building 4065 (5CSV_DG-543) and reported 0.19 µg/L of TCE. MWH reported 0.021 µg/L of PCE and 0.034 µg/L of TCE in the soil vapor sample collected in 5CSV_DG-516, at former leach field AI-Z10. MWH reported 0.0098J µg/L of PCE in soil vapor sample 5CSV_DG-511 near the Boeing Area III EEL facility. There were no VOCs detected in soil vapor samples collected at former leach fields AI-Z13 (5DSV_DG-530), AI-Z14 (5DSV-DG-539), and AI-Z15 (5DSV_DG-532).

4.9.4 Conceptual Site Model

The sources of low-level TCE contamination in the near-surface groundwater in the Metals Clarifier/DOE Leach fields 3 groundwater investigation area are uncertain, although the source of contamination in PZ-005 is very likely the Metals Clarifier. As shown on **Figure 4-28**, there were multiple potential sources of TCE located upgradient of PZ-104 and PZ-105, including Building 4065 and leach field AI-Z10. TCE was not detected in soils in these potential source areas although the analytical DLs of samples collected at Building 4055 were high, potentially masking the presence of TCE. Building 4055 is upgradient of both PZ-104 and PZ-105. The metals clarifier and all the leach fields were removed in the period between 2000 and 2002, removing those potential sources. Buildings 4462, 4463, and 4055 remain in place.

TCE in soils would enter the near-surface groundwater via dissolution in infiltrating precipitation. Note that the low levels found in the groundwater are several orders of magnitude lower than those indicative of a significant release. TCE discharged into the relatively shallow leach fields also may have volatilized, migrating upward and discharging in the vapor phase to the atmosphere. Once in the near-surface groundwater, TCE would migrate with groundwater flow, diffusing into the weathered rock matrix and potentially undergoing reductive dechlorination. The ORP measured during the 2013 groundwater sampling indicated that groundwater is under reducing conditions. The presence of sanitary leach field may have contributed to generating those conditions. Although there are downward vertical gradients in the Metals Clarifier/DOE Leach fields 3 groundwater investigation area, migration of TCE to the unweathered Chatsworth Formation groundwater would be expected to be minimal due to the low initial concentrations, the diffusion of TCE into the weathered rock matrix, and the presence of the underlying fine-grained SPA fine-grained member of Sandstone 2 of the Chatsworth Formation. In general, at those Area IV locations where TCE has been found in the unweathered Chatsworth Formation wells concentrations in the near-surface groundwater are higher. Thus, if TCE is present in the unweathered Chatsworth Formation groundwater it is likely to be at concentrations even lower than those found in the near-surface groundwater.

<u>Possible Data Gap Activities for Metals Clarifier/DOE Leach fields:</u>

- Given the generally low concentrations of TCE found in the near-surface groundwater, the existing near-surface groundwater monitoring well network is considered adequate to monitor the Metals Clarifier/DOE Leach fields 3 TCE plume. Continued annual monitoring of TCE and other VOCs in PZ-005, PZ-104, and PZ-105 is recommended. Less frequent monitoring is recommended for PZ-005 and PZ-104 if TCE concentrations remain below the MCL of 5 µg/L.

- An additional monitoring well located near PZ-104 will be installed to provide TCE concentrations and provide additional groundwater elevation and flow data in the Chatsworth Formation.

The following information was used to determine the depth of the new Chatsworth Formation monitoring well.

- Current purposed location (See Figure 9-1)

- Elevation at purposed location (1,797 feet above MSL)

- Strike and dip of sandstone beds of N70°E and dip 25° to the northwest

- Groundwater interval of interest is first water present above the fine-grained SPA fine-grained member of Sandstone 2

The new monitoring well will be drilled to a total depth of 150 feet at this proposed location. This well will fill the following data gap.

- Provide TCE concentration data in the central portion of the plume

- Bound the plume's vertical extent
- Provide groundwater elevation data in the Chatsworth Formation

4.10 Leach Fields

The 2007 CO lists 17 leach fields within Area IV as AOCs. One leach field, Building 008 Warehouse, was determined to have been misidentified in the RCRA Facility Assessment (RFA). Nine of 13 leach fields under DOE's responsibility fall within the geographic boundaries of one of the groundwater investigation areas described in Sections 4.1 through 4.9. Four are Boeing responsibilities and are not discussed herein. The status of groundwater investigations at the remaining three leach fields (AI-Z2 Building 4064, AI-Z3 Building 4030, and AI-Z4 Building 4093) are described below. **Table 4-3** lists the leach fields, as described in the 2007 CO, and the groundwater investigation area where the leach field is located. **Table 4-4** lists where in this Work Plan the leach fields are discussed. Impacts to groundwater from the leach fields will be evaluated in the RFI Report through evaluation of all the data from the associated groundwater investigation area. Note that the 2007 CO lists an additional leach field that had been identified as an AOC (Building 008 Warehouse), but also includes a comment that it had been incorrectly listed in the RFA as a leach field. The Building 008 Warehouse is not included on **Table 4-3**.

Table 4-3 Cross Reference of Leach fields with 2007 CO

2007 CO Leach field Identifier	Groundwater Investigation Area
AI-Z1, Building 003	SRE i(Boeing)
AI-Z2, Building 4064	Building 4064
AI-Z3, Building 4030	Buildings 4030/4093 Leach fields
AI-Z4, Building 4093	Buildings 4030/4093 Leach fields
AI-Z5, Building 4021	RMHF
AI-Z6, Building 4028	Tritium Plume
AI-Z7, Building 4010/012	Tritium Plume
AI-Z8, Building 4005/006	PDU being addressed by Boeing
AI-Z9, Building 4011	Southeast Drum Storage Area (Boeing)
AI-Z10, Building 4383	
AI-Z11, Building 4009	
AI-Z12, Building 4020	
AI-Z13 Building 4373	
AI-Z14 Building 4363	
AI-Z15 Building 4353	

Notes:
CO – Consent Order
SRE – Sodium Reactor Experiment
HMSA – Hazardous Materials Storage Area
RMHF – Radioactive Materials Handling Facility
PDU – Process Development Unit

Table 4-4 Area IV Leach fields and Associated Groundwater Investigation Areas

2007 CO for Corrective Action Description	Groundwater Investigation Area, GW RI Work Plan Section
AI-Z1, Building 003	SRE is being addressed by Boeing
AI-Z2, Building 4064	Building 064 Leach field GW RI Work Plan Section 4.10.1
AI-Z3, Building 4030	Buildings 4030 and 4093 Leach fields, GW RI Work Plan Section 4.10.2
AI-Z4, Building 4093	Buildings 4030 and 4093 Leach fields, GW RI Work Plan Section 4.10.2
AI-Z5, Building 4021	RMHF, GW RI Work Plan Section 4.7

Table 4-4 Area IV Leach fields and Associated Groundwater Investigation Areas

2007 CO for Corrective Action Description	Groundwater Investigation Area, GW RI Work Plan Section
AI-Z6, Building 4028	Tritium Plume, GW RI Work Plan Section 4.6
AI-Z7, Building 4010/012	Tritium Plume, GW RI Work Plan Section 4.6
AI-Z8, Building 4005/006	PDU being addressed by Boeing
AI-Z9, Building 4011	Southeast Drum Storage Area is being addressed by Boeing
AI-Z10, Building 4383	Metals Clarifier, GW RI Work Plan Section 4.9
AI-Z11, Building 4009	Buildings 4100/4009 are being jointly addressed with Boeing
AI-Z12, Building 4020	Metals Clarifier, GW RI Work Plan Section 4.9
AI-Z13 Building 4373	Metals Clarifier, GW RI Work Plan Section 4.9
AI-Z14 Building 4363	Metals Clarifier, GW RI Work Plan Section 4.9
AI-Z15 Building 4353	Metals Clarifier, GW RI Work Plan Section 4.9

Notes:
CO – Consent Order
GW RI – groundwater remedial investigation
SRE – Sodium Reactor Experiment
RMHF – Radioactive Materials Handling Facility
HMSA – Hazardous Materials Storage Area
PDU – Process Development Unit

4.11 Building 4064 Leach Field

The Building 4064 Leach field is a DOE responsibility per the 2007 CO. The Building 4064 Leach field (AI-Z2) is located about 20 feet northeast of Building 4064 in the northern part of Area IV. Chatsworth Formation groundwater in the vicinity of the leach field is monitored with RD-92. The building, leach field, and well are shown on **Figure 4-30**.

4.11.1 Operation History

Building 4064 was constructed in 1958 and was the former Nuclear Materials Storage Facility. Packaged source material (depleted uranium and thorium) and nuclear material (enriched uranium-233) were stored in the building. There were no process buildings or sinks. There was no reported chemical use in Building 4064 (MWH, 2006b). There were three documented incidents of radiological contamination release at Building 4064:

- In 1963, an area of Cs-137 and Cs-134 contaminated soil and concrete was discovered. The source was suspected to have been a leaking drum of irradiated fuel pins and contaminated soil.
- In 1964, a can of uranium carbide oxidized, resulting in increased alpha radiation levels on the concrete dock.
- In 1967, a drum of uranium oxide (U_3O_8) was opened outside on plastic sheeting and some of the waste fell onto the plastic. Wind dispersed the U_3O_8 resulting in increased alpha radiation on surrounding vegetation (MWH, 2006b).

During demolition of the building in 1993, an area of Cs-137 was excavated from the Building 4064 side yard. The soil was also found to be contaminated with methylene chloride (40 µg/kg) and acetone (130 µg/kg).

The leach field was constructed of 120 linear feet of leach lines branching out from a 750-gallon septic tank. The leach field and septic tank were not used after 1961 but remained in place until they were removed in the period from 1996 through 1999. No elevated metals were found in waste characterization samples.

The location of former leach field AI-Z2 was not sampled by MWH in 2014.

4.11.2 Soils, Geology, and Hydrogeology

Soils in the area are thin. When the leach field was removed, the excavation was not backfilled; instead it was re-graded. Boring logs from the RFI investigation indicate that alluvial soils are only about 1-foot deep. The leach field was located above the subcropping ELV fine-grained member of Sandstone 2, which dips beneath the former Building 4064 footprint. A trench between the former building and the former leach field encountered weathered siltstone at a depth of about 1.5 feet and other borings found siltstone and shale gravel (MWH, 2006b).

Near-surface groundwater is not expected in the shallow soils and weathered bedrock. The nearest piezometer, PZ-113 (15 feet deep), is located south of the leach field and is typically dry.

4.11.3 Extent of Contamination

No contamination has been found in RD-92. In 2004, toluene and acetone were detected below MCLs and both were considered to be lab contamination (MWH, 2006b).

4.11.4 Conceptual Site Model

The soils surrounding the leach field were likely deeper than those now found at the site as no backfilling of the leach field was done when it was removed.

<u>Possible Data Gap Activities for DOE Leach field at Building 4064:</u>

- Install a new near-surface groundwater monitoring well at AI-Z2 leach field.
- No further investigation of the Chatsworth Formation groundwater is necessary as no contamination has been detected in RD-92.
- Continued use of RD-92 as a groundwater level control point for this location of Area IV.

The following information was used to determine the depth of the new near-surface groundwater monitoring well.

- Current purposed location (See Figure 9-1)
- Elevation at purposed location (1,860 feet above MSL)
- Groundwater interval of interest is first water

The new monitoring well will be drilled to first water at this location. The total depth of the well is estimated to be 20 feet bgs. This well will fill the following data gap.

- Provide VOC concentration data in groundwater at the AI-Z2 leach field
- Provide groundwater elevation data in the near-surface groundwater system

4.12 Building 4030 and Building 4093 Leach Fields

The Building 4030 and Building 4093 Leach fields are DOE responsibilities per the 2007 CO. The Building 4030 and Building 4093 leach field groundwater investigation area corresponds to the DOE Leach field 1 RFI site. Groundwater is monitored by Chatsworth Formation monitoring well RD-17. Several buildings in the area around Building 4030 and Building 4093 were used in support of the Kinetics Experiment Water Boiler (KEWB) reactors and the Water Boiler Neutron Source (WBNS) reactor. Both reactors use uranyl sulfate fuel. The RFI identified potential chemical use in several of the buildings and they are included in the Building 4030 and Building 4093 leach field groundwater investigation area. TCE has been detected in RD-17 at concentrations well below the MCL. TCE has not been detected in PZ-112, although it is frequently dry. The buildings, leach fields, and wells used to monitor groundwater are shown on **Figure 4-31**.

4.12.1 Operation History

The Building 4030 leach field (AI-Z3), located southwest of the building, was in use from 1958 to 1961 and received sanitary waste from a 1,000-gallon septic tank. The system included 90 linear feet of pipe. Building 4030 and adjacent Building 4035 were used as a counting room and work shop including the use of a Van de Graff accelerator with tritium targets from 1960 to 1964. Beginning in 1972, the buildings were used for purchasing, shipping, receiving, and warehousing. In 1991 there was a release of less than 10 gallons of diesel fuel. The chemical storage yard at Building 4035 was the site of two releases in 1987: 1,000 pounds of nickel chloride flake and 1 pint of Turco 3878 (sodium chromate).

The Building 4093 leach field (AI-Z4) also operated from 1958 to 1961. Although the construction is not known it is likely to have been 4-inch terracotta clay pipe surrounded by gravel and buried from 2 to 6 feet bgs. Three leach lines, a total length of 234 feet, received waste from a 750-gallon septic tank. The leach field and tank were removed in 1999 (CH2MHill, 2008). Building 4093 was used as the WBNS reactor building from 1958 to 1980. In 1985, the building was decommissioned and all uranyl sulfate fuel was removed. The building was released for unrestricted use in 1987 and was used for storage. Three releases have been documented – in 1959 there was a fission gas release to air, in 1982 there was a uranium-235 (U-235) water release to the floor and concrete shield, and in 1995 a radioactive High Efficiency Particulate Air (HEPA) filter was found in a pile of debris.

Other reactor and support buildings within this groundwater investigation area, with no leach fields, but where the RFI (CH2MHill, 2008) determined chemicals had been used include:

- Building 4073 housed the KEWB reactors that were in operation from 1956 to 1966. The building was decontaminated in 1968 and removed in 1975.
- Building 4023 was used as a liquid metals and analytical lab in support of SNAP from 1962 until the late 1970s. It was used to conduct studies of radioactive contamination transport of Manganese-54 (Mn-54) and Cobalt-60 (Co-60). Also used to conduct a program to remove radioactive isotopes from nuclear fuel operated until 1958. Lithium chloride, potassium chloride, and cadmium were used in the building. Possible releases of Mn-54 occurred in 1980 and 1981 and 0.1 gallon of mercury was released in 1997.
- Building 4074 was a storage and x-ray film processing building that was demolished in 1995.
- Building 4083 was a reactor kinetics control building.

- Building 4103 was a reactor kinetics lab and was also used for storage.
- Building 4123 was used for temporary storage of radiological waste material.
- Building 4453 was used for neutron radiography and uranyl sulfate handling.
- Building 4641 was used for shipping and receiving from 1964 to 1985. Materials handled in the building included radiological material. The parking lot (north of the building) was used for storage of materials and equipment. Releases of mercury (both less than 0.1 gallon) were reported in 1996 and 1997.
- Building 4893 was a reactor pad.

The support infrastructure also included two aboveground 550-gallon diesel storage tanks and two radioactive water "vaulted tanks." Radioactive water was also stored in a 220-gallon UST from 1976 to 1993 (CH2MHill, 2008).

4.12.2 Soils, Geology, and Hydrogeology

Soil, comprised of weathered material from the Upper Burro Flats and ELV fine-grained member of Sandstone 2 of the Chatsworth Formation, are thin (1 to 10 feet thick) across the groundwater investigation area.

The presence of Near-surface groundwater in the Building 4030 and Building 4093 leach field groundwater investigation area is uncertain. Near-surface groundwater has been observed only infrequently in PZ -112, located about 350 feet southeast of the investigation area. PZ-112 is screened from 24 to 34 feet bgs and was last sampled in 2002. However, about 50 feet west of the Building 4093 leach field moisture was noted from 16 to 30 feet bgs during the installation of Chatsworth Formation well RD-17 indicating that shallower groundwater may have been present.

RD-17 is open from 30 to 125 feet. The water table is found in the uppermost part of the well (at about 32 feet bgs in 2013). RD-17 is up- or cross-gradient to the majority of former buildings and other features. The groundwater investigation area is located on a groundwater divide. If present at PZ-112, which is located southeast of the AI-Z3 leach field, the Near-surface groundwater would be expected to flow to the southeast. Chatsworth Formation groundwater would flow to the southeast, south-southwest, and west.

4.12.3 Extent of Contamination

During the RFI, soil vapor VOCs were only detected from a sample at the southeast corner of Building 4631, directly upgradient of PZ-112. Acetone (10 µg/kg) was detected in soil from the former location of the Building 4093 leach field, and low levels of styrene were detected in several other locations (Building 4023, Building 4103/4083, Building 4453). TCE was not detected in soil samples. No VOC contamination above screening levels was detected in soil from the two leach fields.

Soil vapor sample 5ASV DG-576 at former leach field AI-Z3 was collected by MWH. No VOCs were detected in the soil vapor. At AI-Z4, sample 5ASV DG-565 had 1,1-dichloroethane (0.0018 J µg/L), 1,1-dichloroethene (1.011 J µg/L), benzene (0.00076 J µg/L), tetrachloroethene (0.16 J µg/L) and TCE (0.018 J µg/L) in soil vapor

In 2014, TCE was reported for a sample from RD-17 at a concentration of 1 µg/L (well below the MCL of 5 µg/L), and acetone was detected at a concentration of 2.2 J µg/L. The concentration of TCE is very similar to that found in the well prior to 2011 (7.6 µg/L). No source of TCE was found in the historical research or soil sampling during the RFI (CH2MHill, 2008). Acetone was found in the soil of the former Building 4093; however, the low concentration found in RD-17 is indicative of laboratory contamination.

4.12.4 Conceptual Site Model

There is no indication that TCE was used in the buildings and facilities within the Building 4030 and Building 4093 leach field groundwater investigation area. The continuing presence of low levels of TCE in the shallow Chatsworth Formation may indicate the past presence of higher concentrations. When concentrations were elevated, TCE may have diffused into the fractures of the shallow bedrock. The contaminant may be diffusing out of the fractures now. The source of the TCE is unknown as RD-17, located on a groundwater divide, is not downgradient of any known source.

Possible Data Gap Activities for B4030/4093 Leach Fields:

- Due to the low concentrations of TCE found in groundwater and lack of known source areas, only sampling of RD-17 for TCE is warranted.

4.13 Building 4133/Building 4029 Hazardous Waste Management Facility

Building 4133 and Building 4029 are DOE RCRA-regulated facilities that have been combined because they were permitted under the same RCRA permit and, together, they comprise the Hazardous Waste Management Facility (HWMF). The Building 4133 area is located adjacent to the RMHF area and northwest of the Buildings 4030/4093 Leach fields, while the Building 4029 area is located 0.25 mile southeast of Building 4133. They are not connected physically.

Building 4133 was used from 1978 to 1997. Reactive metals such as sodium and potassium were treated in Building 4133 by heating them in a pan for subsequent reaction with air. The result of the process was sodium hydroxide and potassium hydroxide solutions that were then neutralized in a tank. The HWMF was permitted under RCRA in 1983 and a RCRA closure plan was developed following cease of operations in 1997.

There is one shallow monitoring well located at Building 4133; RS-25. RS-25 is a 13.5-foot well installed in 1988 (**Figure 4-32**), and it has been typically dry. EPA sampled purge water from the well in 2010/2011 as it did not recover following purging. One bedrock monitoring well, RD-19, is located downgradient from Building 4133. RD-19 is a 135-foot well, cased and sealed from 0 to 30 feet bgs, installed in 1989. It is located near the beginning of the RMHF drainage, upgradient of RMHF well RD-98. RD-19 has been sampled four times recently and samples have exhibited no contamination.

Building 4029 was originally used from 1959 to 1974 for the storage of radioactive materials. It was shut down in 1974 when all radioactive materials were removed and the below grade storage sumps were removed. In 1978, Building 4029 became part of the HWMF that was permitted under RCRA in 1983. Building 4029 was used for storage of reactive metals prior to their treatment at Building 4133. A RCRA closure plan was developed for the HWMF (MWH, 2003) but never implemented due to the 2007 moratorium placed on demolition of DOE structures in Area IV. There are no monitoring wells associated with Building 4029.

<u>Possible Data Gap Activities for HMWF:</u>

- The recommendations pertaining to groundwater listed in the DTSC-approved RCRA Closure Plan should be implemented. These recommendations include the collection of groundwater from the Near-surface groundwater (if it is found) from the building footprint following building removal.

- In accordance with the RCRA Closure Plan, a new monitoring well will be installed at or near Building 4029 to characterize bedrock groundwater.

References

Boeing Company, 2006. *Final Status Survey Report: Characterization and Final Status Survey Radioactive Materials Handling Facility Perimeter, Contract Number R58KXZ05-09-2532*. The Boeing Company, Canoga Park, CA. Cabrera Services, 2008. *Draft Report. Radiological Support at Area IV Radioactive Materials Handling Facility, Santa Susana Field Laboratory.*

Carroll, J.W., J.M. Marzec, and A.M. Selle, 1982. *RMDF Leach field Decontamination Final Report, ESG-DOE-13385, Rockwell International, Canoga Park, CA*.

CDM Smith 2013. *Former Sodium Disposal Facility Groundwater Interim Measures, Aquifer Testing and Treatment Conceptual Workplan.* December.

CH2M Hill, 2008. *Group 5 – Central Portion of Areas III and IV, RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. November.

Dibblee, T.W., 1992. *Geologic Quadrangle Maps: Los Angeles and Ventura Counties, California*

Groundwater Resources Consultants, Inc. (GRC), 1995. *Well Compendium, Rockwell International Corporation, Rocketdyne Division, Ventura County, California*. September 20.

GRC, 1999a. *Results of Enhanced Dewatering, Building 59, Boeing North American, Inc., Rocketdyne Propulsion & Power, Ventura County, California*. September 10.

GRC, 1999b. *Results of Dewatering Pit D/056, Boeing North American, Inc., Rocketdyne Propulsion & Power, Ventura County, California*. July 23.

Haley & Aldrich, 2010. *Site-Wide Water Quality Sampling and Analysis Plan*. Revision 1, December.

Harding Lawson Associates, 1995. November 2.

Hydrogeologic Inc., (HGL) 2012a. *Final Groundwater Report, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County California*. Prepared for USEPA Region IX. December.

HGL, 2012b. *Final Radiological Characterization of Soils Area IV and the Northern Buffer Zone, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County, California*. Prepared for USEPA Region IX. December.

HGL, 2012c. *Final Surface Water and Sediment Report, Santa Susana Field Laboratory, Ventura County, California*. Prepared for USEPA Region IX. December.

Kersting, A.B., D.W. Efurd, D.L. Finnegan, D.J. Rokop, D.K. Smith and J.L. Thompson, 1999. *Migration of plutonium in ground water at the Nevada Test Site*, Nature 397(6714): 56-59.

MHW, 2003. *Closure Plan Hazardous Waste Management Facility, Buildings T029 and T133, Santa Susana Field Laboratory, Ventura County, California.*

MWH, 2006a. *Report of Results Former Sodium Disposal Facility Groundwater Characterization, Santa Susana Field Laboratory.*

MWH, 2006b. *Group 6 – Northeastern Portion of Area IV, RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. (September 29)

MWH, 2007. *Group 8 – Western Portion of Area IV, RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. (September 29)

MWH, 2009a. *Group 7 Northern Portion of Area IV, RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California*. June.

MWH, 2009b. *Draft Site-Wide Groundwater Remedial Investigation Report*. December.

MWH, 2013. *Results of Geologic Mapping and Excavations along the Western and Eastern FSDF Structures (Photolineaments) Area IV.*

MWH, 2014a. *Report on Annual Groundwater Monitoring, 2013, Santa Susana Field Laboratory, Ventura County, California.*

MWH, 2014b. *Technical Memorandum, Summary of Phase 3 Soil Vapor Sampling in Area IV, Santa Susana Field Laboratory, Ventura County, California.*

Rocketdyne, 1990b. *Area IV Radiological Investigation Report – Santa Susana Field Laboratory, Rockwell International Corporation, Rocketdyne Division*. March 23, 1990.

Rocketdyne Division, 1990. *Environmental Monitoring and Facility Effluent Annual Report, Desoto and Santa Susana Field Laboratories Sites, 1989.*

Rocketdyne Division, 1992. *Environmental Monitoring and Facility Effluent Annual Report, Desoto and Santa Susana Field Laboratories Sites, 1991.*

Rocketdyne Division, 1993. *Environmental Monitoring and Facility Effluent Annual Report, Desoto and Santa Susana Field Laboratories Sites, 1992.*

Rockwell International (Rockwell), 1976. *Building 003 Decontamination and Disposition Final Report*. February.

Rockwell International, 1982a. *Radioactive Materials Disposal Facility Leach field Environmental Evaluation Report, ESG-DOE-13365, Rockwell International, Canoga Park, CA*.

Rockwell International, 1982b. *RMDF Leach field Decontamination Final Report*.

Rockwell, 1983. *Sodium Reactor Experiment Decommissioning Final Report*. Santa Susana Field Laboratory, Ventura County.

Rockwell, 1990. *Final Decontamination and Radiological Survey of the Old Conservation Yard*. August.

Sapere Consulting, Inc. 2005. *Historical Site Assessment of Area IV, Santa Susanna Field Laboratory, Ventura County, California*. May.

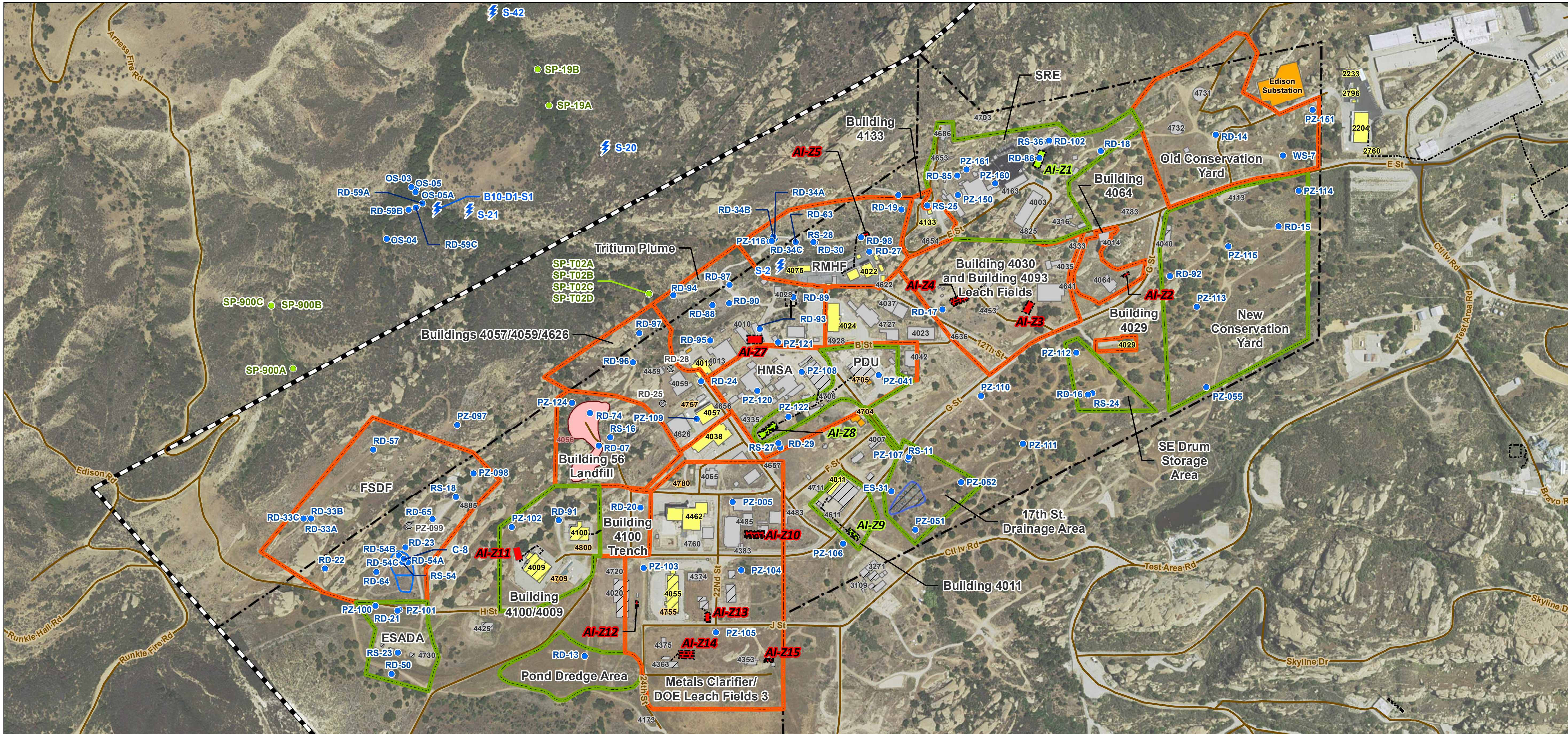
Turner, N.B., J.N. Ryan, and J.E. Saiers, 2006. *Effect of desorption kinetics on colloid-facilitated transport of contaminants: Cesium, strontium, and illite colloids*. Water Resour. Res., 42, W12S09, doi: 10.1029/2006WR004972.

Tuttle, R.J., 1978. Letter dated October 4, 1978, *Status Review – RMDF Leach field, September 1978, Rockwell International, Canoga Park, CA*.

U.S. Department of Energy (DOE), 2005. *Saturated Zone Flow and Transport Model Abstraction, MDL-NBS-HS-000021, DOE Yucca Mountain Project, Las Vegas, NV.*

U.S. Environmental Protection Agency (EPA), 1999. *Understanding Variation in Partition Coefficient, Kd, Values, Volume II: Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium.* U.S. Environmental Protection Agency, Washington, DC.

Zyvoloski, G. A., E. Kwicklis, A.-A. Eddebbarh, B. Arnold, C. Faunt and B. A. Robinson, 2003. *"The site-scale saturated zone flow model for Yucca Mountain: Calibration of different conceptual models and their impact on flow paths."* Journal of Contaminant Hydrology 62-63: 731-750.



LEGEND

- Abandoned Well
- Well/Piezometer
- Seep Well
- Seep
- Road Centerline

Responsibility*
- Boeing
- DOE

Groundwater Investigation Area
- Boeing
- DOE

- Existing Landfill
- Existing Structure
- Existing Substation
- Former Pond
- Demolished Structure
- Boeing Structure
- Former FSDF Pond
- Area IV Boundary
- SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).

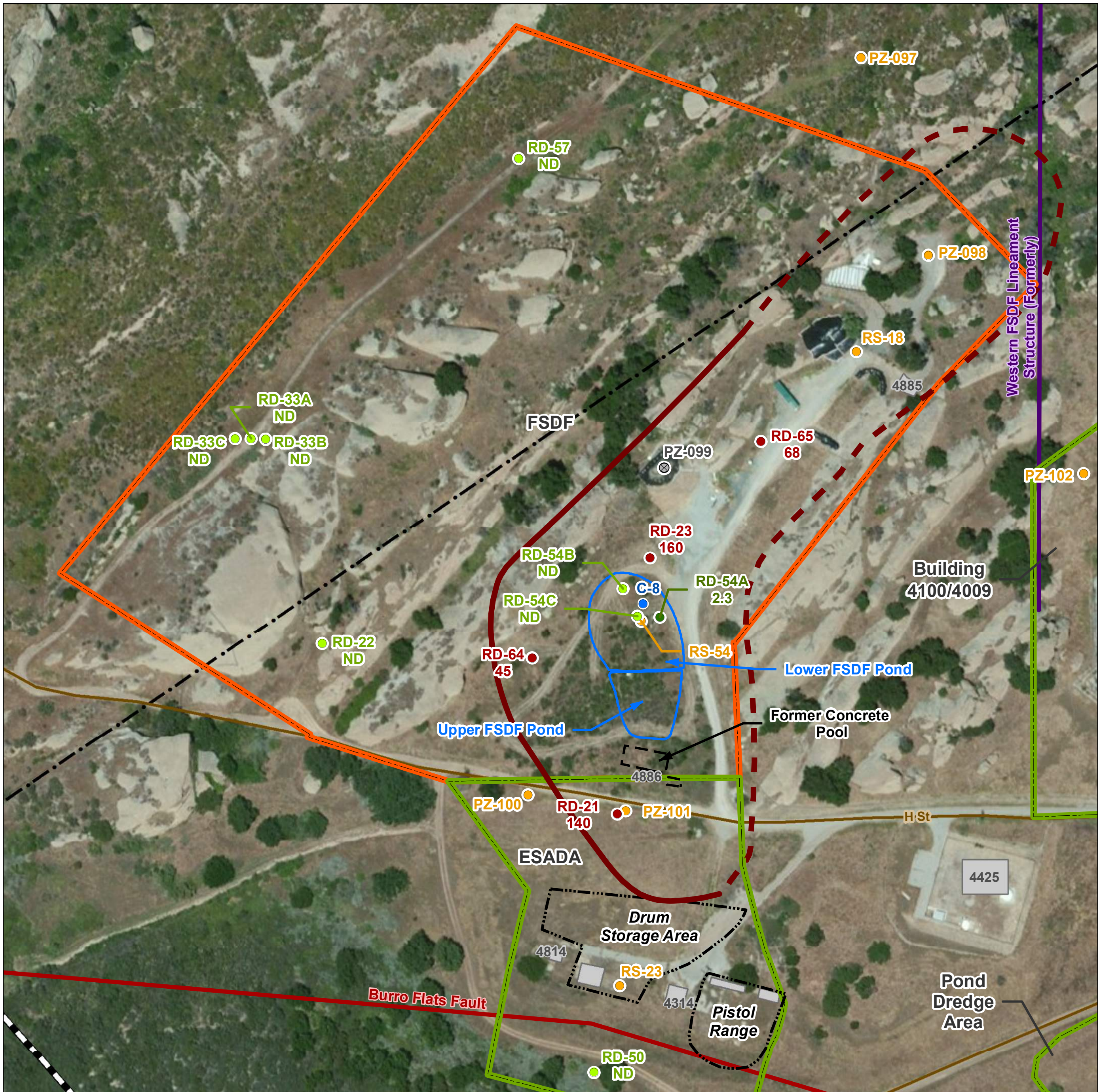
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

0 275 550 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_GW_Investigation_Areas_Revised_20150824.mxd 8/24/2015

CDM Smith

FIGURE 4-1
Area IV Groundwater Investigation Areas



LEGEND

- TCE Detected above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)
- Abandoned Well
- Well/Piezometer
- TCE at 5 ug/L
- Former Concrete Pool
- Road Centerline
- Fault Location
- Structure Location
- Former FSDF Pond

Groundwater Investigation Area

- Boeing
- DOE
- Existing Landfill
- Existing Structure
- Existing Substation
- Former Drainage
- Demolished Structure
- SSFL Property Boundary
- Area IV Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
- Plume boundary dashed where inferred.
- Information provided by MWH following water level survey (February 2014).
- February 2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

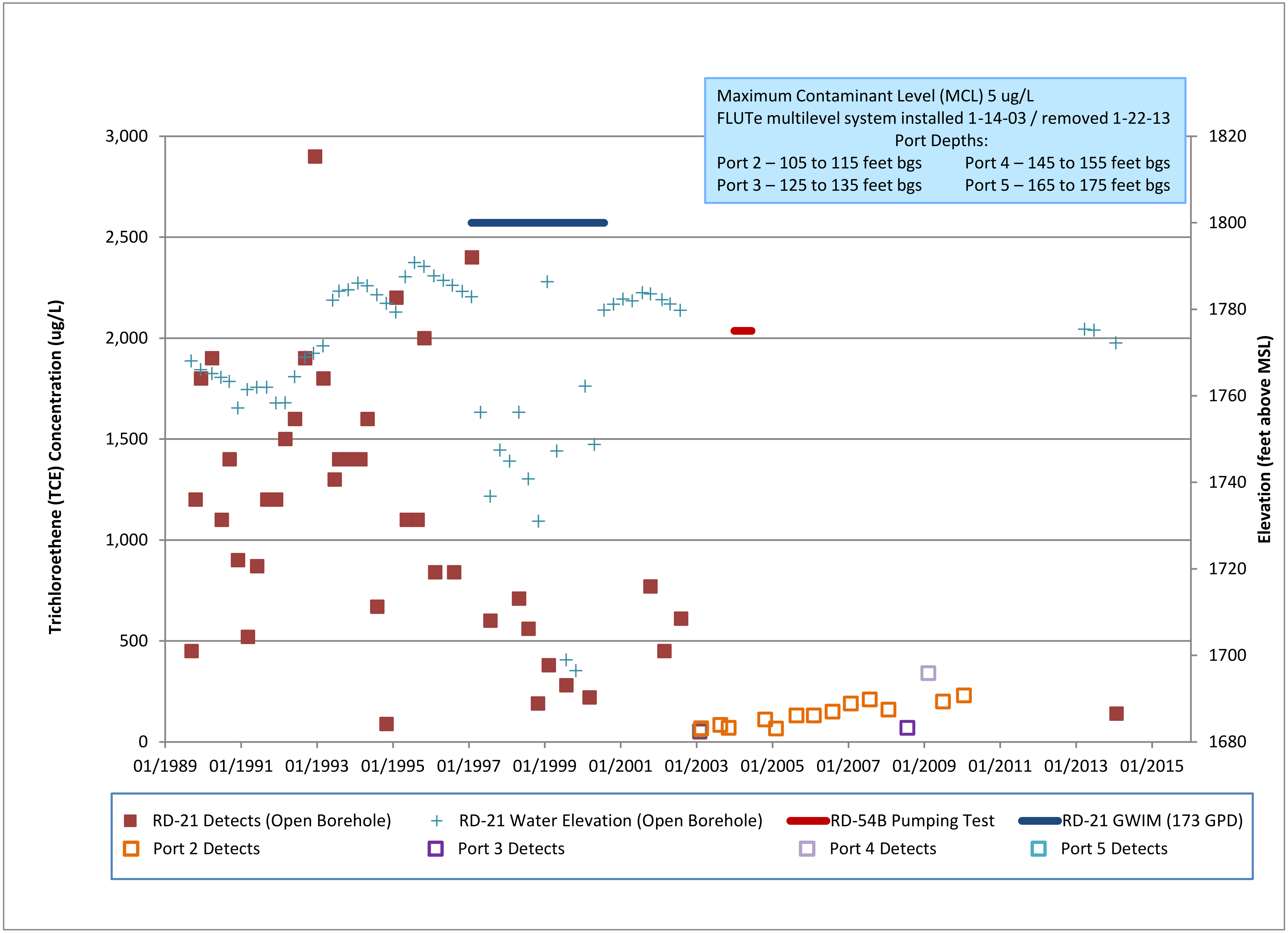
N

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_FSDF_Layout_20150528.mxd 6/10/2015

CDM Smith

FIGURE 4-2
Former Sodium Disposal Facility (FSDF) Layout

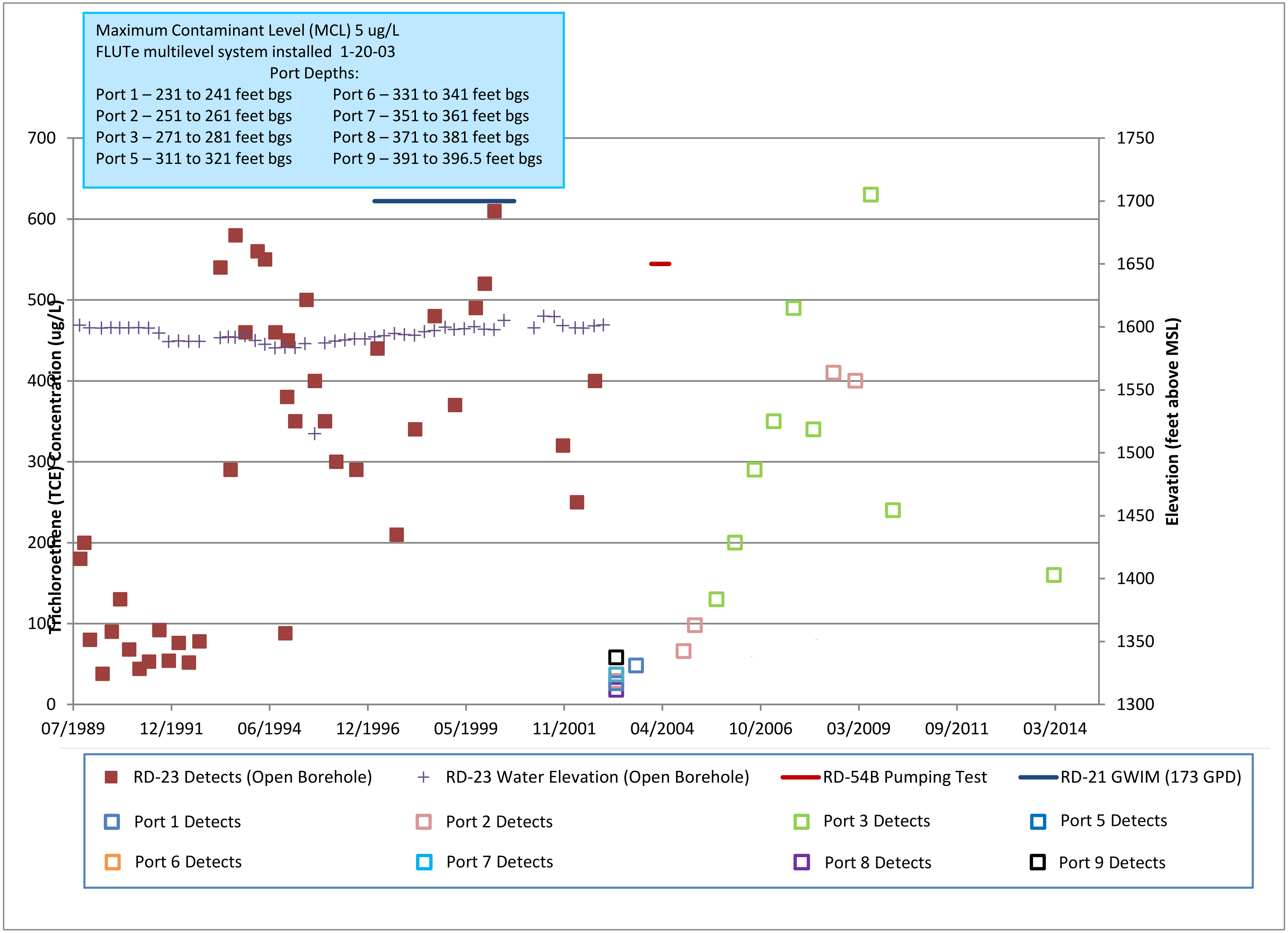


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-21_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-3

TCE Concentrations in RD-21

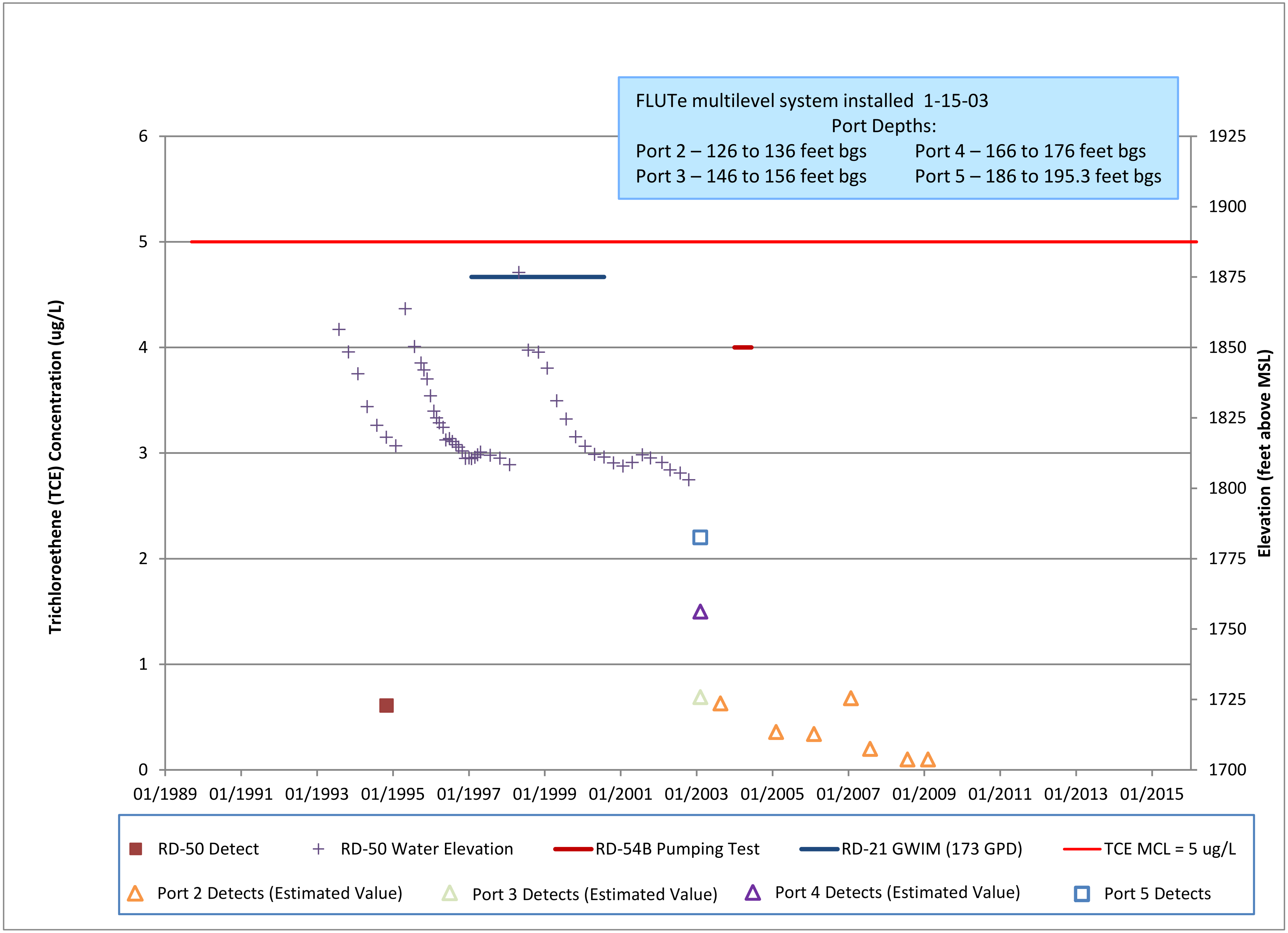


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-23_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-4

TCE Concentrations in RD-23

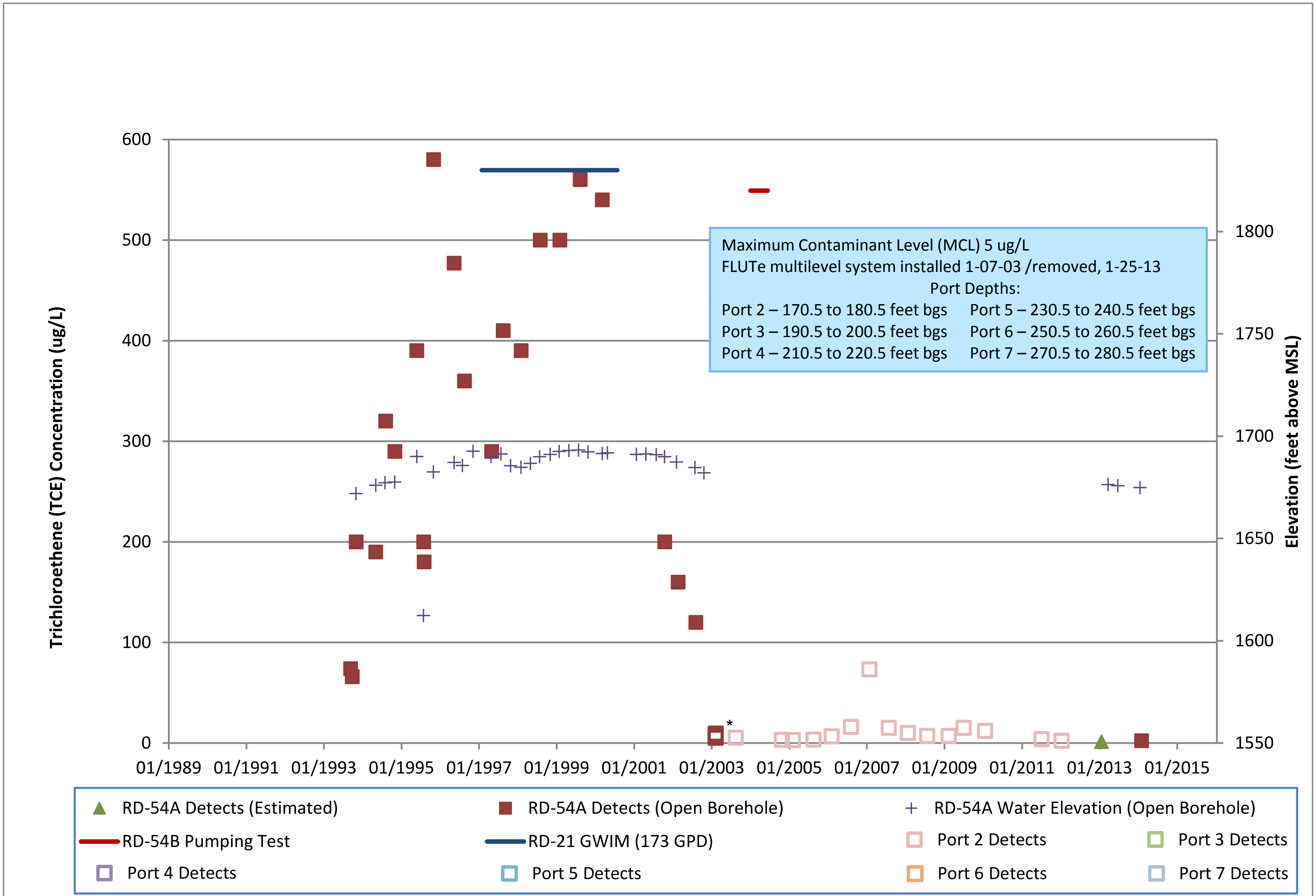


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-50_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-5

TCE Concentrations in RD-50

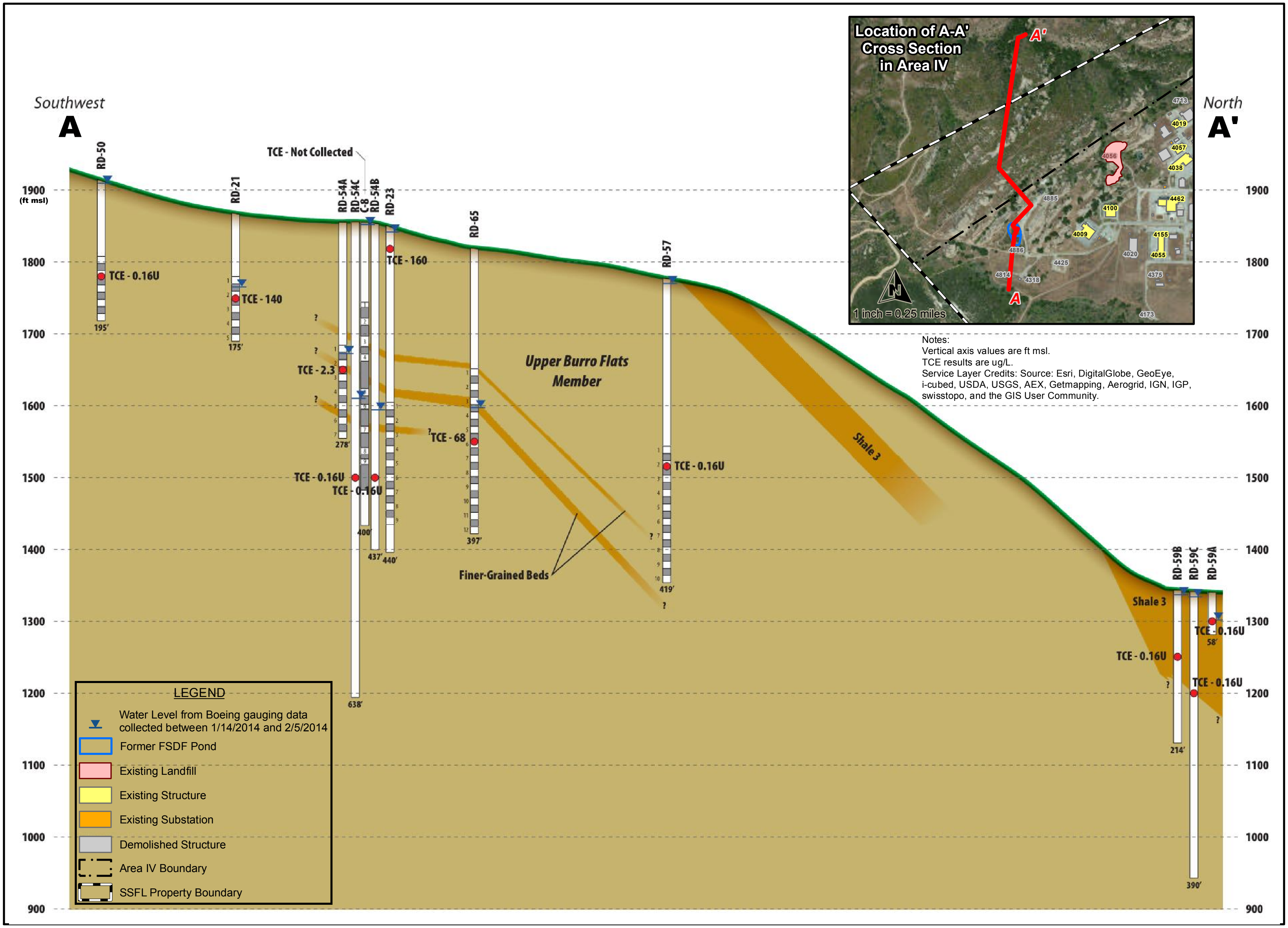


Notes:
- *Detects for Ports 2, 3, 4, 5, 6 and 7.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-54A_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-6
TCE Concentrations in RD-54A

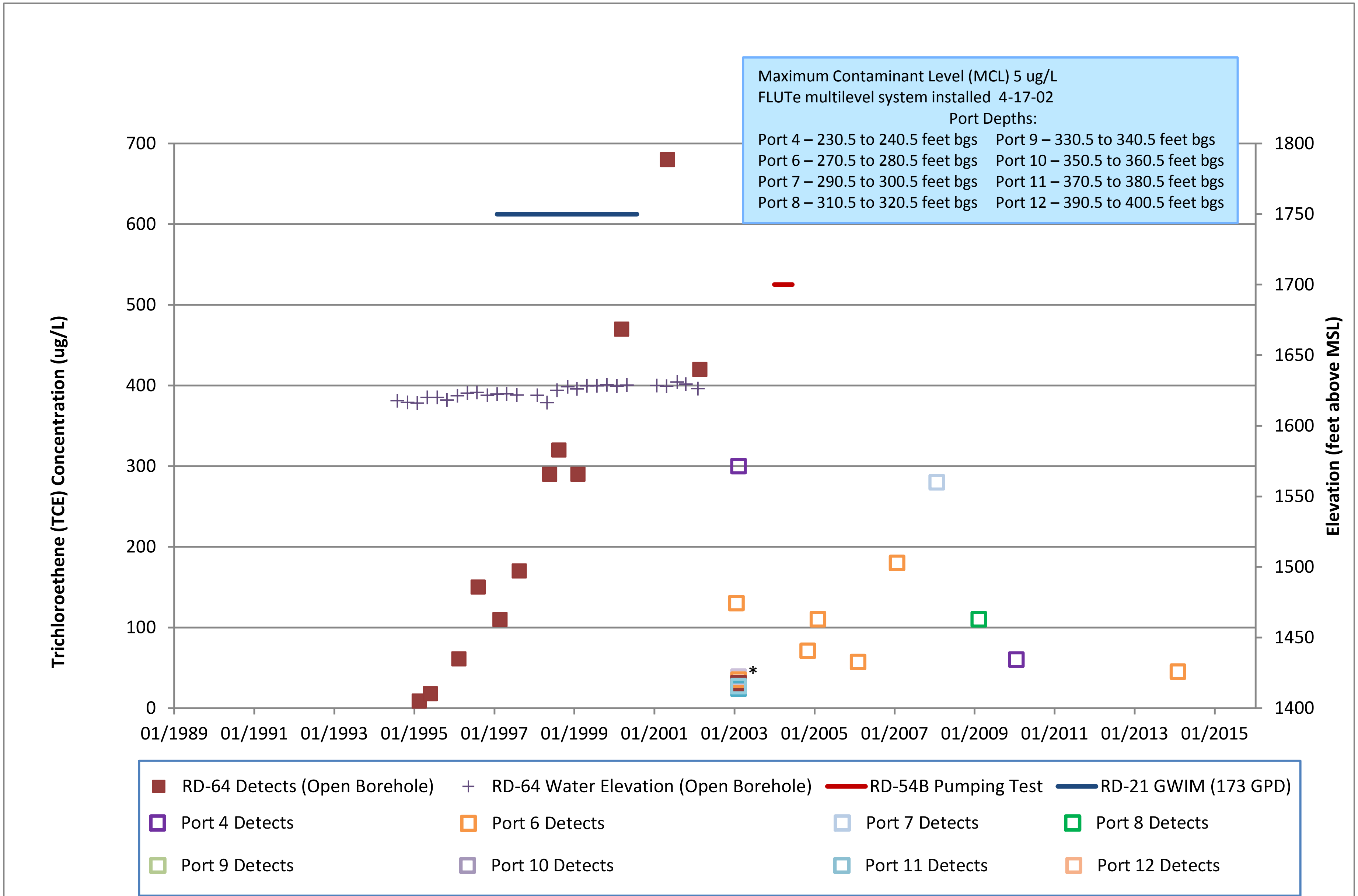


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_TCE_A_A_CrossSection_20150615.mxd 6/15/2015

CDM Smith

FIGURE 4-7

TCE Plume Cross Section A-A' through FSDF



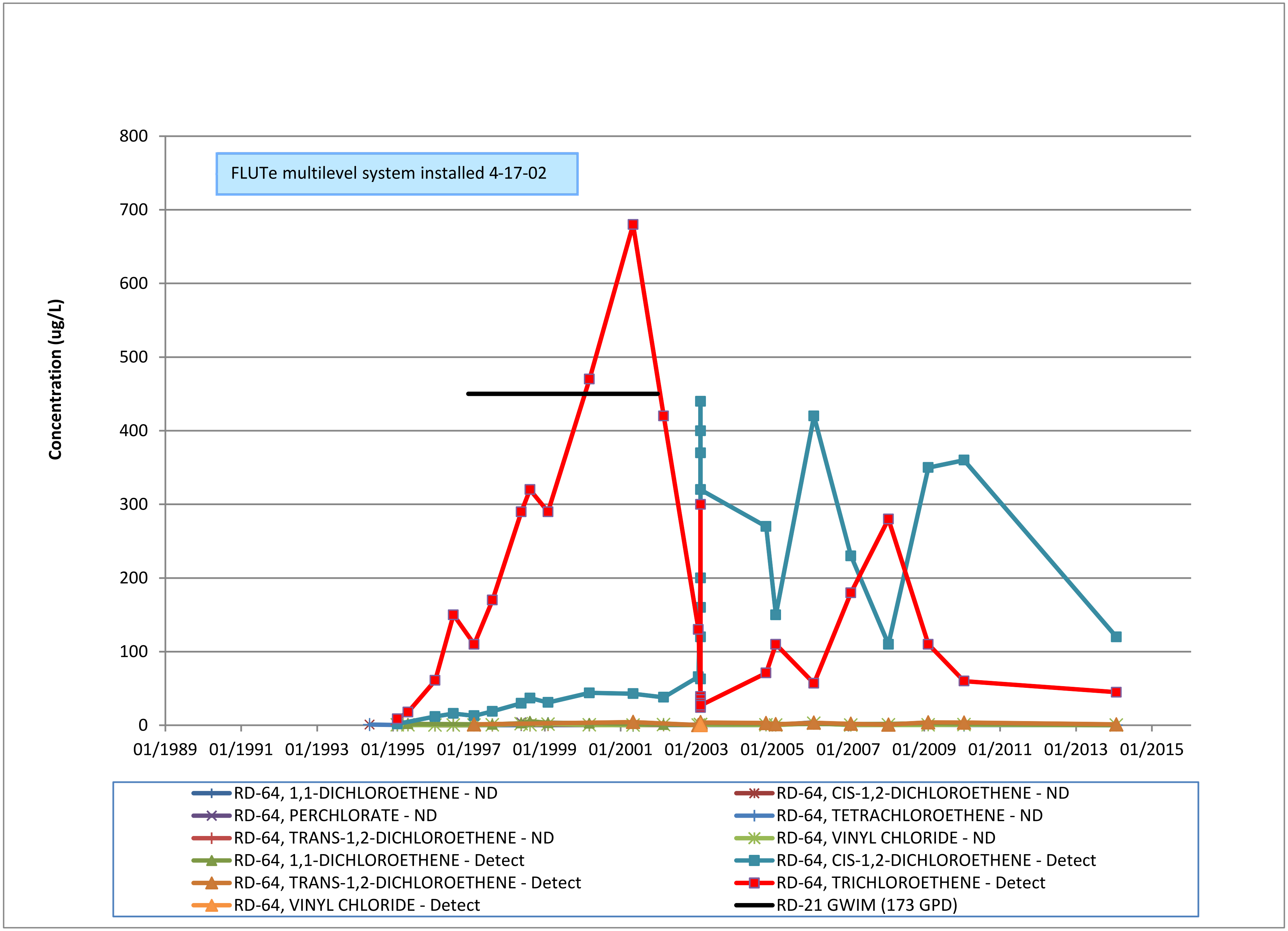
Notes:
- *Detects for Ports 7, 8, 9, 10, 11 and 12.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-64_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-8

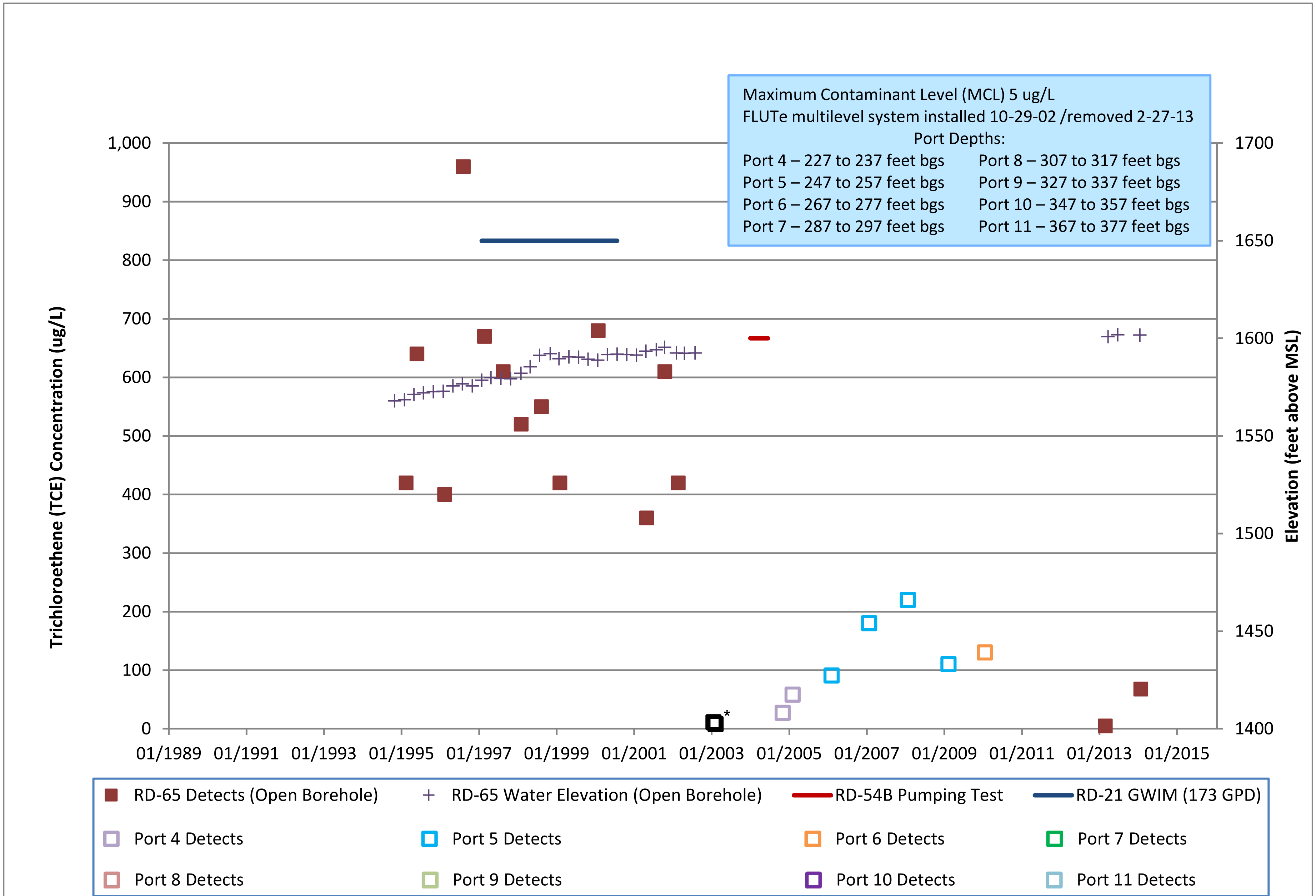
TCE Concentrations in RD-64



C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_Chloroethene_RD-64_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-9
Chloroethene Concentrations in RD-64

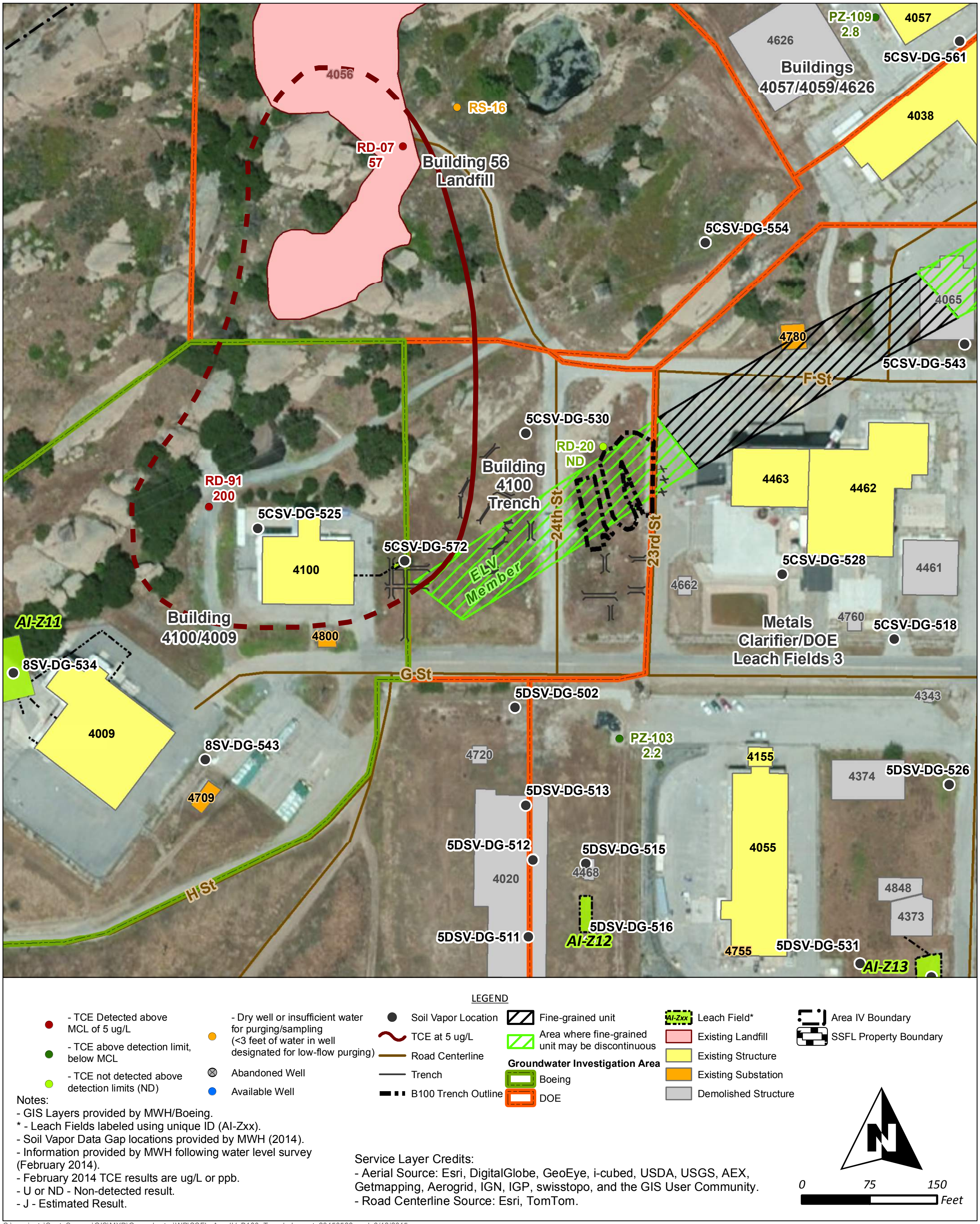


Notes:
- *Detects for Ports 4, 5, 6, 7, 8, 9, 10 and 11.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-65_TCE_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-10
TCE Concentrations in RD-65



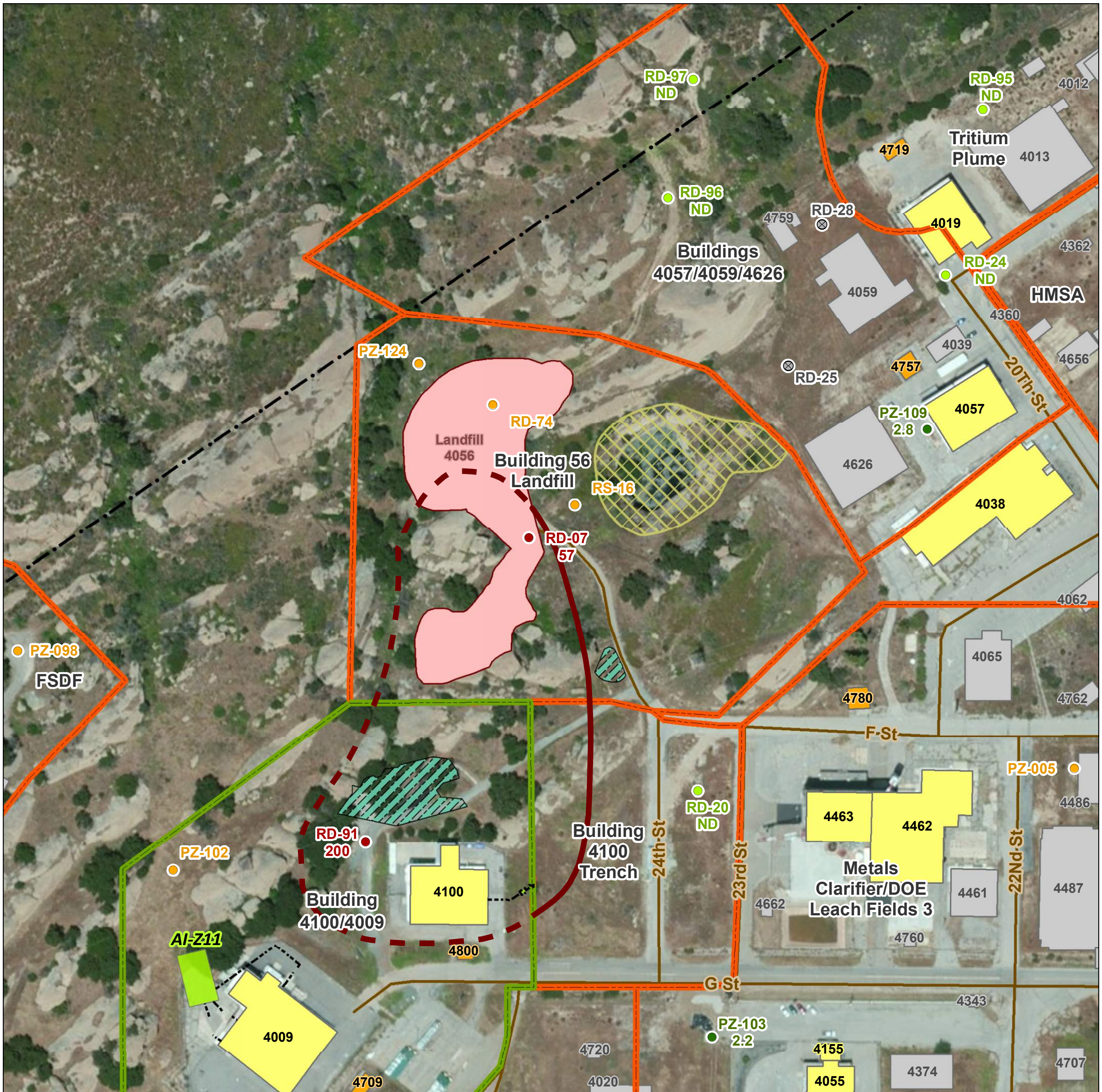
Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Soil Vapor Data Gap locations provided by MWH (2014).
- Information provided by MWH following water level survey (February 2014).
- February 2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_B100_Trench_Layout_20150528.mxd 6/12/2015

CDM Smith

FIGURE 4-11
Building 4100 Trench Layout



LEGEND

- TCE Detected above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)
Abandoned Well
Well/Piezometer
TCE at 5 ug/L
Road Centerline
AI-Zxx Leach Field*
Disturbed Soil
Building 56 Excavated Area

Groundwater Investigation Area
Boeing
DOE
Existing Landfill
Existing Structure
Existing Substation
Demolished Structure
Area IV Boundary
SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Plume boundary dashed where inferred.
- Information provided by MWH following water level survey (February 2014).
- February 2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.

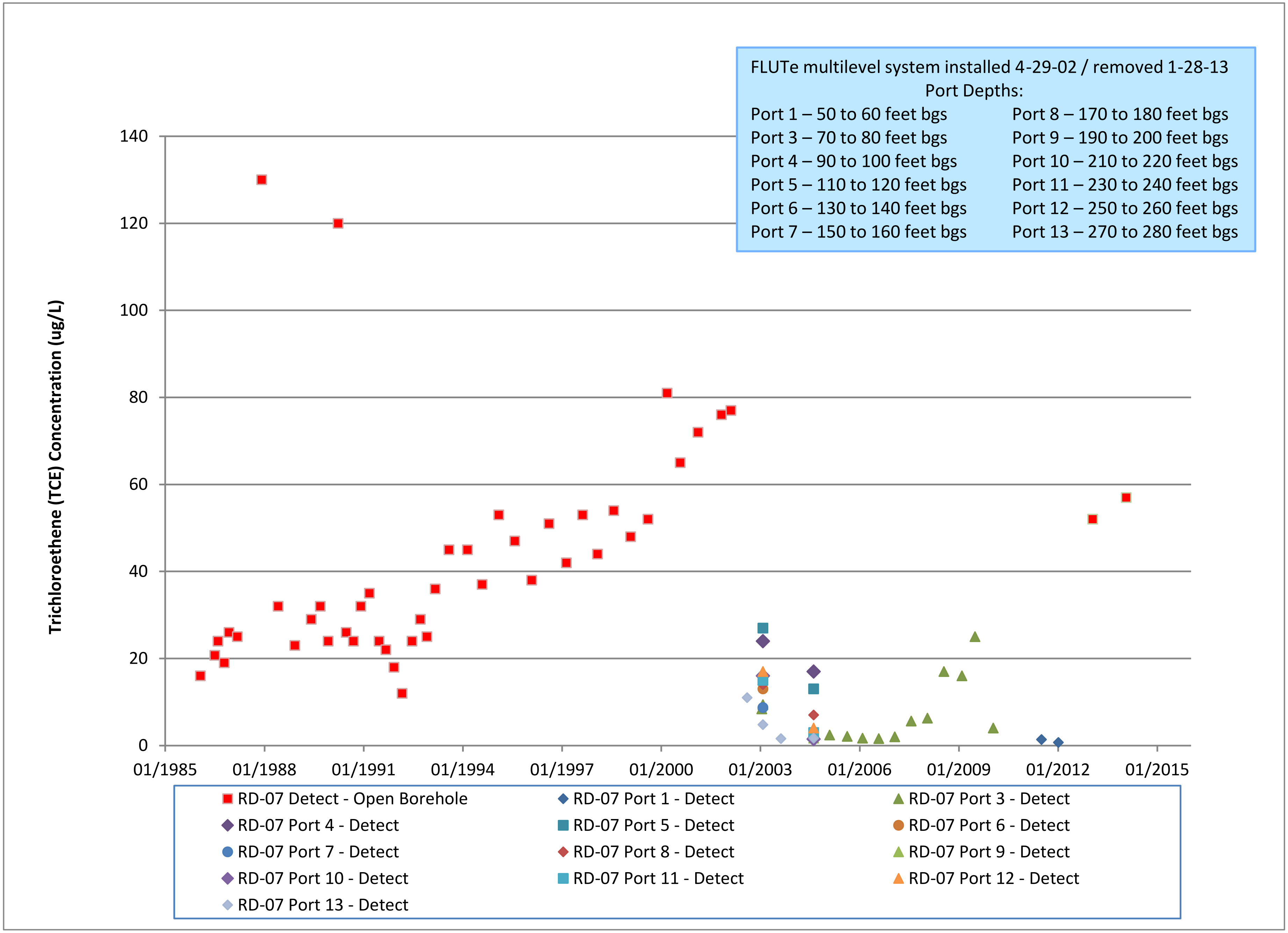
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Bldg56_Landfill_Layout_20150529.mxd 6/15/2015

CDM Smith

FIGURE 4-12
Building 56 Landfill Layout

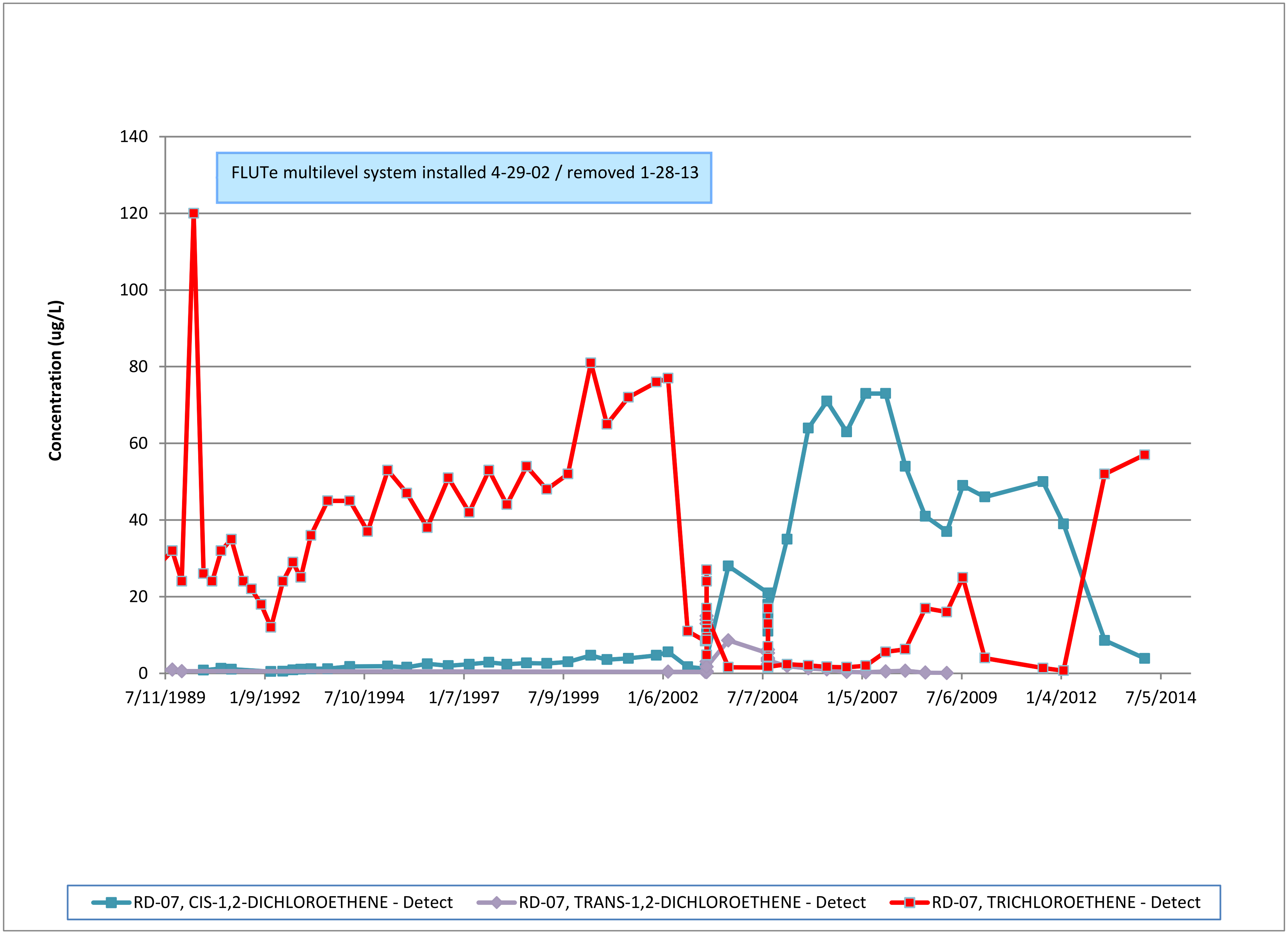


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_RD-07_OpenHole_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-13

TCE Concentrations in RD-07

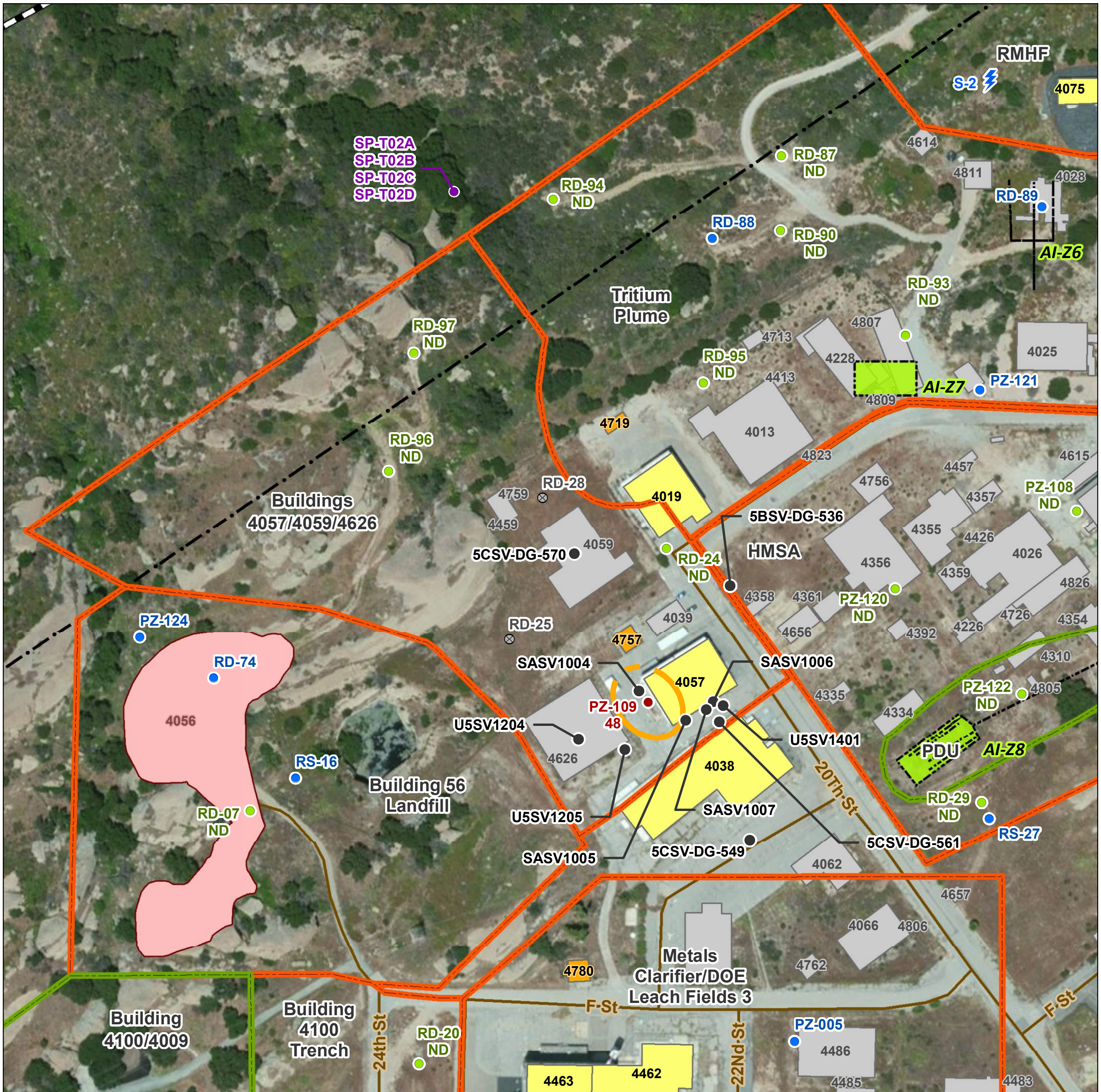


C:_projects\SantaSusana\GIS\MXD\EIS\TrendPlots\SSFL_AreaIV_RD-07_Chloroethene_Conc_TrendPlot.mxd 11/10/2014

CDM Smith

FIGURE 4-14

RD-07 Chloroethene Concentrations



LEGEND

- PCE Detected above MCL of 5 ug/L	Abandoned Well	Road Centerline
- PCE not detected above detection limits (ND)	Soil Vapor Location	PCE above 5 ug/L
Well/Piezometer**	Seep Well	AI-Zxx Leach Field*
	Seep	

Groundwater Investigation Area
- Boeing
- DOE
- Existing Landfill

- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Soil Vapor Data Gap locations provided by MWH (2014).
- Plume boundary dashed where inferred.
** - PCE not collected at location in 1st quarter 2014.
- February 2014 PCE results are ug/L.
- U or ND - Non-detected result.
- PCE plume provided by MWH (2013).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

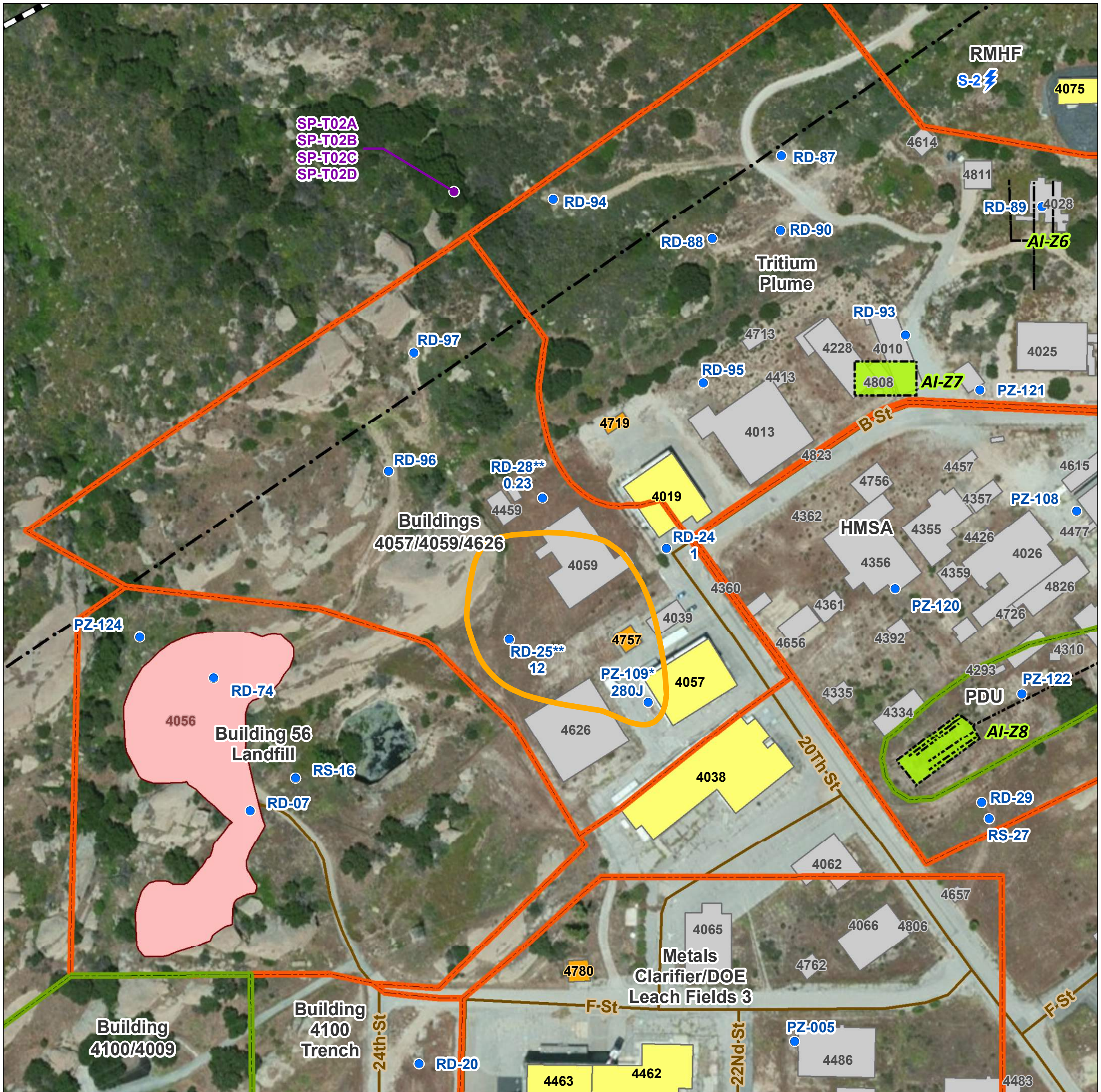
N

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Bldg57_Bldg59_Layout_20150602.mxd 6/19/2015

CDM Smith

FIGURE 4-15
Buildings 4057/4059/4626 PCE Concentrations - 2014



LEGEND

- Well/Piezometer
- Seep Well
- Seep
- Road Centerline
- PCE above 5ug/L
- AI-Zxx Leach Field*

Groundwater Investigation Area
- Boeing
- DOE
- Existing Landfill

- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- 2001 PCE results in ug/L.
- J - Estimated Result.
- *PZ-109 PCE result collected in 2002.
- **Wells RD-25 and RD-28 abandoned in April 2004.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

N

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Bldg57_Bldg59_PCE_2001_20150601.mxd 6/19/2015

CDM Smith

FIGURE 4-16

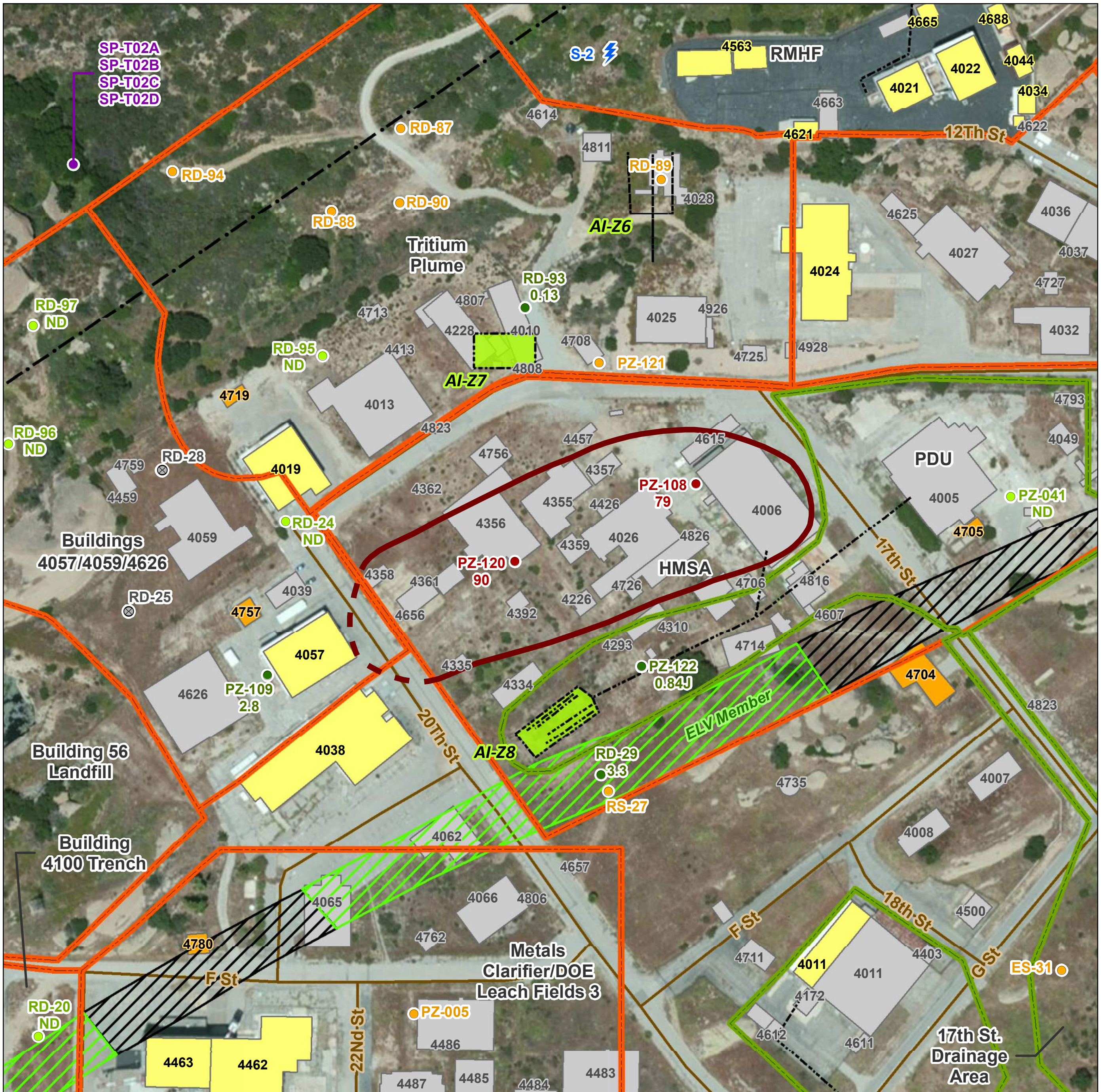
Buildings 4057/4059/4626 PCE Concentrations - 2001

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_PCE_Conc_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-17

PCE Concentrations in PZ-109, RD-24, RD-25 and RD-28



LEGEND

- TCE Detected above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)
- Abandoned Well
- Well/Piezometer
- Seep Well
- Seep
- TCE at 5 ug/L
- Road Centerline

Groundwater Investigation Area
- Boeing
- DOE
- Leach Field* (AI-Zxx)
- Fine-grained unit
- Area where fine-grained unit may be discontinuous
- Existing Landfill
- Existing Structure
- Existing Substation
- Demolished Structure
- SSFL Property Boundary
- Area IV Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Information provided by MWH following water level survey (February 2014).
- February 2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.

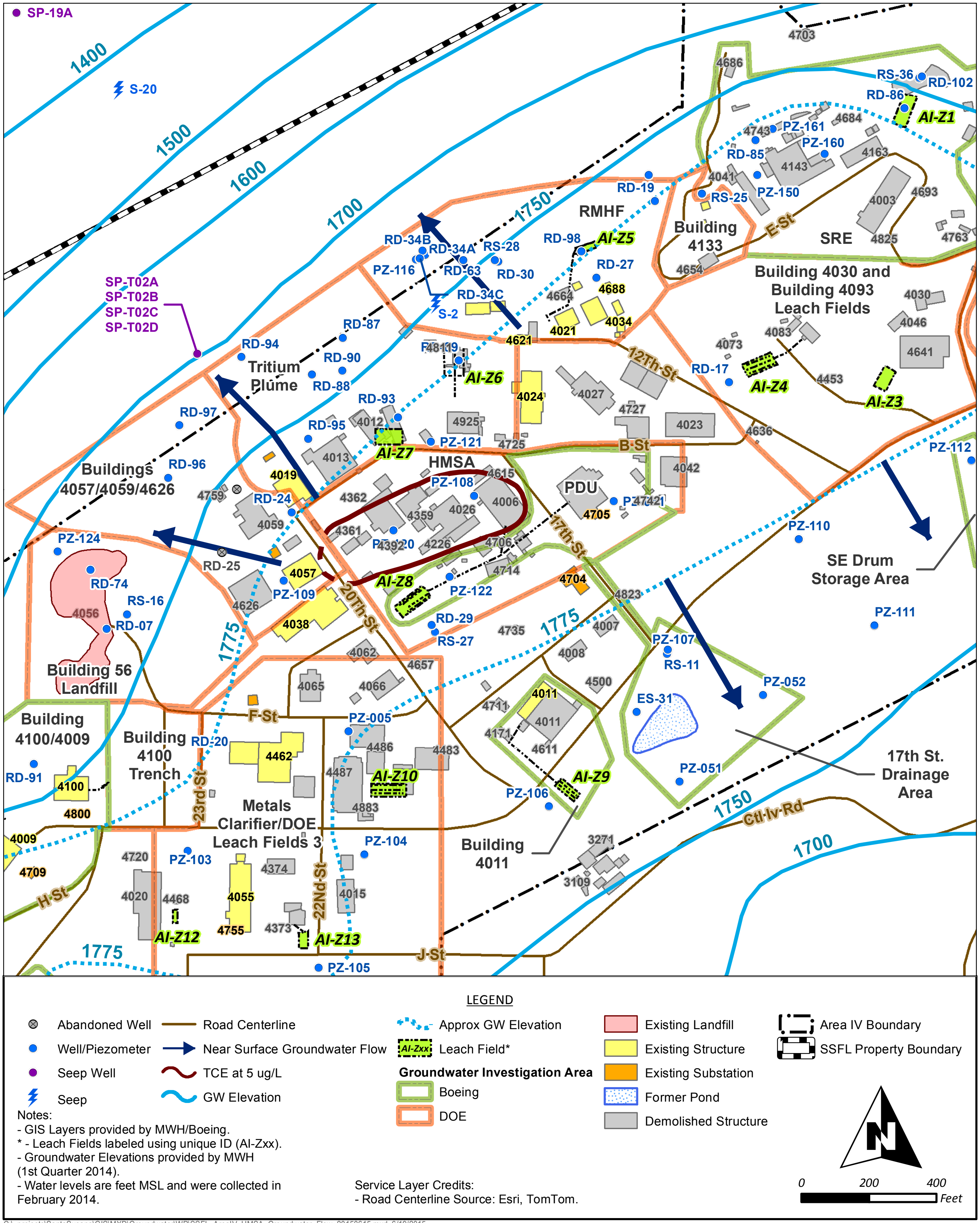
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_HMSA_Layout_20150601.mxd 6/19/2015

CDM Smith

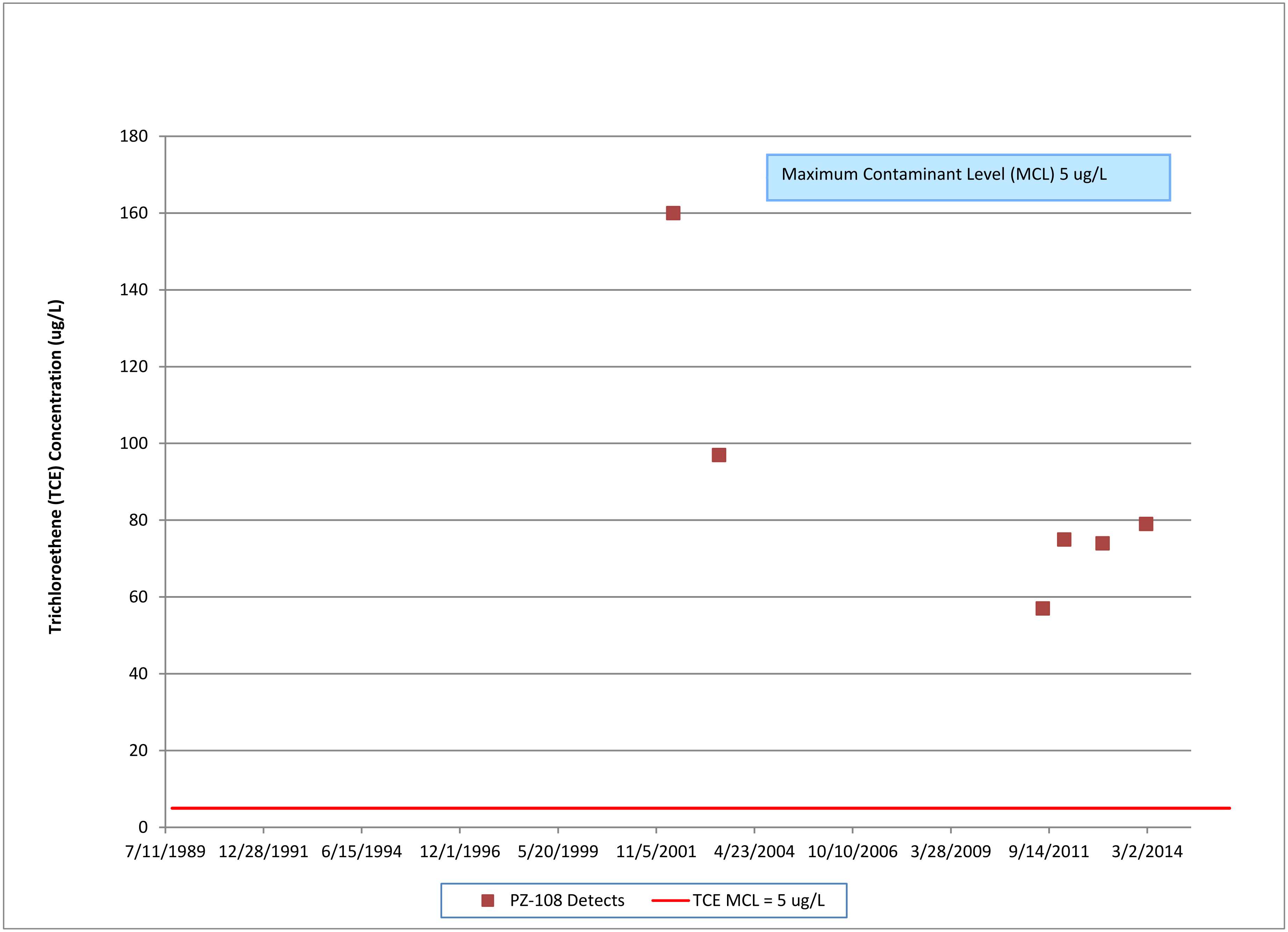
FIGURE 4-18
Hazardous Materials Storage Area Layout



C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_HMSA_Groundwater_Flow_20150615.mxd 6/19/2015

CDM Smith

FIGURE 4-19
Groundwater Flow in Chatsworth Formation, HMSA Groundwater Investigation Area

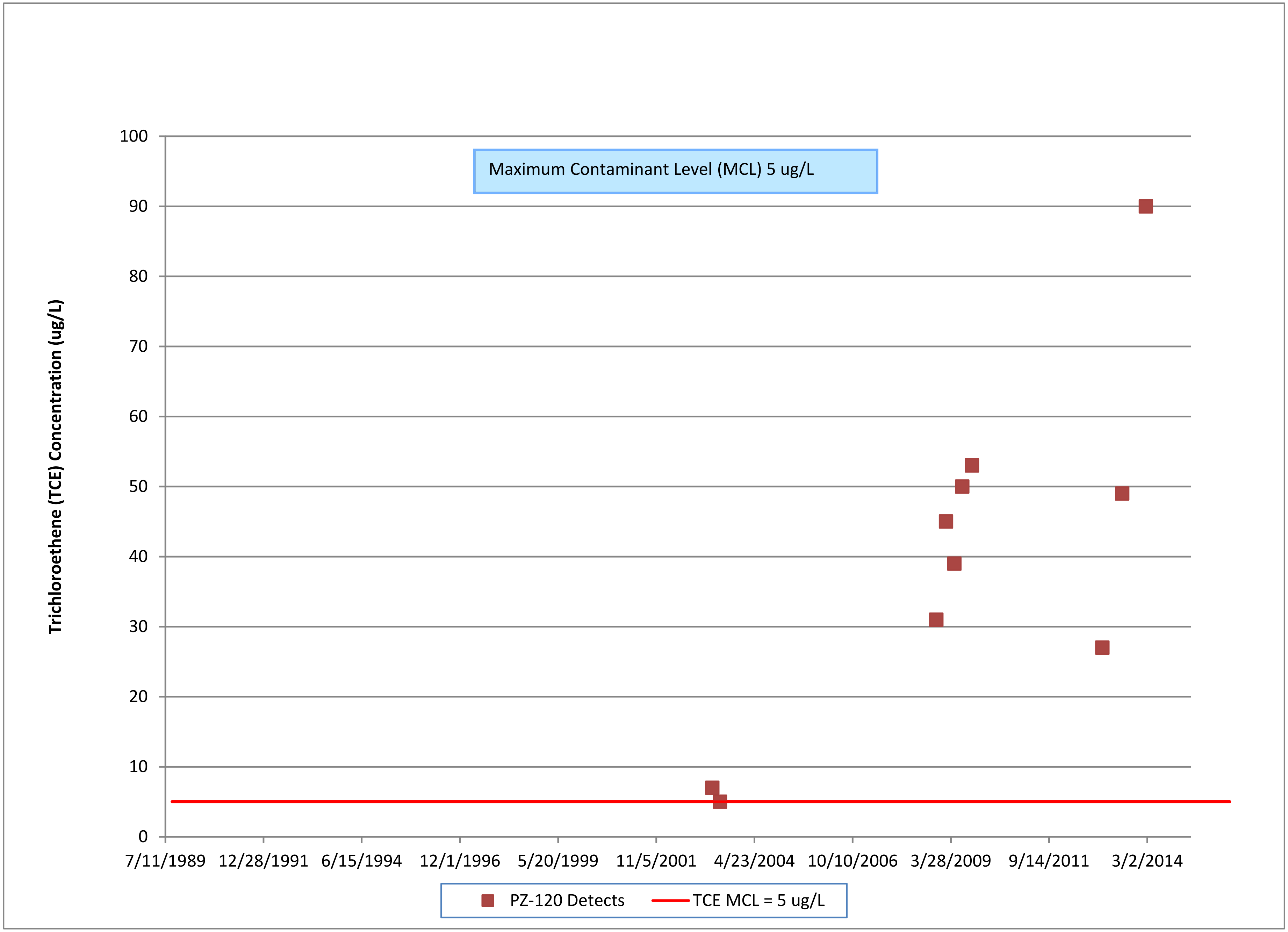


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_HMSA_PZ-108_Perf_Screen_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-20

TCE Concentrations in PZ-108

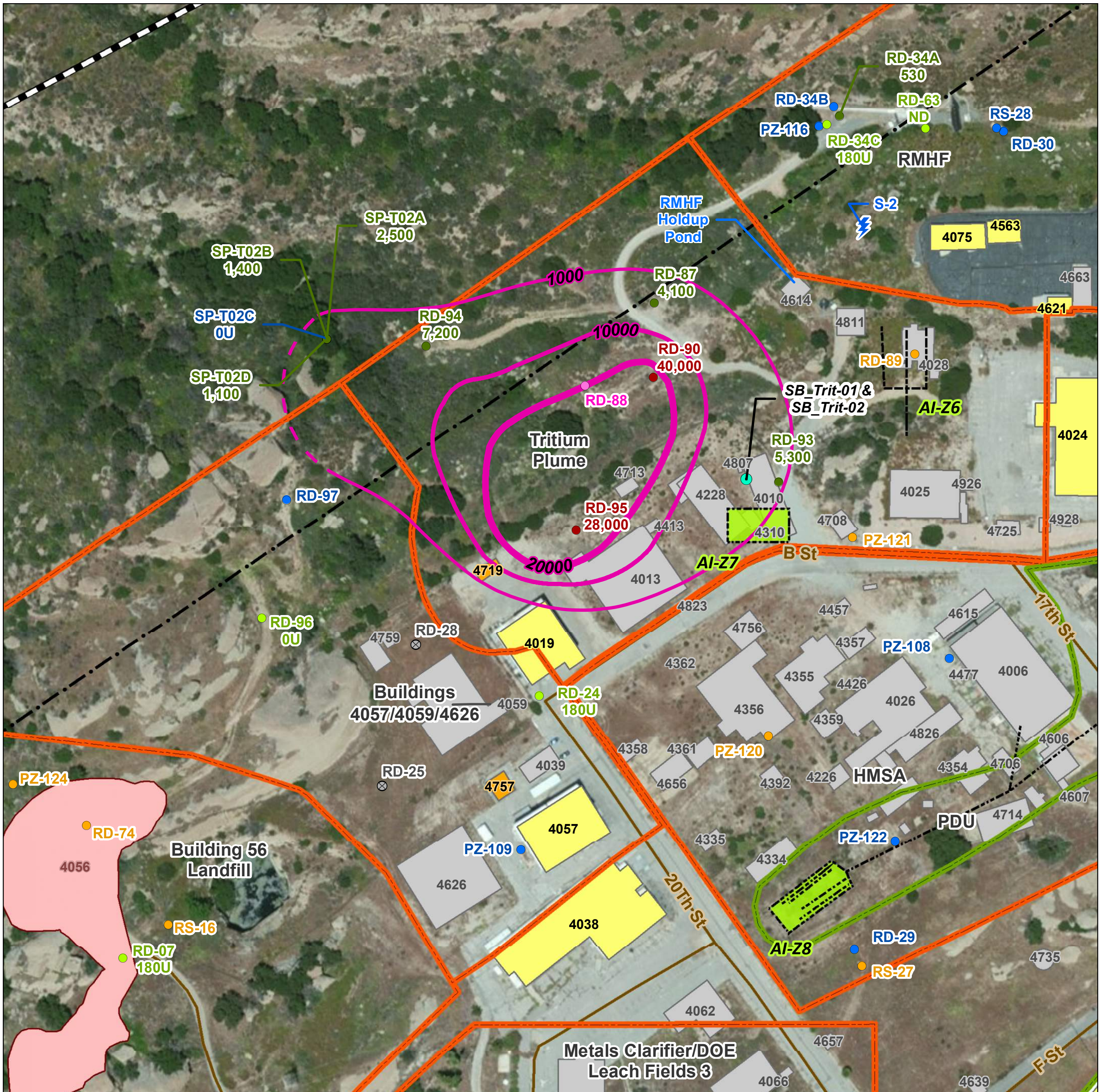


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_HMSA_PZ-120_Perf_Screen_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-21

TCE Concentrations in PZ-120



LEGEND

- Abandoned Well
- Tritium above MCL of 20,000 picocuries/L
- Tritium above detection limit, below MCL
- Tritium not detected above detection limits (ND)
- Tritium sample not collected
- Dry well or insufficient water for purging/sampling (<3 feet of water in wells designated for low-flow purging)
- Well available for sampling in February 2014
- Tritium Soil Boring Location
- Seep
- Tritium at 20,000 Picocuries/L
- Road Centerline
- AI-Zxx Leach Field*

Groundwater Investigation Area

- Boeing
- DOE
- Existing Landfill
- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

N

0 100 200 Feet

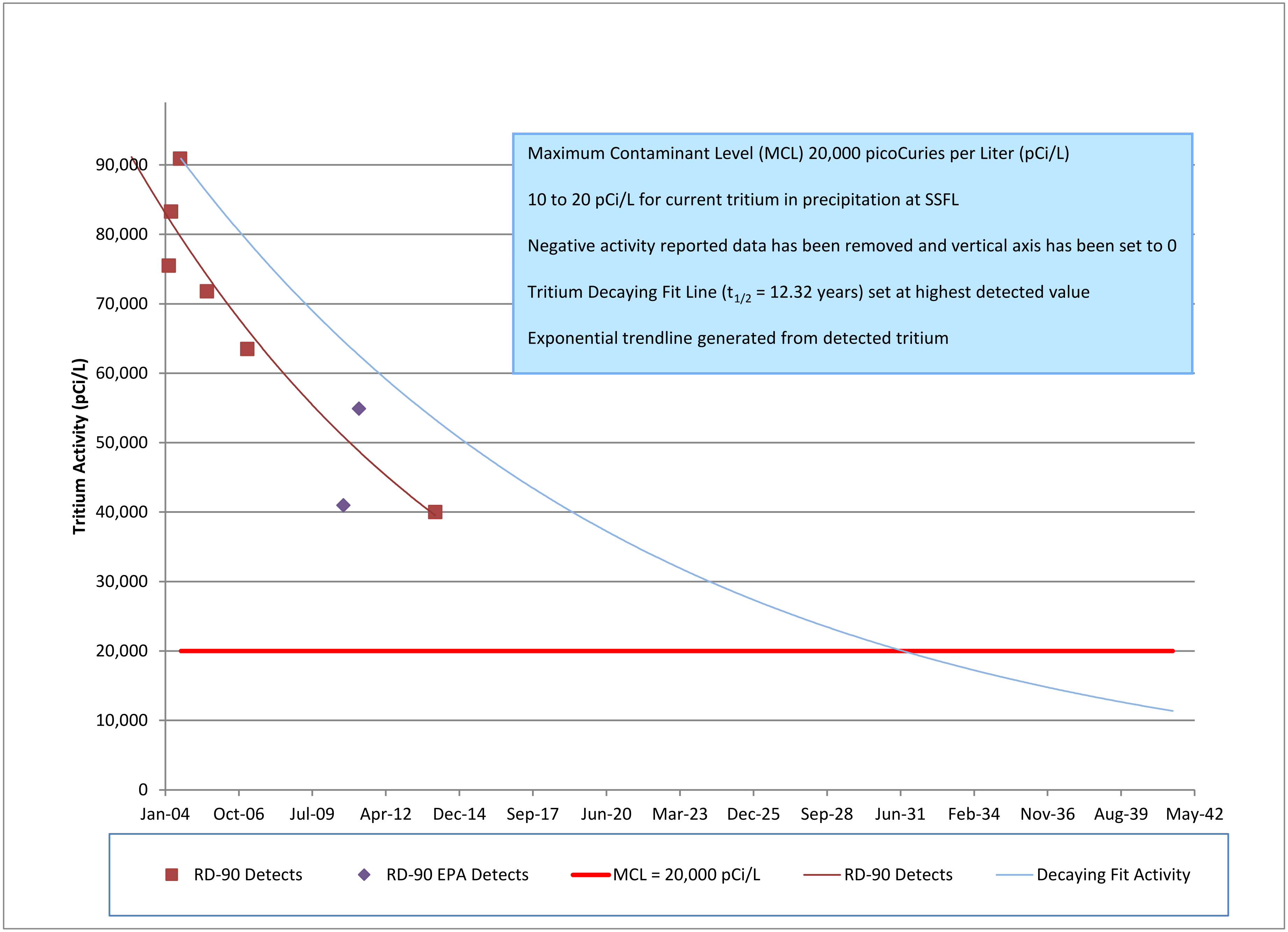
Notes:
- GIS Layers provided by MWH/Boeing.
- Plume boundary dashed where inferred.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Information provided by MWH following water level survey (February 2014).
- February 2014 Tritium results are picocuries/L.
- U or ND - Non-detected result.
- J - Estimated Result.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Tritium_Plume_Layout_20150615.mxd 6/19/2015

CDM Smith

FIGURE 4-22
Tritium Plume Layout

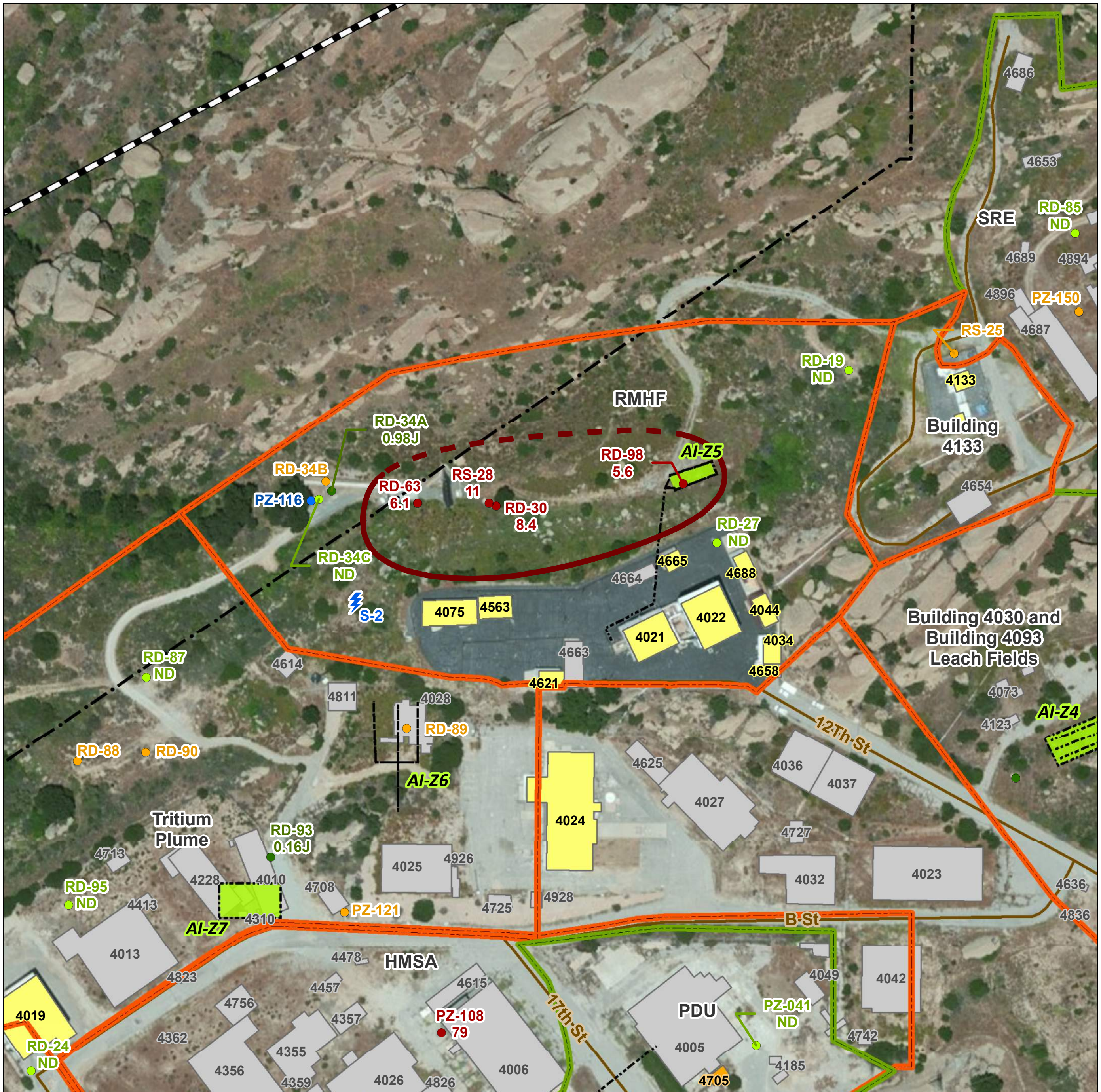


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_Tritium_Decay_RD-90_OpenHole_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-23

Tritium Activity and Decay in RD-90



LEGEND

- TCE Detected above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)

Abandoned Well

Available Well

Seep

TCE at 5 ug/L

Road Centerline

Leach Field*

Groundwater Investigation Area

Boeing

DOE

Existing Landfill

Existing Structure

Existing Substation

Demolished Structure

Area IV Boundary

SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Plume boundary dashed where inferred.
- Information provided by MWH following water level survey (February 2014).
- February 2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.

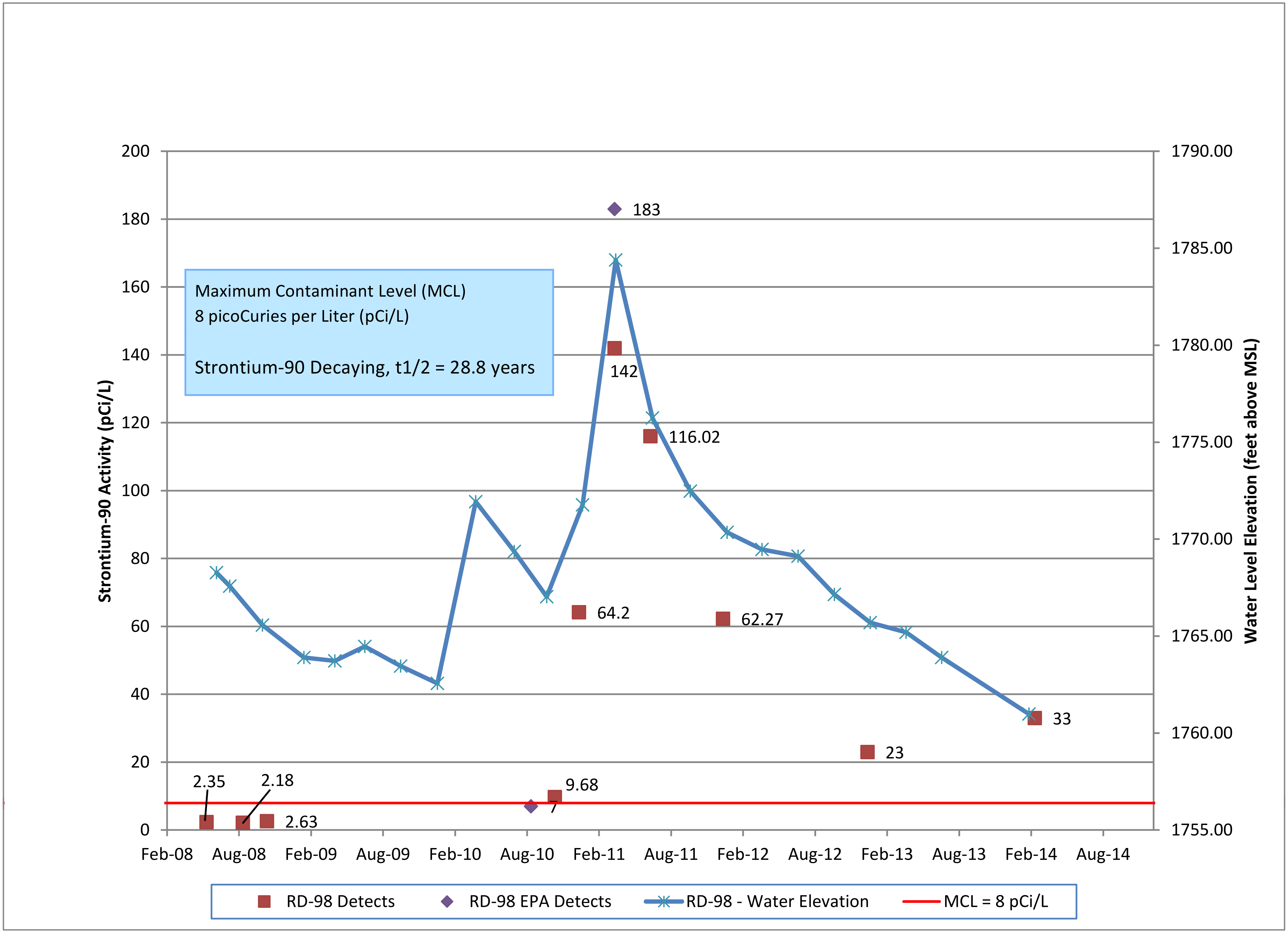
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_RMHF_Layout_20150601.mxd 6/19/2015

CDM Smith

FIGURE 4-24
RMHF Layout

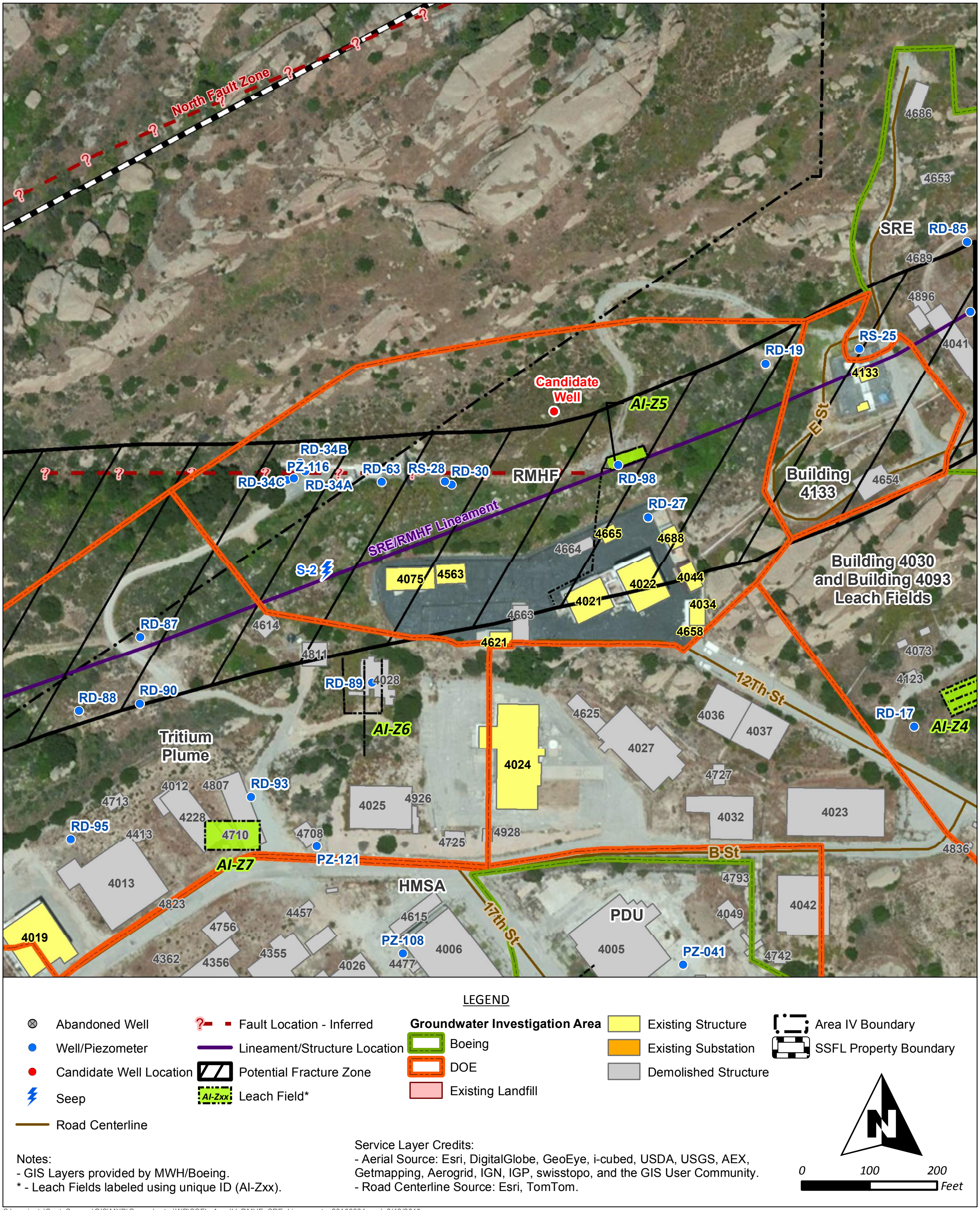


C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\TrendPlots\SSFL_AreaIV_Sr-90_GWElev_RD-98_TrendPlot.mxd 6/15/2015

CDM Smith

FIGURE 4-25

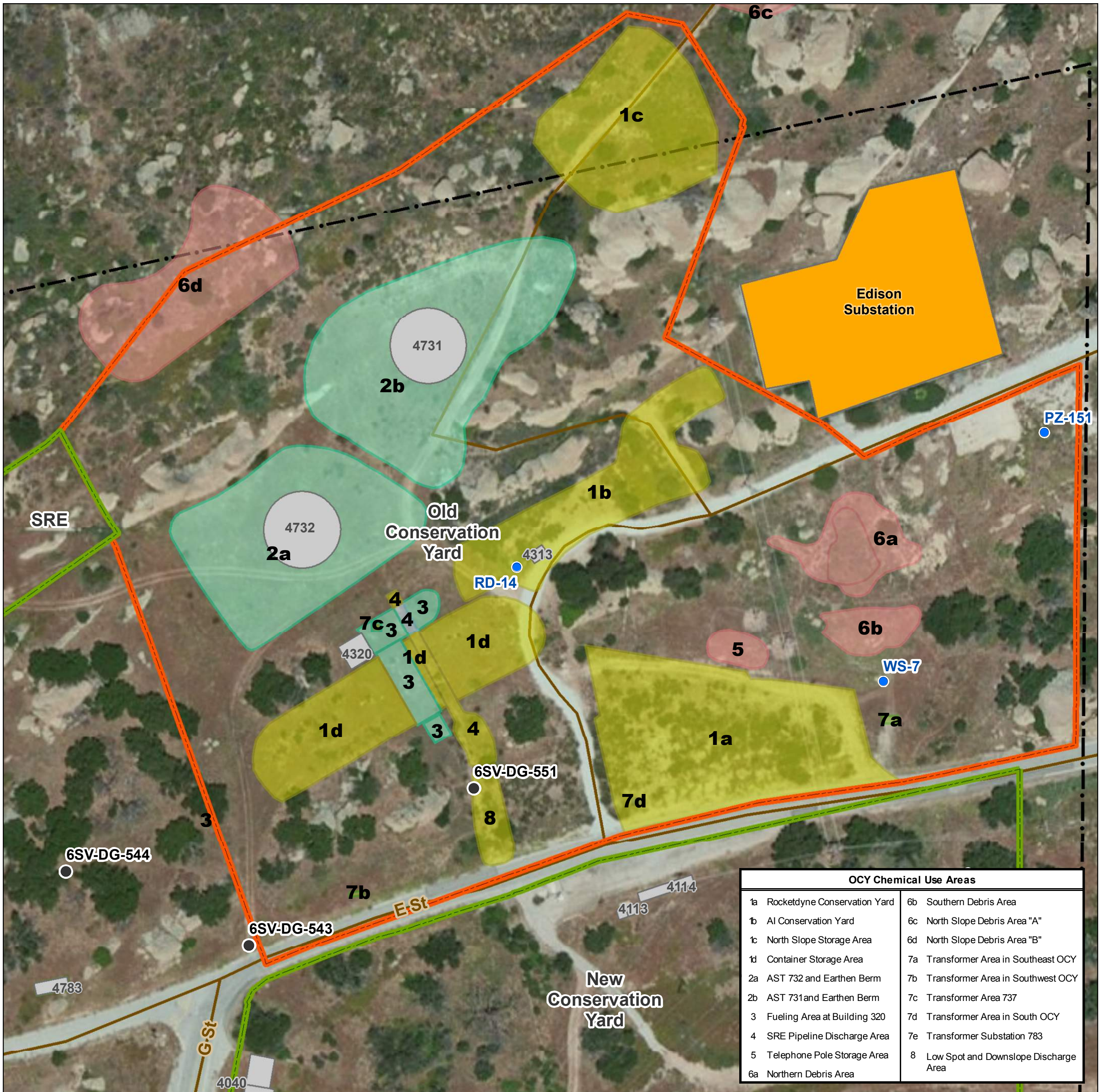
Sr-90 Activity and Groundwater Elevation at RD-98



C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_RMHF_SRE_Lineaments_20150601.mxd 6/19/2015

CDM Smith

FIGURE 4-26
Faults and Aerial Photo Lineaments in the Vicinity of the RMHF



LEGEND

Abandoned Well
Well/Piezometer
Soil Vapor Location
Road Centerline

Chemical Use Areas
Debris
Oil PCB
Petroleum
Potential
Screening

Groundwater Investigation Area
Boeing
DOE
Existing Landfill

Existing Structure
Existing Substation
Demolished Structure

Area IV Boundary
SSFL Property Boundary

N

0 75 150 Feet

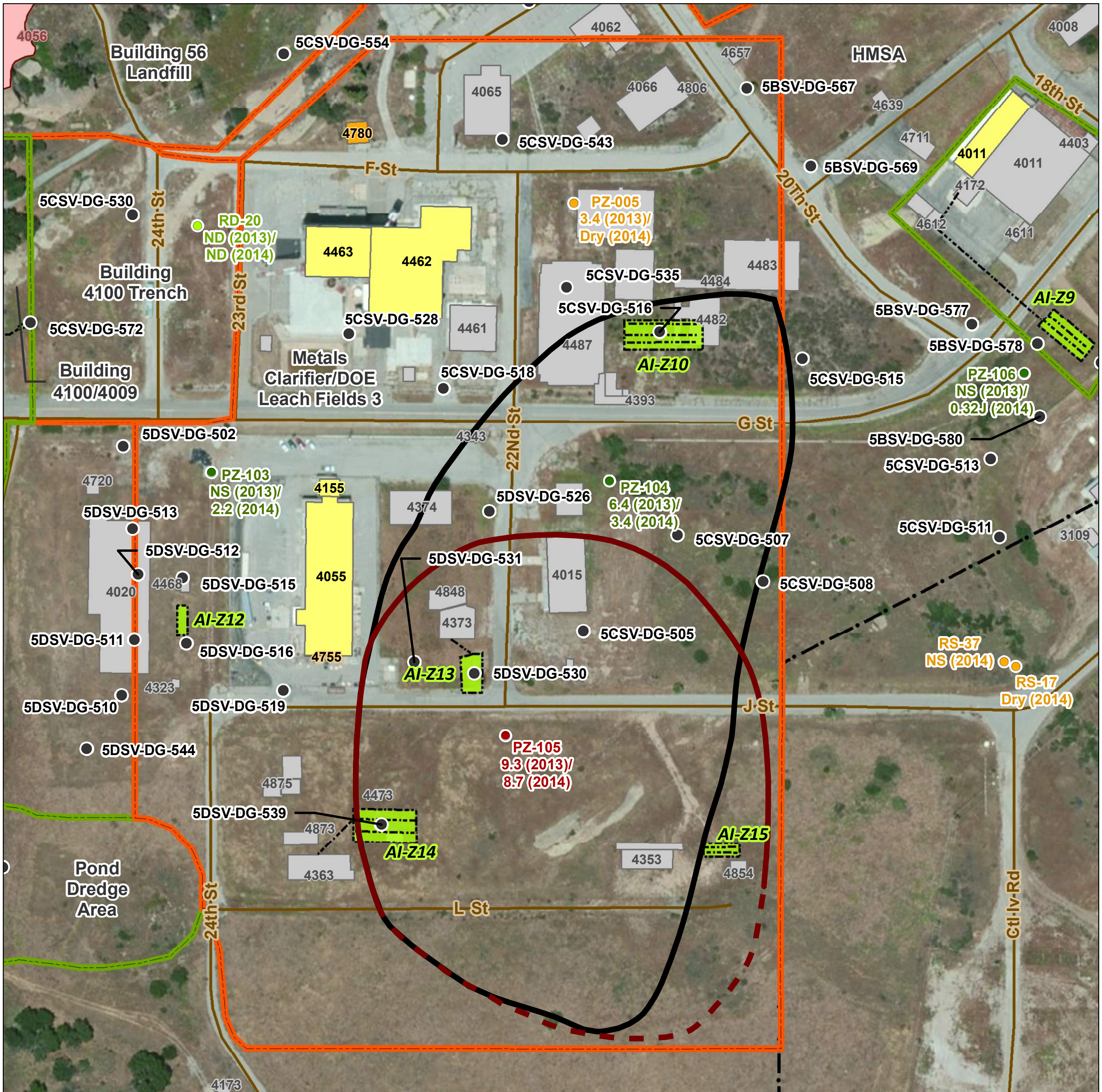
Notes:
- GIS Layers provided by MWH/Boeing.
- Soil Vapor Data Gap locations provided by MWH (2014).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_OCY_Layout_20150601.mxd 6/15/2015

CDM Smith

FIGURE 4-27
Old Conservation Yard Layout



LEGEND

- TCE Detected above MCL of 5 ug/L
- TCE above detection limit, below MCL
- TCE not detected above detection limits (ND)
- Dry well or insufficient water for purging/sampling (<3 feet of water in well designated for low-flow purging)
Abandoned Well
Well/Piezometer
Soil Vapor Location
TCE at 5 ug/L (2014)
TCE at 5 ug/L (2013)
Road Centerline
Leach Field*

Groundwater Investigation Area
Boeing
DOE
Existing Landfill

Existing Structure
Existing Substation
Demolished Structure
Area IV Boundary
SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Soil Vapor Data Gap locations provided by MWH (2014).
- Plume boundary dashed with question marks where inferred.
- Information provided by MWH following water level survey (February 2014).
- 2013/2014 TCE results are ug/L or ppb.
- U or ND - Non-detected result.
- J - Estimated Result.
- NS - Not Sampled for VOCs.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

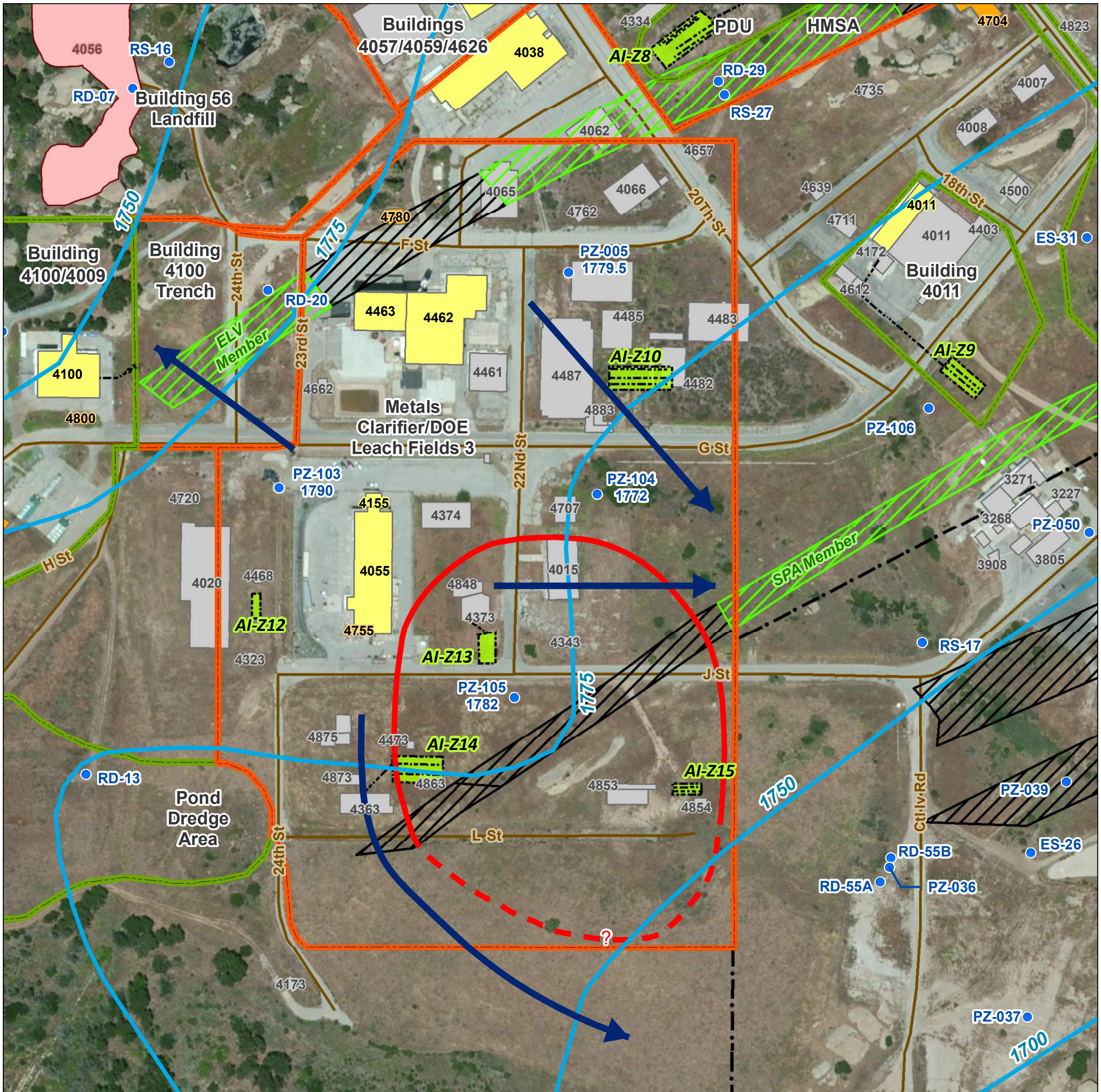
N

0 100 200 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_MetalsClarifier_Layout_20150601.mxd 6/15/2015

CDM Smith

FIGURE 4-28
Metals Clarifier/DOE Leach Fields 3 Layout



LEGEND

- Abandoned Well
- Well/Piezometer
- Road Centerline
- Near Surface Groundwater Flow
- TCE at 5 ug/L
- GW Elevation
- Approximate GW Elevation
- Fine-grained unit
- Area where fine-grained unit may be discontinuous
- AI-Zxx Leach Field*
- **Groundwater Investigation Area**
  - Boeing
  - DOE
- Existing Landfill
- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labled using unique ID (AI-Zxx).
- Plume boundary dashed with question marks where inferred.
- Groundwater Elevations provided by MWH (3rd Quarter 2013).
- Water levels are feet MSL and were collected in 2013.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

N

0 125 250 Feet

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_MetalsClarifier_PotSurface_2013_20150615.mxd 6/15/2015

CDM Smith

FIGURE 4-29

2013 Potentiometric Surface at Metals Clarifier/DOE Leach Fields 3

LEGEND

Abandoned Well
Well/Piezometer
Road Centerline
Leach Field*
Groundwater Investigation Area
Boeing
DOE
Existing Landfill
Existing Structure
Existing Substation
Demolished Structure
Area IV Boundary
SSFL Property Boundary

0 75 150 Feet

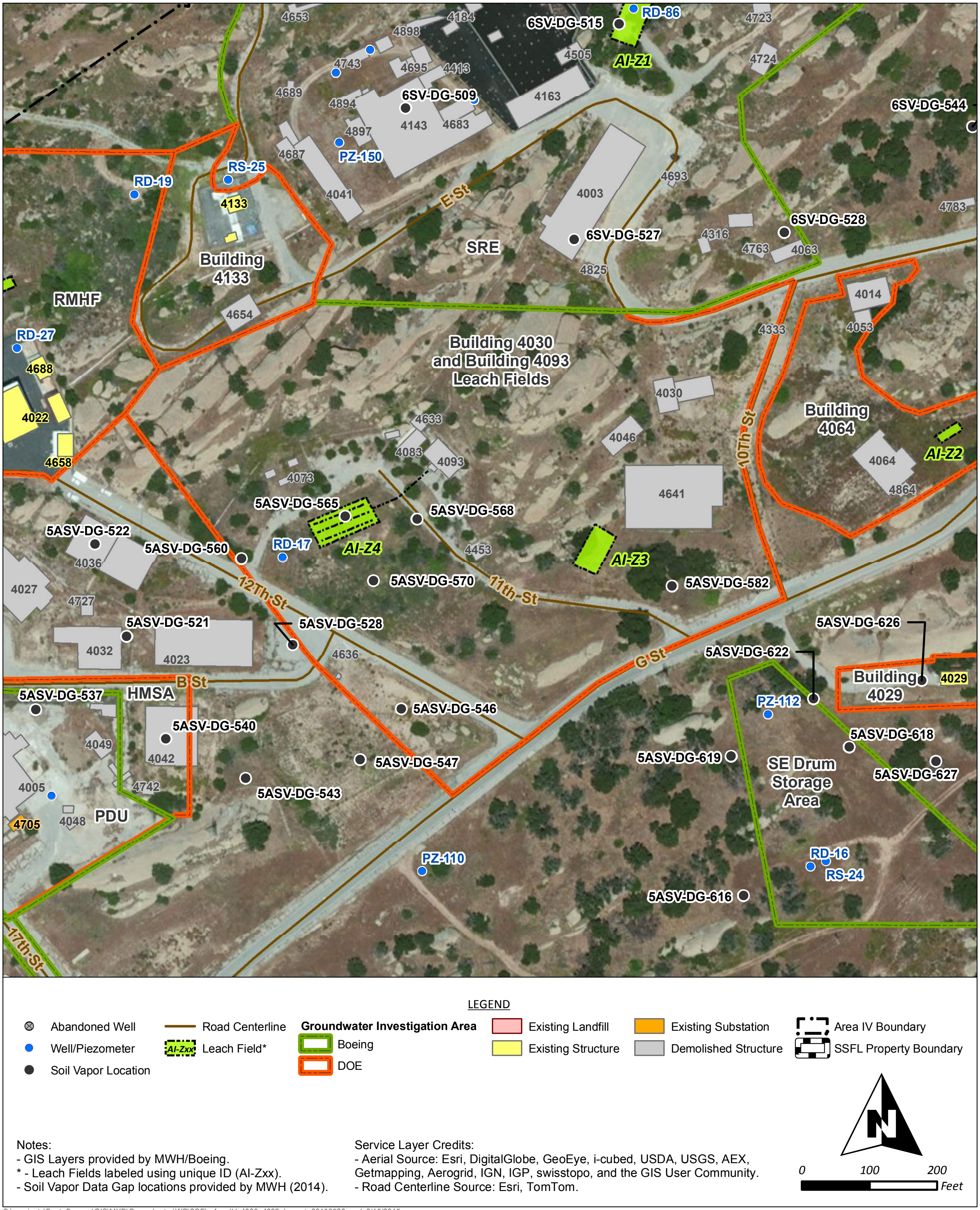
Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_B4064_Layout_20150601.mxd 6/1/2015

CDM Smith

FIGURE 4-30
Building 4064 Leach Field Layout



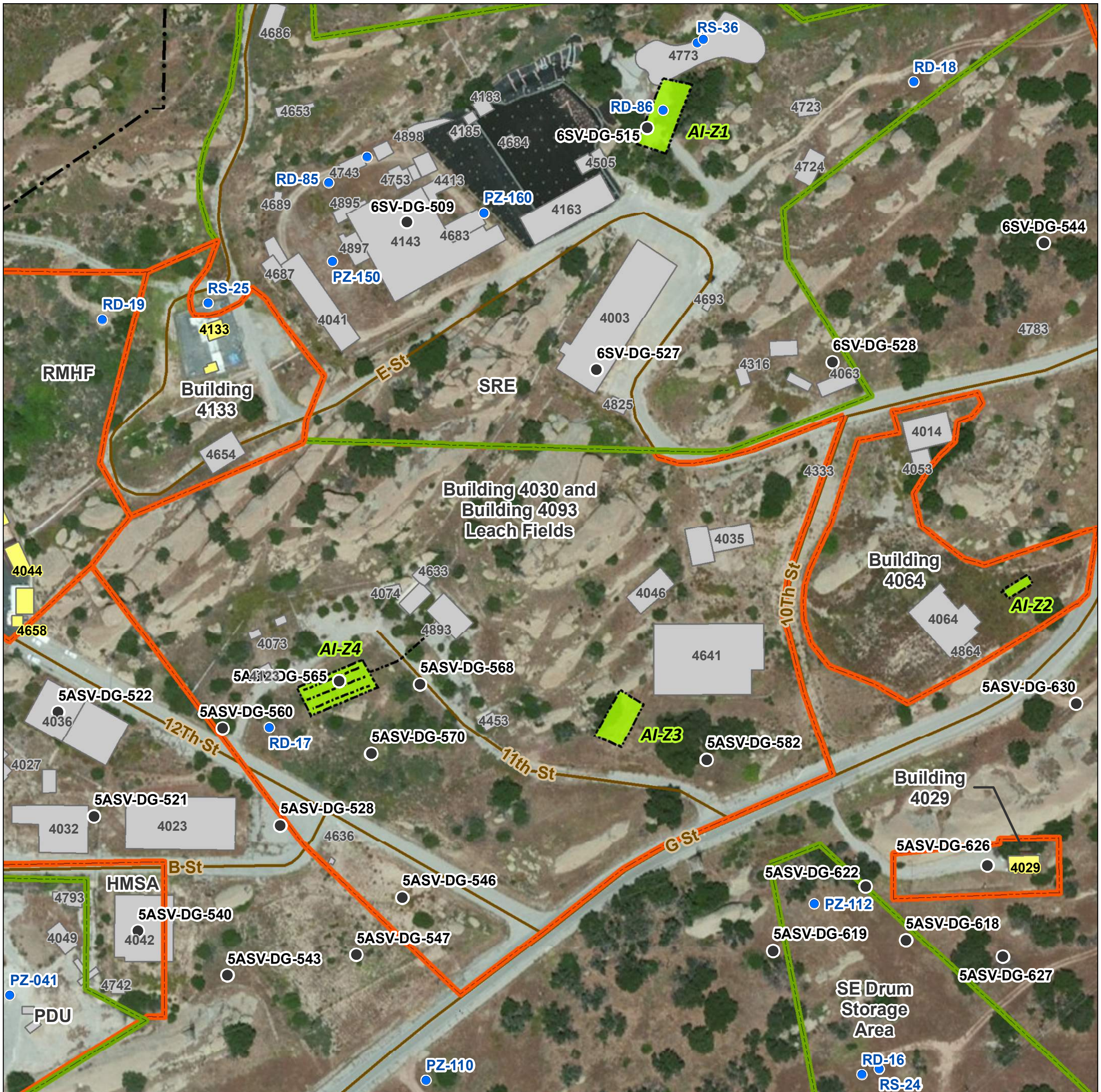
Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Soil Vapor Data Gap locations provided by MWH (2014).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_4030_4093_Layout_20150528.mxd 6/15/2015

CDM Smith

FIGURE 4-31
4030/4093 Leach Fields Layout



LEGEND

- Abandoned Well
- Well/Piezometer
- Soil Vapor Location
- Road Centerline
- Leach Field*

Groundwater Investigation Area

- Boeing
- DOE
- Existing Landfill
- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

0 100 200 Feet

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).
- Soil Vapor Data Gap locations provided by MWH (2014).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_HWMF_Layout_20150601.mxd 6/15/2015

CDM Smith

FIGURE 4-32

Building 4133/Building 4029 - Hazardous Waste Management Facility

Section 5

Seeps and Springs

The conceptual site model (CSM) for groundwater contaminant movement at Santa Susana Field Laboratory (SSFL) is that contaminants, once released into the aquifer, move with groundwater flow. Groundwater flow is typically downward and laterally through cracks and fractures in the sandstone bedrock, with some lateral flow emerging at the surface as seeps and springs (seeps), typically on the side slopes below SSFL (Groundwater Advisory Panel, 2009). Groundwater with site contaminants emerging on side slopes may pose a risk to the environment. The seeps also provide monitoring points for measuring impacted groundwater downgradient of source locations.

Investigation of the presence of seeps in areas surrounding SSFL was initiated in 1985 as part of field reconnaissance work to physically locate seeps on the ground. Since 1985, more than 160 seeps have been located in areas surrounding SSFL, with as many as 10 seeps being found in locations downgradient of the Area IV primary groundwater impact areas: Former Sodium Disposal Facility (FSDF), Building 56 Landfill, Tritium Plume, and Radioactive Materials Handling Facility (RMHF) trichloroethene (TCE)/strontium (Sr)-90 plume. **Figure 5-1** illustrates the locations of the key seeps relative to Area IV.

Investigation and sampling of seeps has been conducted under a series of work plans including MWH (2002), MWH (2010), and University of Guelph (2012a). An overall seeps investigation work plan for SSFL (Pierce et al., 2012) was approved by Department of Toxic Substance Control (DTSC) in December 2012. Results of the investigations have been reported in several documents including MWH (2003), MWH (2004), University of Guelph (2012b), and University of Guelph (2014).

Water quality of seeps downgradient of Area IV is being sampled using shallow monitoring probes or directly from seep discharge (for example, seep S-21). The probes were installed using either a Shaw Portable Core Drill (Shall Drill) or Winkie Drill. The probe at location SP-19A was installed using a hand auger. Installation details are provided in **Table 5-1**.

Table 5-1. Seep Cluster Construction Details

Seep Well	Date of Installation	Depth (feet)	Screen Interval (feet)	Outer Diameter (inches)	Material
SP-T02A	Dec 2013	9.48	7.5-9.48	0.840	PVC
SP-T02B	Dec 2013	12.42	10-12.42	0.840	PVC
SP-T02C	Jan 2014	24.3	19-24.3	0.840	PVC
SP-T02D	Dec 2013	35.18	30-35	0.840	PVC
SP-19A	Oct 2011	10.0	7-10	1.05	PVC
SP-19B	Oct 2011	18.83	16-18.8	1.05	PVC
SP-29A	NA	3.8	3.3-3.8	0.5	NA
SP-29B	NA	16.2	14.7-16.2	0.5	NA
SP-29C	NA	21.9	Water-filled Packer	1.65 core	NA
SP-424A	NA	8.8	3.3-8.8	0.5	NA
SP-424B	NA	16.9	15-16.9	0.5	NA
SP-424C	NA	19.6	16.6-19.6	0.5	NA
SP-900A	Oct 2013	10.0	3.736.6-10	0.840	PVC

Table 5-1. Seep Cluster Construction Details

Seep Well	Date of Installation	Depth (feet)	Screen Interval (feet)	Outer Diameter (inches)	Material
SP-900B	Oct 2013	18.41	16-18.41	0.840	PVC
SP-900C	Oct 2013	30.13	26.5-30	0.840	PVC

Notes:
Dec – December
Jan – January
Oct – October
PVC – Polyvinyl chloride
NA – Not applicable

The seep monitoring probes and Seep S-21 have been sampled at least once for volatile organic compounds (VOCs), metals, general minerals, and perchlorate. **Table 5-2** provides key results for carbon disulfide, toluene, TCE, perchlorate, and tritium. **Table 5-3** provides recent seep sample results for general hydrochemistry and inorganic parameters. [Note: These tables are incomplete in that they do not contain data for all of the seeps associated with Area IV. The authors of this Work Plan are still researching the database for seep results.]

Starting in 2015, all seep locations will be sampled for key analytes as part of the DOE Area IV groundwater monitoring effort. The analytes include water quality parameters, metals, VOCs, and tritium (see **Table 5-4**).

Table 5-2. Seep Cluster Analytical Results

		SP-19A	SP-19A	SP-19B	SP-19B	SP-21A	
Date		11/21/11	06/19/13	11/21/11	06/19/13	10/29/13	
Analyte	**Units**						
Carbon Disulfide	µg/L	<0.48	<0.48	<0.48	0.96J	NA	
Toluene	µg/L	<0.36	<0.36	0.54J	<0.36	<0.10R	
Trichloroethene	µg/L	<0.26	<0.26	<0.26	<0.26	<0.10R	
Perchlorate	µg/L	<0.95	NA	<0.95	NA	0.95U	
		SP-900A	**SP-900A**	**SP-900B**	**SP-900B**	**SP-900C**	**SP-900C**
Date		11/5/13	02/19/14	11/5/13	02/19/14	11/5/13	02/20/14
Carbon Disulfide	µg/L	<0.25	NA	<0.25	NA	0.63J	NA
Toluene	µg/L	1.3J	<0.17	1.2J	<0.17	12	0.25J
Trichloroethene	µg/L	<0.25	<0.16	<0.25	<0.16	<0.25	<0.16
Perchlorate	µg/L	<0.95		<0.95		<0.95	
		SP-T02A	**SP-T02B**	**SP-T02C**	**SP-T02D**		
Date		02/20/14	2/20/14	2/20/14	2/20/14		
Carbon Disulfide	µg/L	NA	NA	NA	NA		
Toluene	µg/L	0.75J	0.35J	0.44J	<0.17		
Trichloroethene	µg/L	<0.16	<0.16	<0.16	<0.16		
Perchlorate	µg/L	NA	NA	NA	NA		
Tritium	pCi/L	2,500	1,400	<260	1,100		

Notes:
µg/L – microgram per liter
pCi/L – picocuries per liter
< - Result is less than
NA – Not applicable
J- Value is estimated
R – Result is rejected

Table 5-3. Results of General Hydrochemistry and Metals Analysis

		SP-19A		SP-19B		SP-900A	SP-900B	SP-900C
Date		11/21/11	06/19/13	11/21/11	06/19/13	11/5/13	11/5/13	11/6/13
Analyte	**Units**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Calculated Parameters								
Anion Sum	me/L	10.5	9.99	20.7	20.5	9.24	40.4	31.7
Bicarb. Alkalinity (calc. as $CaCO_3$)	mg/L	301	270	392	400	310	370	360
Calculated TDS	mg/L	596	597	1210	1240	510	2500	1900
Carb. Alkalinity (calc. as $CaCO_3$)	mg/L	2	3	2	2.7	2.2	1.7	2.2
Cation Sum	me/L	9.81	10.4	19.3	21.8	9.07	38.7	31.9
Hardness ($CaCO_3$)	mg/L	280	300	620	720	360	1600	1300
Ion Balance (% Difference)	%	3.21	2.2	3.35	2.98	0.93	2.17	0.32
Langelier Index (@20C)	N/A	0.735	0.922	0.921	1.14	0.922	1.15	1.21
Langelier Index (@40C)	N/A	0.488	0.675	0.676	0.899	0.674	0.91	0.964
Saturation pH (@20C)	N/A	7.14	7.15	6.79	6.71	6.97	6.55	6.6
Saturation pH (@40C)	N/A	7.38	7.4	7.03	6.96	7.21	6.789	6.84
Inorganics								
Total Ammonia-N	mg/L	0.13	0.089	0.42	<0.050	0.16	ND	0.34
Conductivity	umho/cm	950	980	1800	1800	870	3200	2600
Fluoride (F-)	mg/L	NA	0.85	NA	1.32	0.56	0.25	0.24
Dissolved Organic Carbon	mg/L	0.9	3.9	2.7	4.2	1.8	1.3	3
Orthophosphate	mg/L	0.01	<.010	<0.01	<0.010	<0.010	<0.010	<0.010
pH	pH	7.87	8.07	7.71	7.86	7.89	7.7	7.81
Dissolved Sulfate (SO_4)	mg/L	150	160	460	460	91	1400	1000
Alkalinity (Total as $CaCO_3$)	mg/L	300	280	390	410	310	370	360
Dissolved Chloride (Cl)	mg/L	44	38	110	100	39	130	110
Nitrite (NO_2)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.010	<0.010	0.026
Nitrate (NO_3)	mg/L	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10
Nitrate + Nitrite	mg/L	<0.05	<0.10	<0.05	<0.10	<0.10	<0.10	<0.10

Notes:

me/L – millimol per liter

mg/L – milligram per liter

% - percent

µmho/cm – microhoms per centimeter

µg/L – microgram per liter

< - Result is non-detect

N/A – Not applicable

J- Value is estimated

R – Result is rejected

< - less than

$CaCO_3$ – calcium carbonate

N – Nitrogen

F- - Fluoride

SO_4 – sulfate

Cl – chloride

NO_2 – nitrite

NO_3 – nitrate

TDS – total dissolved solids

For completeness, groundwater monitoring parameters for seep wells at SSFL are presented in **Table 5-4** (DTSC, 2015).

Table 5-4. Groundwater Monitoring Parameters for Seep Wells Associated with Area IV

Location Name	Ref GIA Number(s) (Figure 2, 2010 SWWQSAP*)	Identified Groundwater Impacts (Table III 2010 SWWQSAP*)	Monitoring Schedule	
			Annually	Semi-Annually
Seep Cluster Monitoring Locations in or above Brandeis-Bardin Campus				
SP-900A SP-900B SP-900C	17	VOCs / 8260B Perchlorate / 314.0	All Wells	Sample Well with Highest GW Elevation
SP-19A SP-19B SP-19C	13	VOCs / 8260B 1, 4 Dioxane / 8260SIM Fluoride / 300.0 Metals / 6010, 6020 Sodium 6010 / 6010 Perchlorate / 314.0 Radiochemistry / 900.0, 901.1, 905.0, 906.0, 908.0	All Wells	Sample Well with Highest GW Elevation
SP-424A SP-424B SP-424C	13, 7	VOCs / 8260B 1, 4 Dioxane / 8260SIM Fluoride / 300.0 Metals / 6010, 6020 Sodium 6010 / 6010 Perchlorate / 314.0 Radiochemistry / 900.0, 901.1, 905.0, 906.0, 908.0	All Wells	Sample Well with Highest GW Elevation
SP-T02A ** SP-T02B ** SP-T02C ** SP-T02D **	Not applicable	VOCs / 8260B Radiochemistry / 900.0, 901.1, 905.0, 906.0, 908.0	All Wells	Sample all wells

* Haley and Aldrich, 2010

References

DTSC, 2015. *Seep Sampling at SSFL (e-mail from DTSC to DOE, Boeing, and NASA - DTSC identified seep cluster wells for monitoring)*. June.

Groundwater Advisory Panel, 2009. *Site Conceptual Model for the Migration and Fate of Contaminants in Groundwater at the Santa Susana Field Laboratory, Simi, California*. December

Haley & Aldrich, 2010. *Site-Wide Water Quality Sampling and Analysis Plan, Revision 1*. December.

MWH, 2002. *Spring and Seep Sampling Work Plan, Santa Susana Field Laboratory, Ventura County, California.* March

MWH, 2003. *Spring and Seep Sampling and Analysis Report, Santa Susana Field Laboratory, Ventura County, California.* March.

MWH, 2004. *Technical Memorandum Spring and Seep Field Reconnaissance, Santa Susana Field Laboratory, Ventura County, California*. December.

MWH, 2010. *Groundwater Remedial Investigation Data Gap Sampling and Analysis Plan, Santa Susana Field Laboratory, Ventura County, California*. March.

Pierce, A., Parker, B., and Cherry, J. 2012. *Workplan for Completion of Seeps and Springs Investigation at the Santa Susana Field Laboratory, Ventura County*. CA.

University of Guelph, 2009. *Review of 2006 and 2007 Data. Seeps and Springs Study, Santa Susana Field Laboratory, Ventura County, California*.

University of Guelph, 2012a. *Work Plan for Completion of Seeps and Springs Investigation at Santa Susana Field Laboratory, Ventura County, California*.

University of Guelph, 2012b. *Seeps and Springs Study, Installation of Well Clusters: Overview of 2011 Field Work.* May

University of Guelph, 2014. *Technical Memorandum, Area IV Seeps Investigation, Santa Susana Field Laboratory, Ventura County, California*. October.

Section 6
Fault Studies

Geologic faults can be zones of interconnected fractures and, therefore, can potentially provide a conduit or a barrier for the transport of groundwater through the fractured rock aquifer.

Three geologic structures – the Burro Flats fault, the Northern fault, and the Sodium Reactor Experiment-Radioactive Materials Handling Facility (SRE-RMHF) lineament – are being evaluated to determine if additional studies were required to determine if they are acting as hydraulic conduits for contaminated groundwater. The Burro Flats fault and the SRE-RMHF lineament were selected for evaluation relative to United States Department of Energy (DOE)-responsibility Area IV groundwater issues due to their proximity to known contaminant sources and plumes. The Northern fault is a common feature along the northern boundary of Santa Susana Field Laboratory (SSFL).

To address a data gap discussed in the Groundwater Remedial Investigation (RI) (RFI) Report (MWH, 2009), MWH investigated lineaments located in parallel drainages north of the Former Sodium Disposal Facility (FSDF) as potential geologic features that could restrict or redirect groundwater movement. The FSDF "structures" were identified as lineaments that could be faults. Groundwater flow modeling at that time simulated groundwater flow convergent along the structures. To address these issues, MWH excavated four trenches within the drainages for visual observations of soil, weathered bedrock, and bedrock conditions. Based on their observations, MWH concluded that the lineaments referred to as FSDF structures should no longer be classified as faults (or fracture zones [MWH, 2013]). Therefore, no further investigation of the FSDF structures is proposed.

6.1 Northern Fault Zone

A long, generally east-west oriented structural feature is found along the northern boundary of the SSFL (**Figure 6-1**). Per the Groundwater RI (RFI) Report, the Northern fault may also be along the northern boundary of the NBZ above Area IV. The western portion of the fault consists of a 600- to 800-foot-wide zone of relatively closely spaced deformation bands. While the feature is identified as a fault in the eastern part of the SSFL (Area I), the physical characteristics of the western extension (north of Area II and IV) are not known. In these areas it is recognized as an aerial photo lineament or probable fault. The projected location of the Northern fault is north of the Tritium plume area and RMHF trichloroethene (TCE) plume. For the RMHF TCE plume, the closest well to the fault (RD-34B), 200 feet to the south, exhibits TCE less than the maximum contaminant level (MCL). Neither area of impacted groundwater is anticipated to reach the Northern fault feature at concentrations exceeding their respective MCLs. DOE proposes to incorporate data regarding the Northern fault from studies being conducted by Boeing and National Aeronautics and Space Administration (NASA). This information will be incorporated into DOE's Area IV Groundwater RCRA Facility Investigation (RFI) Report, as appropriate.

6.2 SRE-RMHF Lineament

The SRE-RMHF lineament (**Figure 4-26**) is oriented east-northeast/west-southwest and appears to be associated with the SRE drainage and the drainage immediately north of the RMHF. The lineament trace is a zone of unknown width. Several bedrock monitoring wells are installed along the lineament, including the RD-34 well cluster, RD-63, RD-30, RD-98 in the RMHF drainage, and potentially RD-19, RD- 85, and RD-86 within the area of the SRE. The 2014 potentiometric data from the Chatsworth Formation aquifer indicates that groundwater flow in this area is to the northwest (**Figure 2-3**). However, it appears that contamination originating at the RMHF leach field may follow the drainage to the west (**Figure 4-26**). The lineament may be a zone of fractured rock that promotes the transmission of groundwater.

The candidate well proposed for installation northwest (downgradient) in the RMHF groundwater investigation area will provide additional information about the character of groundwater flow in the lineament:

- Water level data, used in conjunction with data from other wells in the northwest part of Area IV, will help define the direction of flow.
- The presence or absence of TCE may also indicate the direction of groundwater flow (migration of contamination).
- Borehole geophysics will provide an indication of the degree of fracturing. A higher degree of fracturing may indicate that the well is located within a fracture zone associated with the lineament.

6.3 Burro Flats Fault

The Burro Flats fault (**Figure 6-1**) is an east-west oriented fault that extends the length of the SSFL property along its southern boundary. For Area IV the fault demarks the abutment of the Chatsworth Formation with the Santa Susana Formation. In the conceptual model for the FSDF (and Empire State Atomic Development Authority [ESADA], a Boeing responsibility) groundwater investigation areas the Burro Flats fault is assumed to mark the southern extent of TCE and provide a hydraulic barrier because the fault juxtaposes the sandstones of the Chatsworth Formation on the north with the less permeable micaceous claystone and siltstone of the Santa Susana Formation on the south. The location of monitoring well RD-50 in relation to the Burro Flats fault is not known. The boring log indicates that the well is constructed in sandstones suggesting that it is located on the north (Chatsworth Formation) side of the fault.

Groundwater Resources Consultants (GRC) performed a hydraulic communication study at SSFL in 1996 (GRC, 1997). A number of extraction wells were activated and water levels monitored in bedrock wells. Water supply well WS-9A, located almost 4,000 feet east along the Burro Flats fault from RD-50, was used for the test. Changes in water levels in RD-50 during that 45-day test period could not be attributed to activation or deactivation of WS-9A or any other of the pumping wells. Other wells along the fault, including wells much closer to WS-9A, also did not show a lowering of water levels during pumping.

Studies will be performed on RD-50 (as part of the FSDF groundwater investigation area) to clarify its relationship to the fault:

- To determine if the well is open within the Chatsworth Formation or the Santa Susana Formation, water quality data (calcium carbonate) will be collected for comparison to data from wells whose construction is known.

- Borehole geophysics and video logging will be performed to identify fractures and bedding planes. A high density of fractures may indicate that RD-50 is within a fracture zone created by the fault.
- During the FSDF groundwater interim measure (GWIM), nearby wells (e.g., RD-21) will be pumped while the water level in RD-50 is monitored. This will provide information concerning the hydraulic connection to the other and the presence and concentration of contaminants of concern (COCs) at the FSDF (and ESADA areas).

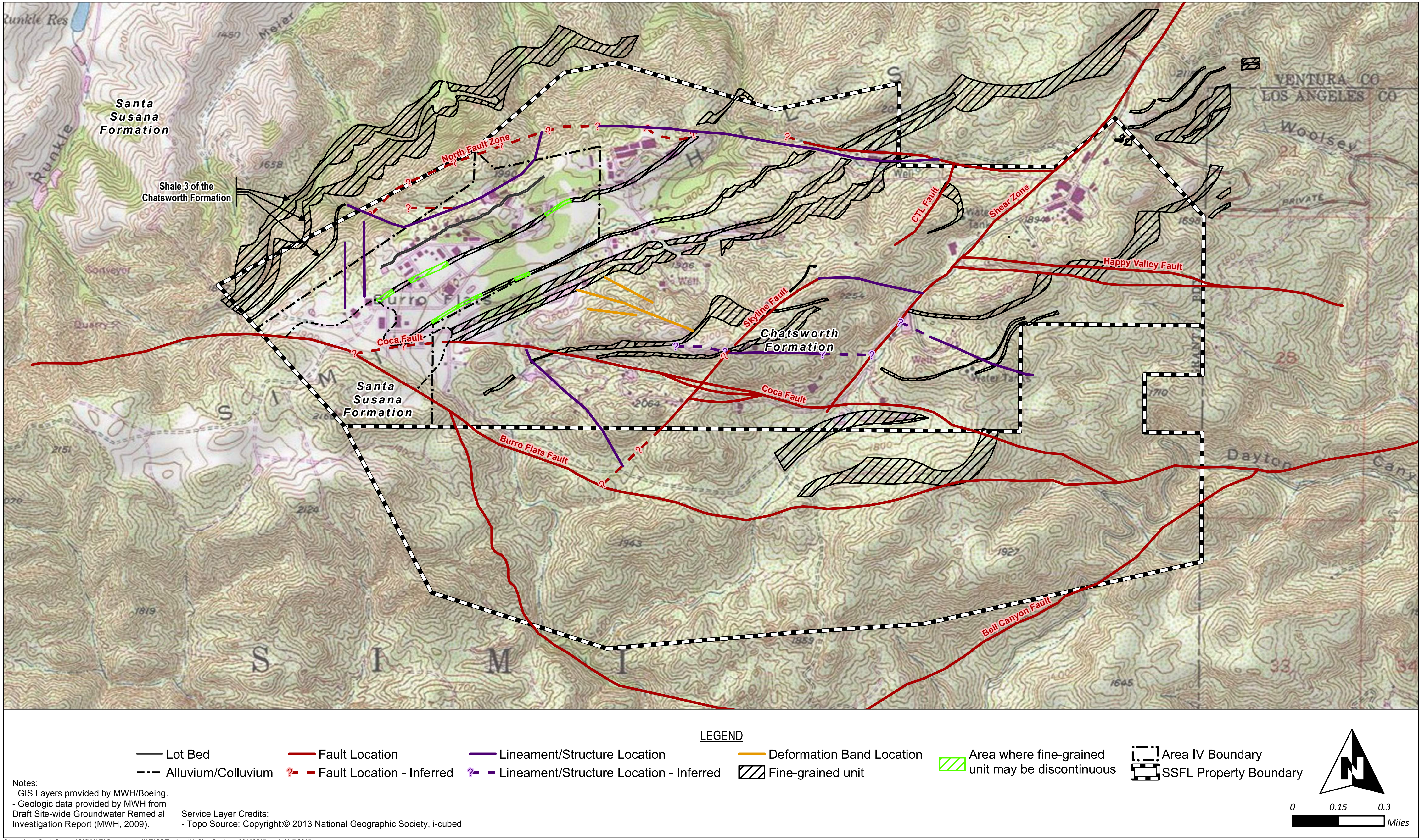
References

GRC, 1997. *Hydraulic Communication Study, Santa Susana Field Laboratory, Boeing North American, Inc., Ventura County, California.*

MWH, 2009. *Draft Site-Wide Groundwater Remedial Investigation Report.*

MWH, 2013. *Technical Memorandum, Results of Geologic Mapping and Excavations along the Western and Easter FSDF Structures (Photolineaments) Area IV*.

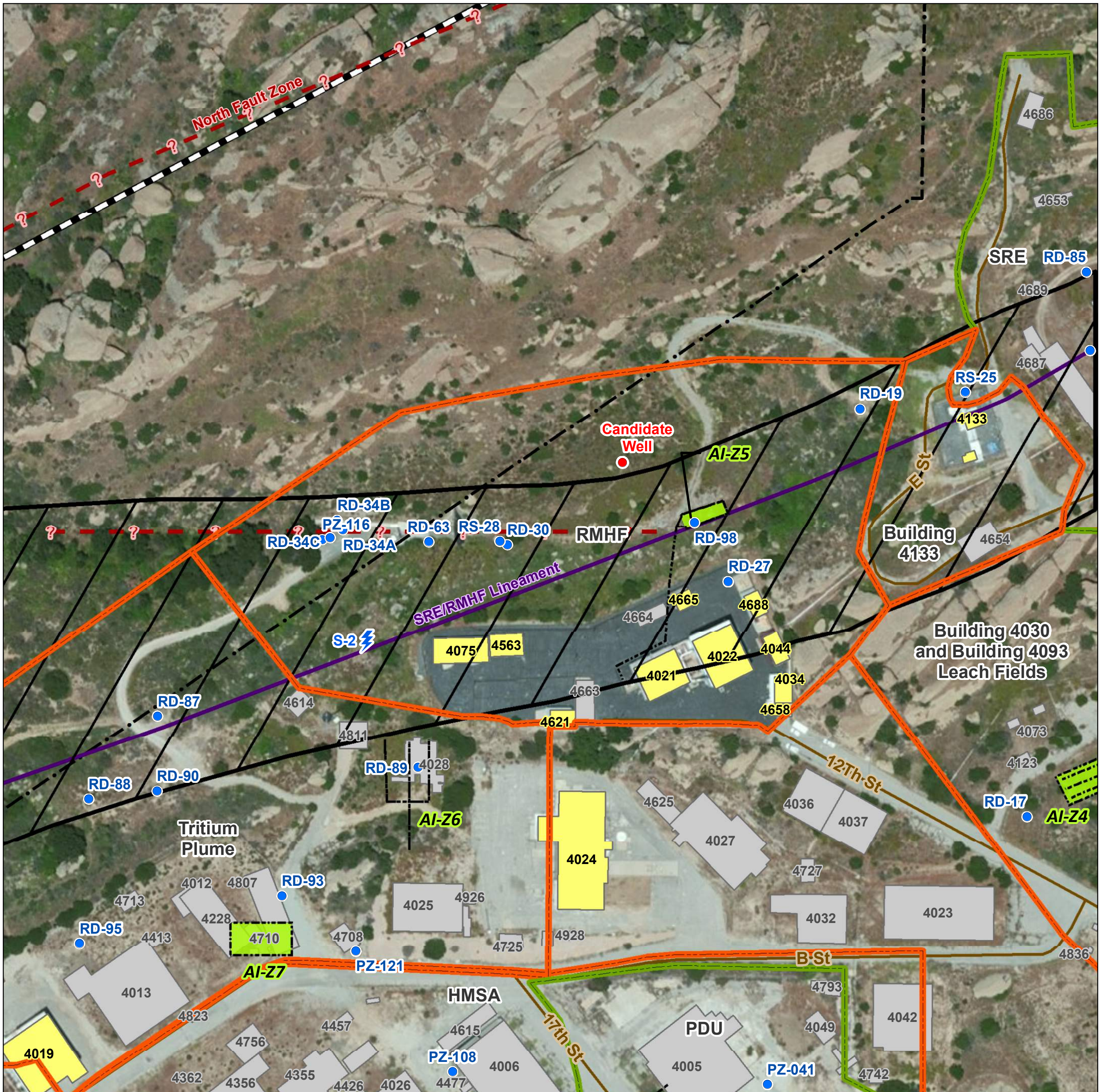
This page intentionally left blank.



C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_Site_Geology_20150617.mxd 6/17/2015

CDM Smith

FIGURE 6-1
SSFL Geology



LEGEND

- Abandoned Well
- Well/Piezometer
- Candidate Well Location
- Seep
- Road Centerline
- Fault Location - Inferred
- Lineament/Structure Location
- Potential Fracture Zone
- AI-Zxx Leach Field*

Groundwater Investigation Area
- Boeing
- DOE
- Existing Landfill

- Existing Structure
- Existing Substation
- Demolished Structure
- Area IV Boundary
- SSFL Property Boundary

0 100 200 Feet

Notes:
- GIS Layers provided by MWH/Boeing.
* - Leach Fields labeled using unique ID (AI-Zxx).

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_RMHF_SRE_Lineaments_S6_20150601.mxd 6/19/2015

CDM Smith

FIGURE 6-2
Faults and Aerial Photo Lineaments in the Vicinity of the RMHF

Section 7

Flow and Transport Modeling

Note to reviewers: United States Department of Energy (DOE) is in the process of acquiring the services of Dr. Scott James of Baylor University and Dr. Bill Arnold to lead the efforts for the update of the flow and transport models that reflect Area IV conditions. One of their first tasks will be to provide a more detailed discussion relative to proposed model updates, input parameters, and expected model outputs.

The Santa Susana Field Laboratory (SSFL) is perhaps the most studied and characterized fractured sandstone mountain in the State of California. Extensive efforts led by MWH America's, Inc. (MWH) and the university team, as funded by Boeing, have yielded a comprehensive site-wide (mountain-scale) flow model, which has been extensively calibrated against site-wide data (MWH, 2009). While the overall applicability and accuracy of the model is commendable, it must be noted that it was built and calibrated with the overarching goal of reflecting mountain-scale flows (magnitudes and directions) with particular emphasis on Areas I and III, areas that Boeing has direct responsibility and reflecting the portions of SSFL with the greatest groundwater impact by solvents. Because the model was developed to reflect site-wide groundwater flows (general flow directions and magnitudes), it does not represent a fine level of detail and does not claim to honor all known and inferred groundwater flow directions. In particular, because of the way that site characterization data are included into the calibration process, areas with higher data density tend to be those where the model is most accurate. Hence, Areas I and III are likely to be most accurate in this mountain-scale model.

While DOE acknowledges the significant effort that has been spent calibrating the mountain-scale model, DOE believes that it does not characterize the flow paths in Area IV with sufficient accuracy to make important investigation and remediation decisions. To improve DOE's ability to predict flow and transport in Area IV, a local-scale flow and transport model using the Finite Element Head and Mass Transfer Code (FEHM) software was completed (Kelkar and Zyvoloski, 1991; Zyvoloski, Robinson et al., 1997; Dash, 2005). The numerical model was built by and is currently being maintained by Los Alamos National Laboratory (LANL) using funding provided by DOE. Because an enormous amount of data are available with which to develop a flow and transport model for the SSFL site as a whole, development of a FEHM flow and transport model of Area IV should be relatively straightforward. The grid will be developed with Los Alamos Grid Tool Box (LAGriT) (LANL, 2001) and populated with the same hydrostratigraphic unit data used in the regional-scale model, but incorporating more details for Area IV hydrogeologic features. Because the model domain will encompass only Area IV and extend only so far outside as to ensure appropriate locations of boundaries, it can be more refined than the grid used in the regional-scale model. Lateral boundaries of the local-scale model could be specified to be consistent with fluxes extracted from the regional-scale model if desired. In addition, because the model will only be calibrated against data within the model domain, it will necessarily honor the data in Area IV and ensure that known local flow directions are accurately reflected. The new model will incorporate more recent data and data proposed for collection in this Work Plan (e.g., selective interval sampling, recent water levels data, updated groundwater chemistry, new seep cluster well data, results of trenching the Former Sodium Disposal Facility [FSDF] structures, etc.) for improved calibration and hypothesis testing.

The FEHM code has several options and features for contaminant transport simulations including particle tracking, matrix diffusion, sorption, dispersion, radioactive decay, and chemical degradation. FEHM is also capable of modeling unsaturated and saturated flow, using simplified representations of vadose zone flow or full multi-phase flow. Gas and vapor phase transport can also be simulated. The same software used to calibrate the regional-scale model, Model Independent Parameter Estimate and Uncertainty Analysis (PEST) (Doherty 2009, Doherty 2010), will be used to calibrate the FEHM model specifically to Area IV data. FEHM has been extensively integrated with PEST and is an appropriate choice of modeling tools for the site (Zyvoloski, Kwicklis et al. 2003; James, Doherty et al. 2009). It is anticipated that simulated flow directions and particle paths in Area IV will be sufficiently accurate such that important remediation decisions can be made by DOE and Department of Toxic Substances Control (DTSC).

7.1 Groundwater Modeling Approach for Area IV

The approach for the Area IV groundwater flow and transport modeling in Area IV in support of completing the groundwater RFI involves implementing sequential activities described in this section. These activities address increasingly complex objectives of the modeling, which will be based on regulatory requirements and the development of the corrective measures study.

Activity 1 – Steady-state particle tracking with the updated mountain-scale groundwater flow model

Objectives:

- Delineate general flow paths and potential discharge locations from sites of groundwater contamination.

Tasks:

- Correct representation of the FSDF structures and other geological features.
- Incorporate new water-level measurements in the flow model calibration.
- Run particle tracking from sites of known contamination in Area IV.

Implementation:

- Use the existing mountain-scale flow model, as implemented in the FEFLOW software, with minor changes to include calibration to the new water-level measurements.

Activity 2 – Steady-state contaminant transport modeling with a higher-resolution model of Area IV

Objectives:

- Predict flow paths and contaminant transport times from sites of groundwater contamination at the resolution of small- to medium-sized sources.
- Include contaminant transport processes of advection, dispersion, matrix diffusion, sorption, and contaminant degradation in migration predictions.

Tasks:

- Generate a higher-resolution grid of the Area IV groundwater flow system alone.
- Extract groundwater flow values for Area IV from the mountain-scale flow model to specify boundary conditions in the new model.
- Correct representation of the FSDF structures and other geological features.
- Incorporate new water-level measurements in the flow model calibration.
- Evaluate variations in transport parameters in Area IV, such as fracture spacing, fracture aperture, and matrix porosity to include in transport modeling.

Implementation:

- Create a new sub-model for Area IV implemented with the FEHM software, and contaminant transport using the resident time distribution particle tracking method. (Note that contaminant transport capabilities in FEFLOW may permit use of this software, but such implementation has not been demonstrated).

Activity 3 – Transient contaminant transport modeling with very high-resolution model(s) of individual contaminant plumes

Objectives:

- Predict transient groundwater flow and contaminant transport from sites of groundwater contamination at the resolution of individual sources, plumes, and wells.
- Include contaminant transport processes of advection, dispersion, matrix diffusion, sorption, and contaminant degradation.
- Do predictive planning for potential remediation options, including pump-and-treat.

Tasks:

- Generate a high-resolution grid(s) of the area around individual contaminant plumes.
- Extract groundwater flow values around plumes from the mountain-scale flow model or the Area IV flow model to specify boundary conditions in the plume model(s).
- Incorporate heterogeneity in aquifer properties at the scale of individual well logs.
- Use data on contaminant concentrations in wells for model calibration.

Implementation:

- Create a new sub-model(s) for areas around individual plumes implemented with the FEHM software, and contaminant transport using the finite-element and dual-porosity transport methods.

References

Dash, Z., 2005. *Software Users Manual (UM) for the FEHM Application Version 2.30. Los Alamos, NM, Los Alamos National Laboratory*: 205.

Doherty, J. E., 2009. *Manual for PEST: Model Independent Parameter Estimation. J. E. Doherty. Brisbane, Australia, Watermark Numerical Computing*: 336.

Doherty, J. E., 2010. *Addendum to the PEST Manual. J. E. Doherty. Brisbane, Australia, Watermark Numerical Computing:* 131.

James, S. C., J. E. Doherty and A.-A. Eddebbarh, 2009. "*Practical postcalibration uncertainty analysis: Yucca Mountain, Nevada.*" Ground Water 47(6): 851-869.

Kelkar, S. and G. A. Zyvoloski, 1991. *An efficient, three dimensional, fully coupled hydro-thermalmechanical simulator: FEHMS. SPE Symposium for Reservoir Simulation*. Anaheim, CA.

LANL, 2001. *Software Code: LAGriT V1.0*. Los Alamos, NM, Los Alamos National Laboratory.

MWH, 2009. *Draft Sitewide Groundwater Characterization Report, Santa Susana Field Laboratory, Ventura County, California*.

Zyvoloski, G. A., E. Kwicklis, A.-A. Eddebbarh, B. Arnold, C. Faunt and B. A. Robinson, 2003. "*The site-scale saturated zone flow model for Yucca Mountain: Calibration of different conceptual models and their impact on flow paths*." Journal of Contaminant Hydrology 62-63: 731-750.

Zyvoloski, G. A., B. A. Robinson, Z. V. Dash and L. Trease, 1997. *Summary of the models and methods for the FEHM application – A finite element mass- and heat-transfer code*. Los Alamos, NM, Los Alamos National Laboratory.

Section 8

Study of Contaminant Fate

Section 4 introduced groundwater investigation areas (GIAs) with corresponding data that potentially indicate the presence of decomposition or reduction in concentration of groundwater contaminants, particularly in relation to chlorinated solvents. This section builds upon that information addressing contaminant fate and whether natural attenuation may be occurring, how monitored natural attenuation (MNA) may be demonstrated, and the potential for the native hydrogeochemical system's ability to attenuate and degrade site-related chemicals present in groundwater.

In 2013, *Summary of Groundwater Sampling Results to Support Area IV Environmental Impact Statement, Santa Susana Field Laboratory, Ventura County, CA* (MWH America's, Inc. [MWH], 2013) was submitted to Department of Toxic Substance Control (DTSC). This document discussed activities performed to evaluate MNA within Area IV. DTSC provided comments on this document (DTSC, 2014), which included a request to submit a new work plan to determine the nature and extent of groundwater contaminants and the effectiveness of natural degradation processes in Area IV. This section provides the planned work elements to address the latter of the two subject matters commented by DTSC – the effectiveness of natural degradation processes in Area IV. DTSC provided guidance on what the agency would need to see for MNA demonstration. Questions raised by DTSC that will be answered during the MNA evaluation include:

- Has degradation of chlorinated solvents occurred in Area IV?
- Is the reduction of tetrachloroethene (PCE) and daughter products a result of biodegradation or a result of other processes (e.g., dilution)?
- Is there evidence of complete dechlorination of PCE/trichloroethene (TCE)? Is there evidence of partial dechlorination?
- Is there a rate limiting step?
- Are contaminants being reduced via other natural attenuation mechanisms (advection, dispersion, and sorption)?

Additionally, DTSC requested further information on the effects of groundwater levels, rainfall, and pumping activities at the site on MNA. Where appropriate and relevant, this information is provided and discussed for proposed MNA field and analytical work.

In general, this Work Plan to evaluate MNA of chlorinated solvents is in accordance with the United States Environmental Protection Agency's (EPA) *Technical Protocol for Natural Attenuation of Chlorinated Solvents in Groundwater* (i.e., EPA MNA Protocol) (EPA, 1998). However, because of some advancements in analytical tools (i.e., compound-specific isotope analysis [CSIA] and polymerase chain reaction [PCR]), there are some evaluations that are recommended that are not included in EPA's protocol. This section includes a summary of the previous MNA evaluation work performed, objectives of the MNA evaluation, a discussion of areas where MNA evaluation is required, parameters to be sampled, and the MNA evaluation method.

8.1 Summary of Previous Area IV MNA Evaluation

Monitoring for the attenuation of chlorinated solvent(s) in groundwater plumes may be a valid remedial option in Area IV, assuming that certain environmental conditions exist and can be documented. In July 2013, a *Draft Technical Memorandum – Summary of Groundwater Sampling Results to Support Area IV Environmental Impact Statement* (Tech Memo) (MWH, 2013) was submitted that summarized results of the MNA evaluation to date. This excerpt from the technical memorandum describes work performed at Santa Susana Field Laboratory (SSFL, including Area IV).

> *A conceptual model has been developed for the site (Cherry et al., 2009) based on decades of various types of characterization data, a component of which indicates that even slow rates of degradation can have very meaningful impacts on reducing the longevity of contaminant plumes. A discussion of the fate of TCE at SSFL in general has been presented previously (MWH, 2009a). That document also described the significant field and laboratory studies that have been performed at the site regarding the fate of TCE. In summary, biological transformation of TCE to DCE is occurring in the rock matrix at the site as evidenced by increased ratios of DCE to TCE in matrix pore water along the flow path (Hurley et al., 2007; see Figure 89 therein). These observations have also been supported by CSIA (Pierce, 2005). Vinyl chloride (VC) and ethene are generally not detected in significant concentrations at the site and were not observed in significant amounts in both field and the laboratory studies (Pierce, 2005; Darlington et al., 2008; Zimmerman, 2010). However, observation of VC and ethene is complicated by both detection limit issues (e.g., the detection limit for VC in analysis of rock core samples is ~450 µg/L) and the fact that both VC and ethene are known to biodegrade under many of the geochemical conditions observed at the site (Davis and Carpenter, 1990; Bradley and Chapelle, 1996; Bradley and Chapelle, 2002; Semprini et al., 1990). As such, field evidence for reductive dechlorination to ethene is difficult to measure through sampling particularly considering its short half-life. Some of these reactions are also known to occur for DCE as well (Semprini et. al., 1990; Bradley et al., 1998). In addition, abiotic degradation reactions have been observed in both field and laboratory studies, and indicate DCE is being transformed to carbon dioxide (CO_2) or small, soluble non-chlorinated products (e.g., acetylene, formate, glycolate) that would be easily converted to CO_2 (Kanner and Bartha, 1982; Pierce, 2005; Darlington et al., 2008; Darlington et al., 2013). More recently, microbial analysis of matrix rock samples indicate the presence of Dehalococcoides spp. (Dhc) or Dhc-equivalent microorganisms that are capable of transforming DCE to ethene.*

Based on these historical observations, it was suggested that all three lines of evidence for natural attenuation via destructive mechanisms are supported. On January 29, 2014, DTSC provided comments to the 2013 technical memorandum, and in general the same conclusion was not reached by the DTSC based on the data provided.

The primary comments raised by DTSC in response to the technical memorandum were as follows:

- Adequate spatial and temporal groundwater data have not been collected to evaluate fate and transport or MNA to support the development of an Environmental Impact Statement (EIS).
- A work plan should be developed that includes a preliminary screening of natural attenuation parameters according to the EPA MNA Protocol (EPA, 1998). Proposed sampling should be in accordance with Table 2.3 of the EPA MNA Protocol (EPA, 1998).

- There was confusion regarding the historical data collection rationale, particularly related to well depth sample intervals. Significant differences are observed in monitoring well data with and without Flexible Liner Underground Technology™ (FLUTe™) systems installed and it was not clear what the various monitoring objectives were based on the different monitoring techniques used.

- The purpose of the systems, the rationale for port selection, and reasons for removal are not documented. As a result, much of the prior data cannot be used to evaluate presence or trends of groundwater contaminants. One purpose of this Work Plan is to establish a common, documented basis for groundwater characterization going into the future.

Historical data and previous evaluations/assessments, including usability and completeness of previously collected data, are presented in Section 8.3. Section 8.4 presents the wells proposed for MNA demonstration sampling and groundwater collection methods and analysis to be performed, respectively.

8.2 Objectives of MNA Demonstration

Based on comments by DTSC, the objectives of the Area IV MNA demonstration were re-evaluated. The revised MNA demonstration will focus on site contaminant delineation and fate and transport and an evaluation of MNA parameters based on the EPA MNA Protocol (EPA, 1998).

As described in the EPA MNA Protocol (EPA, 1998) and EPA's Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17 (EPA, 1997), three primary lines of evidence can be used to estimate natural attenuation of chlorinated ethenes. These three primary lines of evidence are:

1. A historical trend of decreasing contaminant mass;

2. Hydrogeologic and/or geochemical data that can indirectly demonstrate the attenuation conditions present; and

3. Data from field or microcosm studies that can directly demonstrate attenuation processes.

The first line of evidence alone does not demonstrate that contaminant mass is being destroyed, only that observed contaminant mass is decreasing. However, if the second line of evidence can be used to prove that conditions are conducive to destroying contaminant mass and not just attenuated physically, the combination of these two lines of evidence can be used to demonstrate that natural attenuation is occurring by contaminant destruction. The third line of evidence is often required if the first two lines of evidence are not conclusive, and site-specific studies are required. With exception of a small summary of previous microcosm work performed, this section will only address the first two lines of evidence.

Under naturally-occurring conditions, the primary destructive pathway for chlorinated ethenes is through anaerobic reductive dechlorination. Because this process occurs sequentially, there are metrics than can be evaluated to determine if attenuation is occurring because of physical processes (i.e., volatilization, sorption, dilution) or due to mass destruction from biological degradation. Specific questions that will be answered during the MNA evaluation include:

- Has degradation of chlorinated solvents occurred in Area IV?

- Do hydrogeochemical conditions support destruction of chlorinated solvents in Area IV? Are these conditions consistent throughout Area IV?
- Is there evidence of complete dechlorination of PCE/TCE? Is there evidence of partial dechlorination?
- Is there a rate limiting step?
- Are contaminants being reduced via other natural attenuation mechanisms (advection, dispersion, and sorption)?

In biological reductive dechlorination of chlorinated ethenes, the parent chlorinated ethene is sequentially dechlorinated as follows (EPA, 1998):

PCE → TCE → 1,2-DCE (*cis*-1,2-DCE, *trans*-1,2-DCE) or 1,1-DCE→ VC → ethene

The EPA MNA Protocol (EPA, 1998) states: "Chlorinated solvent plumes can exhibit three types of behavior depending on the amount of solvent, the amount of biologically available organic carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being used. Individual plumes may exhibit all three types of behavior in different portions of the plume."

Knowledge of the aquifer geochemistry is needed to understand the microbial processes that occur in the groundwater system. Geochemical parameters such as dissolved oxygen (DO), oxidation reduction potential (ORP), total organic carbon (TOC), anions (i.e., sulfate, chloride) and pH can be used to demonstrate the presence of an anaerobic groundwater system and indicate conditions suitable for reductive dechlorination.

In areas where 1,2-DCE accumulates and is suspected of failing to be further dechlorinated (1,2-DCE stall), there are multiple reasons why the 1,2-DCE stall is occurring. First, data may suggest that geochemical conditions are the dominant factor influencing the progression of the dechlorination process. Iron reduction, sulfate reduction, or methanogenesis could all be influencing the accumulation and persistence of 1,2-DCE. Iron and sulfate respiration can competitively inhibit reductive dechlorination, especially for lesser chlorinated compounds such as 1,2-DCE. Second, pH outside optimal range for complete dechlorination may contribute to 1,2-DCE-stall. Lastly, the absence of a robust population of chlorinated ethene-specific degrading bacteria may also cause 1,2-DCE stall since other bacteria such as *Dehalobacter* are capable of dechlorinating PCE and TCE to 1,2-DCE, but only Dhc is capable of reductively dechlorinating 1,2-DCE and VC.

It should be noted that although PCE and TCE will not degrade under aerobic conditions, aerobic degradation pathways have been documented for both 1,2-DCE and VC. Therefore, under certain circumstances, combined anaerobic dechlorination of parent compounds followed by aerobic dechlorination of 1,2-DCE and VC is possible.

The Area IV MNA demonstration program has been designed to understand the groundwater system and degradation versus complete dechlorination, and validate the use of MNA for chlorinated groundwater plumes in Area IV.

8.3 Historical Data and Evaluations for Identification of MNA Wells

Section 4 presents area by area evaluations of groundwater quality conditions across Area IV. Based on the data review, the following United States Department of Energy (DOE)-related Area IV locations were identified as candidate locations for MNA demonstration.

- Radioactive Materials Handling Facility (RMHF)
- Building 56 Landfill
- Former Sodium Disposal Facility (FSDF)
- Hazardous Material Storage Area (HMSA)
- Buildings 4057, 4059, 4626
- Building 4363/4373 Leach fields/Metals Clarifier

Sampling information, analytical data, and general conclusions presented by others for each area well is discussed in this section. The program introduced in the section is intended to provide a baseline for MNA with emphasis on data repeatability and comparability for future data collection and evaluation. As such, standardized methods will be used to allow comparison of data across the MNA study period.

Rationale for inclusion of a well to be included in the MNA sampling program has been provided in the section as well.

8.3.1 Radioactive Materials Handling Facility

See Section 4.7 for a description of the RMHF and associated hydrogeologic conditions.

Wells within the RMHF GIA include:

- RD-27
- RD-30
- RD-34A
- RD-34B
- RD-34C
- RD-63
- RS-28

Natural attenuation and hydrogeochemical conditions at the RMHF have been measured at RD-30, RD-34A, and RD-63.

RD-30

Current understanding:

- RD-30 water levels responded to the 1996 RD-63 pumping test
- Chlorinated ethene concentrations decreased during RD-63 pumping (1997 through 2006)
- Since termination of RD-63 pumping, chlorinated ethene concentrations have remained stable (e.g., TCE has been less than 11 micrograms per liter [μg/L])
- Stable contaminant concentrations observed since 2005 may be the result of dispersion of contaminants from the rock matrix

Sampling of RD-30 is **not** recommended for MNA demonstration because contaminant concentrations are too low to identify presence of TCE breakdown products.

RD-34A

Current understanding:

- RD-34A water levels responded to the 1997 through 2006 RD-63 pumping
- Chlorinated ethene concentrations decreased prior to RD-63 pumping
- Chlorinated ethene concentrations remained stable during RD-63 pumping
- Since termination of RD-63 pumping TCE concentrations have remained relatively stable
- Chlorinated ethene concentrations observed since 2005 may show some evidence of dechlorination based on the presence of 1,1-dichloroethene (1,1-DCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and *trans*-1,2-dichloroethene (*trans*-1,2-DCE)
- Stable concentrations observed since 1996 may be the result of dispersion of contaminants from the rock matrix
- TCE concentrations are below maximum contaminant level (MCL) since 2010

RD-34A is **not** recommended for MNA demonstration as TCE is below the MCL and the concentrations of daughter products are below detection.

RD-63

Current understanding:

- RD-63 was used as the RMHF location pumping well and water level in the well declined during pumping
- Chlorinated ethene concentrations remained relatively stable during the second half of RD-63 pumping and were generally less then concentrations prior to pumping
- Upon termination of RD-63 pumping, TCE concentrations initially increased and then stabilized through the most recent sampling; concentrations are between 5.7 and 6.4 µg/L
- TCE, *cis*-1,2-DCE, and 1,1-DCE were present in groundwater at roughly equal ratios through the late 1990s sampling period
- Chlorinated ethene concentrations observed in these well may show some evidence of dechlorination

RD-63 is recommended for MNA demonstration. RD-63 is located downgradient from the RMHF leach field and completed as an open borehole from 20 feet to 230 feet. Although recent TCE concentrations are low, sampling interval data for RD-63 is limited and packer testing of the well is recommended to determine if discrete intervals with higher TCE concentrations are present.

8.3.2 Building 56 Landfill

See Section 4.3 for a description of the Building 56 Landfill GIA and hydrogeologic setting.

Wells within the Building 4056 Landfill GIA include:

- PZ-124
- RD-07
- RD-74
- RS-16

Natural attenuation and hydrogeochemical conditions at the Building 4056 Landfill have been measured at RD-07. The other wells are too shallow to obtain groundwater samples on a regular basis.

RD-07

Current understanding:

- Prior to FLUTe™ installation in 2003, chlorinated ethene concentrations did not exhibit strong dechlorination trends

- Following installation of the FLUTe™ and selected port sampling, *cis*-1,2-DCE was detected at higher concentrations than TCE

- The FLUTe™ system was removed in January 2013 and samples collected from the open borehole showed a reversal with TCE being detected at greater concentrations than *cis*-1,2-DCE

- TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected in 1990s

- It is believed that dechlorination is occurring in RD-07; however, a complete understanding of the physical processes in RD-07 is required

Sampling of RD-07 is recommended for MNA demonstration. **Figure 4-12** shows chlorinated ethene (TCE, *cis*-1,2-DCE, and *trans*-1,2-DCE) concentrations in RD-07, prior to FLUTe™ installation in April 2002, during FLUTe™ sampling between April 2002 and January 2013, and following FLUTe™ removal. Samples collected from the open borehole following FLUTe™ removal show TCE and 1,2-DCE concentrations both returning to pre-FLUTe™ installation trends. Dechlorination is believed to be occurring in RD-07. However, the zones where this process is occurring is not fully understood and identifying those zones will be the subject of selected interval sampling (packer testing).

8.3.3 Former Sodium Disposal Facility

A description of the FSDF and its hydrogeological conditions is presented in Section 4.1.

Wells within the FSDF GIA include:

- RD-21 (located between FSDF and Empire State Development Authority [ESADA] Area)
- RD-22
- RD-33A
- RD-33B
- RD-33C
- RD-54A
- RD-54B
- RD-54C
- RD-64
- RD-65
- RS-18
- RS-54

Natural attenuation and hydrogeochemical conditions at the FSDF have been evaluated for wells RD-54A, RD-65, and RD-21 (located between the FSDF and ESADA areas). The other wells are either dry or exhibit chlorinated ethene concentrations too low for MNA evaluation.

RD-21

Current understanding:

- Prior to the aquifer pumping, TCE concentrations in RD-21 fluctuated between 89 and 2,900 µg/L
- TCE concentrations declined and stabilized to about 600 µg/L during the groundwater pumping
- Installation of the FLUTe™ system in RD-21 is believed to have occurred after 2001
- Prior to FLUTe™ installation, chlorinated ethene concentrations did not exhibit strong dechlorination trends
- Following installation of the FLUTe™ and selected port sampling, *cis*-1,2-DCE was detected in higher concentrations than TCE through 2008
- *Trans*-1,2-DCE concentrations were also detected following the aquifer pumping and through 2010
- The FLUTe™ system was removed in January 2013 and samples collected from the open borehole showed a reversal with TCE being detected at greater concentrations than *cis*-1,2-DCE
- TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected in 2000s; however, *cis*-1,2 DCE was detected slightly above the detection limit
- It is believed that dechlorination is occurring in RD-21; however, a complete understanding of the physical processes in RD-21 is required

RD-21 is recommended for sampling for MNA demonstration. However, since this well is located between the FSDF Area (2007 Consent Order [CO] responsibility –DOE] and the ESADA Area (2007 CO responsibility – The Boeing Company [Boeing]), internal discussion between DOE and Boeing may be required prior to performing additional work on RD-21.

RD-54A

Current understanding:

- Chlorinated ethene concentrations generally increase from well installation in 1993 through 1995
- TCE concentrations decrease in 1996 then increase during the RD-21 aquifer testing
- Water levels are assumed to have declined during the 1997 through 2001 pumping of RD-21 (173 gallons per day)
- Installation of the FLUTe™ system in RD-54A is believed to have occurred in January 2003
- Prior to FLUTe™ installation, chlorinated ethene concentrations may have shown a dechlorination trend

- Following installation of the FLUTe™ and selected port sampling, TCE was detected at lower concentrations than previous TCE samples collected from the open borehole, and *cis*-1,2-DCE was detected at higher concentrations than TCE through 2013
- *Trans*-1,2-dichlorethene concentrations were also detected in this well
- The FLUTe™ system was removed in January 2013 and samples collected from the open borehole showed slightly higher concentration of *cis*-1,2-DCE versus TCE
- TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected from the FLUTe™ since 2007
- It is believed that dechlorination is occurring in RD-54A; however, a complete understanding of the physical processes in RD-54A is required

RD-54A is recommended for sampling for MNA demonstration. As shown on **Figure 4-6**, TCE concentrations have dropped dramatically in this well. Chlorinated ethene concentrations generally increased from well installation in 1993 through 1995. TCE concentrations decrease in 1996 then increased during the RD-21 pumping. Prior to FLUTe™ installation in 2003, chlorinated ethene concentrations may have shown a dechlorination trend. Following installation of the FLUTe™ and selected port sampling, TCE was detected well below previous TCE concentrations collected from the open borehole and *cis*-1,2-DCE was detected in higher concentrations than TCE through 2013. *Trans*-1,2-dichlorethene was also detected in this well. The FLUTe™ system was removed in January 2013 and samples collected from the open borehole showed slightly higher concentrations of *cis*-1,2-DCE compared to TCE. TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected from the FLUTe™ since 2007.

RD-65

Current understanding:

- Chlorinated ethene concentrations generally remained stable from well installations in 1995 through 2002 as well as during the RD-21 aquifer testing period
- Installation of the FLUTe™ system in RD-65 in October 2002 resulted in a dramatic decrease in TCE concentrations
- Prior to FLUTe™ installation, chlorinated ethene concentrations may have shown dechlorination trends
- Following installation of the FLUTe™ and selected port sampling, TCE was detected at well below previous TCE samples collected from the open borehole
- *Cis*-1,2-DCE and *trans*-1,2-dichlorethene concentrations were also detected in this well
- The FLUTe™ system was removed in February 2013 and samples collected from the open borehole showed slightly higher concentration of TCE vs. *cis*-1,2-DCE
- TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected from the FLUTe™ since 2006

- It is believed that dechlorination is occurring in RD-65; however, a complete understanding of the physical processes in RD-54A is required

RD-65 is recommended for sampling for MNA demonstration. **Figure 4-10** shows TCE concentrations in RD-65. TCE concentrations generally remain stable from well installations in 1995 through 2002 including during the RD-21 GWIM period. Installation of the FLUTe™ system in RD-65 is believed to have occurred in October 2002 based on the dramatic decrease in TCE concentrations observed in other wells following installation of the FLUTe™ system. Prior to FLUTe™ installation, chlorinated ethene concentrations may have shown dechlorination trends. Following installation of the FLUTe™ and selected port sampling, TCE was detected at concentrations well below previous TCE samples collected from the open borehole. *Cis*-1,2-DCE and *trans*-1,2-dichlorethene were also detected in this well. The FLUTe™ system was removed in February 2013 and samples collected from the open borehole showed slightly higher concentration of TCE vs. *cis*-1,2-DCE. TCE concentrations collected from the open borehole were comparable to earlier TCE concentrations detected from the FLUTe™ since 2006. It is believed that dechlorination is occurring in RD-65.

8.3.4 Hazardous Material Storage Area

The history of the HMSA and hydrogeologic setting is provided in Section 4.5.

Wells present within the HMSA include:

- PZ-041
- PZ-108
- PZ-120
- PZ-122
- RD-29
- RS-27

Natural attenuation and hydrogeochemical conditions measured by others in wells at the HMSA include PZ-108 and PZ-120. These wells are discussed in detail below. The bedrock wells do not exhibit sufficient chlorinated solvent concentrations for MNA demonstration.

PZ-108

Current understanding:

- TCE concentrations have decreased since the well was first sampled in 2002 and appears to have stabilized around 80 µg/L since 2012
- *Cis*-1,2-DCE concentrations have remained stable over the monitoring period
- PZ-108 is located within a groundwater divide area with relatively flat horizontal gradient

PZ-108 is recommended for sampling for MNA demonstration. PZ-108 is screened from 16 to 26 feet below ground surface (ft bgs) and is located near the northeastern extent of the TCE plume. A groundwater divide is found in the area and groundwater flow has a relatively flat horizontal gradient. TCE concentrations in PZ-108 have decreased since it was first sampled in 2002 and appear to have stabilized around 80 µg/L since 2012. TCE concentrations do not appear to be effected by water level changes.

The assumed TCE degradation product *cis*-1,2-DCE has been detected in the well since 2002 and concentrations have ranged between 9 µg/L and 3.4 µg/L during the monitoring period. Although not exhibiting dechlorination trends at this time, it will be helpful to collect additional MNA data to evaluate why complete dechlorination is not occurring.

PZ-120

Current understanding:

- TCE and *cis*-1,2-DCE show an increasing concentration trend since well installation in 2003
- 1,1-DCE has also been detected in this well
- PZ-120 is located within a groundwater divide area with relatively flat horizontal gradient

PZ-120 is recommended for sampling for MNA demonstration. PZ-120 is screened from 15 to 25 ft bgs and is located in the central mass of the HMSA TCE plume. Similar to PZ-108, this area has minimal horizontal groundwater flow and believed to be near the groundwater divide. TCE, *cis*-1,2-DCE, and 1,1-DCE have been detected in groundwater. TCE and *cis*-1,2-DCE generally mirror each other with TCE concentrations being higher than *cis*-1,2-DCE. 1,1-DCE has been present when TCE was detected at or above 31 µg/L. Although not conclusive, dechlorination may be occurring.

8.3.5 Buildings 4057/4059/4626

The history for this GIA and hydrogeologic conditions are described in Section 4.4. This location has one well of interest for MNA demonstration; PZ-109. PZ-109 has exhibited PCE concentrations and the presence of TCE in this well may be the result of dechlorination of PCE.

PZ-109

Current understanding:

- PCE concentrations have steadily decreased since first detected in 2002
- TCE concentrations remain below its MCL in 2013 and 2014

PZ-109 is recommended for sampling for MNA demonstration to evaluate if the decreasing trend in PCE concentrations is due to destruction or physical attenuation mechanisms.

8.3.6 Metals Clarifier (Building 4065)

The history of the Metals Clarifier/DOE Leach field 3 GIA and the hydrogeologic setting is presented in Section 4.9.

Wells within the Metals Clarifier (Building 4065) GIA considered for MNA demonstration include:

- PZ-005
- PZ-104
- PZ-105

Natural attenuation and hydrogeochemical conditions have been measured by others for these wells. These wells are discussed in detail below.

PZ-005

Current understanding:

- PCE and TCE concentrations have decreased since their highest detection in 2002
- PCE and TCE are below their respected MCL in 2013

PZ-005 is **not** recommended sampling for MNA demonstration as the current concentrations of TCE breakdown products would be expected to be too low to measure.

PZ-104

Current understanding:

- TCE concentrations have decreased since their highest detection in 2003
- *Cis*-1,2-DCE has been detected slightly above the detection limit in 2013 and 2014
- TCE concentration is below MCL in 2014

PZ-104 is **not** recommended sampling for MNA demonstration as the TCE was below its MCL and TCE breakdown product concentrations would be expected to be too low to measure.

PZ-105

Current understanding:

- TCE concentrations are relatively stable since well installation in 2002
- 1,1-DCE has also been detected in this well at very low concentrations
- Although not exhibiting strong dechlorination trends at this time, this area with little TCE changes may show dechlorination in the future

PZ-105 is recommended for sampling for MNA demonstration. PZ-105 is screened from 17 to 27 ft bgs and located at the southern extent of the TCE plume. TCE concentrations have ranged from 3 μg/L to 12 μg/L with the majority of detections being near 9 μg/L. There does not appear to be a strong correlation between TCE concentrations and water levels in the well. Groundwater elevations in the Metals Clarifier suggest a rather flat water table surface (gradient) flowing towards the southeast.

1,1-DCE was detected (estimated) one time in 2009 at 0.1 μg/L. This single detection is believed to be an outlier and not an indication that dechlorination is occurring in the area. Although not exhibiting dechlorination trend at this time, this area with little horizontal groundwater movement may show dechlorination in the future.

8.4 MNA Demonstration Sampling Protocols

Rationale for selection of wells to be included in MNA was provided in Section 8.3. This section includes the sampling method rationale, analytes, and depth (or interval) to be sampled to establish baseline MNA. Vertical discrete results will be used to establish the MNA baseline. Subsequent sampling events will sample the same vertical discrete sample interval to identify trends in those intervals.

Intra-well flow within the well will be addressed prior to MNA sampling. Water levels, saddle packer testing, and/or geophysical log data will be used to identify intervals where intra-well flow is occurring. This information will be used to inform the MNA sample interval selection. Discrete intervals will be sampled for the MNA program.

Physical conditions that effect contaminant concentrations and trends in groundwater will be collected and analyzed. Physical conditions include groundwater levels, rainfall, and relationship of groundwater sample with fracture zones.

This program establishes a baseline condition and allows continued monitoring of natural attenuation using consistent sampling and analysis approach. MNA will continue until adequate data has been collected to evaluate the effectiveness of natural attenuation. Evaluation periods will be from the first sample event to the last.

The complexity of variables and their effect on chlorinated ethene concentrations in groundwater is the primary reason for recommending a MNA baseline for those wells recommended in Section 8.3. To establish a MNA baseline, this Work Plan was developed using methods and protocols to reduce or eliminate variability that can be problematic during evaluation of the data. Comparability of data during MNA demonstration sampling has been emphasized.

The following variables are described in general and then discussed in detail for each well.

8.4.1 Groundwater Elevation Levels

In wells that intersect the water table, chlorinated ethene concentrations detected in groundwater has been shown to be effected by fluctuating water table elevations. The increase or decrease in TCE is well-specific and demonstrates the importance of sampling fractures and bedding planes that transport TCE to the monitoring well. It is also believed that hydrogeochemical conditions that support dechlorination are not expected to exist in widely fluctuating water level zones due to the presence of oxygen during periods when the zone is not saturated.

8.4.2 Sample Interval

Selecting the correct sample interval in an open borehole or a FLUTe™ well is important to identify where dechlorination conditions exist and comparability of data in the future. Demonstrated through drilling logs, geophysics investigations, and water level measurements, open borehole and FLUTe™ ports intersect multiple fractures and bedding planes capable of transporting chlorinated solvents at different rates. In addition, these fractures and bedding planes most likely have different hydrogeochemical conditions that may or may not be supportive of dechlorination. Borehole logging and straddle packer testing and sampling will be used to identify these intervals or zones of interest and are discussed below.

Borehole Logging

The following tools are proposed to identify fractures, bedding planes, or zones that contain water and which may be a conduit for transport of TCE through or into the formation:

- Temperature logging of groundwater in bedrock wells
- TDS Trace Test
- Vertical Groundwater Flow and Gradient
- Acoustic Borehole Televiewer
- Optical Borehole Televiewer

Prior to use of these tools the FLUTe™, if present, must be removed. In all wells, if the FLUTe™ is removed, a blank FLUTe™ will be installed following logging/packer testing to prevent the open borehole from acting as a conduit and to protect deeper zones from contamination that may only be present in the shallower zones.

General steps for implementing borehole logging are as follows:

1. Obtain water level and chemical data from open borehole or FLUTe™ ports
2. Remove FLUTe™, as necessary
3. Perform borehole logging

4. Report intervals of interest to appropriate team (sampling, pumping, MNA, site model, etc.)
5. Protect borehole with blank FLUTe™

Straddle Packer Testing and Sampling

Due to the length of the open boreholes and current condition of the FLUTe™s in DOE-related areas of Area IV and the inability to obtain groundwater levels and samples from some zones of interest, straddle packer sampling of specific intervals is proposed. Use of passive samplers was considered but was determined that specific interval sampling would best serve the data needs of Area IV. Interval sampling will be the result of cumulating previous data and with new information obtained from additional borehole logging and selecting the best interval to be sampled or pumped.

General steps for implementing straddle packer testing and sampling are as follows:

1. Obtain water level and chemical data from open borehole or FLUTe™
2. Remove FLUTe™, as necessary
3. Perform borehole logging – select intervals of interest
4. Collect water samples using straddle packer
5. Protect borehole with blank FLUTe™

8.4.3 Sampling Method

Following identification of intervals of interest for MNA, SNAP samplers, bladder pumps, or other methods will be deployed to the zone and sample(s) will be collected. Groundwater samples will be analyzed for constituents presented in Section 8.5.

General steps for sampling are as follows:

1. Obtain water level and chemical data from open borehole
2. Perform borehole logging – select intervals of interest
3. Collect water samples using straddle packer
4. Evaluate water samples from intervals of interest – select intervals for MNA sampling
5. Collect water samples from selected intervals using Snap samplers ™, bladder pumps or other methods.
6. Evaluate data for dechlorination and establish MNA baseline

8.5 Sampling Method and Analysis

The sampling method will be selected based on the need to collect groundwater that has not been exposed to the atmosphere for dissolved gas analyses. Snap samplers™ can seal the sample *in situ* (i.e., in the water column). A bubble strip sample uses a collection cell and specialty bottles developed by Microseeps to collect a sample for hydrogen and other dissolved gases using a standard bladder pump. Groundwater MNA samples will be analyzed for volatile organic compounds (VOCs), cations, anions, TOC, dissolved gases, tritium, and strontium-90 (Sr-90).

Groundwater sample analysis will be consistent with EPA's MNA Table 2.3 - *Analytical Parameters and Weighting for Preliminary Screening for Anaerobic Biodegradation Processes, Required Analysis* (EPA, 1998). The following parameters will be analyzed during the MNA evaluation:

- Nitrate (by EPA Method 353.2)
- Sulfate (by EPA Method 300.0)
- Hydrogen
- VOCs (by EPA Method 8260B/C)

- Sulfide (by EPA Method 376.2)
- Methane (by Method RSK 175)
- TOC
- Chloride (by EPA Method 300.0)
- Ethene (by Method RSK 175)
- Ethane (by Method RSK 175)
- Alkalinity (by EPA Method 310.1)

Not included in EPA's MNA Table 2.3 are tritium and Sr-90. Tritium will be analyzed by EPA Method 906.0 and Sr-90 by EPA Method 905.0. In addition, field parameters will be collected for DO, ORP, pH, temperature, specific conductivity, and ferrous iron (performed in the field using Hach™ 8146 water quality method).

8.6 MNA Evaluation

Following borehole logging and hydraulic evaluation of discrete intervals in selected boreholes within DOE portions of Area IV, site contaminant fate and transport will be better understood. Combining these data with MNA data (VOC and biogeochemical data) will then be used to evaluate the effectiveness of MNA in the multiple plumes within Area IV. The baseline MNA data will be compared to the EPA MNA Protocol Table 2.3 to determine the viability of MNA at this site.

However, as discussed earlier in this section, since the EPA MNA Protocol (EPA, 1998) was published, there have been other advancements in the understanding of natural attenuation of chlorinated solvents. Included in these advancements are the use of CSIA and molecular tools (e.g., PCR) to determine if reductive dechlorination is occurring. Additionally, direct oxidation and abiotic pathways do exist for complete dechlorination of 1,2-DCE and VC. However, the EPA MNA protocol does not include any of these parameters in the scoring/evaluation process.

Therefore, recommendations may be made following the baseline MNA evaluation for additional characterization using these new techniques, based on the data collected.

References

Bradley and Chapelle, 1996. *Anaerobic mineralization of vinyl chloride in Fe(III)-reducing aquifer sediments*. Environ. Sci. Technol. 40:2084-2086.

Bradley et al., 1998. *Anaerobic oxidation of [1,2-^{14}C]dichloroethene under Mn(IV)-reducing conditions*. Appl. Environ. Microbiol. 64:1560-1562.

Bradley and Chapelle, 2002. *Microbial Mineralization of Ethene Under Sulfate Reducing Conditions*. Bioremediation Journal 6 (1): 1-8.

Cherry et al., 2009. *Site Conceptual Model for the Migration and Fate of Contaminants in Groundwater at the Santa Susana Field Laboratory, Simi Valley, CA.*

Darlington et al., 2008. *Biotic and Abiotic Anaerobic Transformations of Trichloroethene and cis-1,2-Dichloroethene in Fractured Sandstone*. Environmental Science & Technology. 42(12):4323-4330.

Darlington et al., 2013. *Anaerobic abiotic transformations of cis-1,2-dichloroethene in Fractured Sandstone*. Chemosphere 90:2226-2232.

Davis and Carpenter, 1990. *Aerobic biodegradation of vinyl chloride in groundwater samples*. Appl. Envron. Microbiol. 56:3878-3880.

DTSC, 2014. *Response to Draft Technical Memorandum – Summary of Groundwater Sampling Results to Support Area IV Environmental Impact Statement.* January 29, 2014.

Hurley et al., 2007. *Revised Source Zone Characterization at the Santa Susana Field Laboratory: Rock Core VOC Results for Coreholes C1-C7*.

Kanner and Bartha, 1982. *Metabolism of acetylene by Norfardia rhodochrous*. J. Bact. 150(2):989-992.

MWH, 2009a. *Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory, Ventura County, CA*. December

MWH, 2013. *Summary of Groundwater Sampling Results to Support Area IV Environmental Impact Statement, Santa Susana Field Laboratory, Ventura County, CA*. July 19, 2013

Pierce, 2005. *Isotopic and Hydrochemical Investigation of the Major Ion Origin and Trichlorinated ethene Degradation in Fractured Sandstone*. Master of Science Thesis, Department of Earth Sciences, University of Waterloo.

Semprini, et al., 1990. *A field evaluation of in-situ biodegradation of chlorinated ethenes; Part 2, results of biostimulation and biotransformation experiments*. Ground Water 28:715-727.

USEPA (EPA), 1997. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. EPA/9200/4-17. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA (EPA), 1998. *Technical Protocol for Natural Attenuation of Chlorinated Solvents in Groundwater*. EPA/600/R-98/128. U.S. Environmental Protection Agency. Office of Research and Development, Washington, D.C.

Zimmerman, 2010. New Opportunities for Groundwater Hydrochemistry and Degradation Investigations Provided by the Snap Sampler®. University of Guelph, Ontario, Canada.

Section 9

Area IV Groundwater Investigation Scope of Work

The evaluations performed and documented in the previous sections of the Work Plan (Section 2.4 and Sections 4 through 7)[1] incorporated the vast amount of existing data into conceptual site models (CSMs) for each groundwater investigation area (GIA). Data gaps in the CSMs were identified and activities identified to fill the data gaps are described below.

In addition, requirements for a groundwater sampling and analysis program appropriate to address unknowns for the Area IV groundwater remedial investigation have been identified as part of the overall data evaluation. The approach and details for obtaining the data will be incorporated into a Groundwater Field Sampling and Analysis Plan, and wells and associated analytes will be discussed in an update of the Water Quality Sampling and Analysis Plan (WQSAP).

Table 9-1 provides the summary of site investigative work necessary to address data gaps discussed in prior sections of this document. The data gaps and data collection needs are grouped in **Table 9-1** by GIAs under United States Department of Energy's (DOE) responsibility. Those areas under The Boeing Company's (Boeing) responsibility will be addressed separately by Boeing. Current plans are to begin field work to minimize these DOE data gaps during summer 2015. **Figure 9-1** shows the locations of the proposed new wells.

---

[1] The monitored natural attenuation recommendations presented in this Work Plan will be implemented as a separate action by DOE from the work proposed in Table 9-1.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
FSDF (Section 4.1.)	Corehole 8 (C-8) located in the pond area of the FSDF is a DOE responsibility[i]. C-8 is a nominal 5-inch diameter, 400-ft deep corehole drilled in the former FSDF pond area and within the TCE groundwater plume. C-8 has a casing from 0 to 65 ft bgs, providing for the shallowest observation of bedrock conditions for wells in the FSDF area. C-8 is currently equipped with the Blake FLUTe™. Drilling information, porewater, and groundwater data suggest that Near-surface groundwater has not been isolated from the deeper Chatsworth Formation groundwater. Isolation failure may be the result of conductor casing not being extended deep enough into the unweathered Chatsworth Formation, the borehole remaining open between completion of drilling and installation of the FLUTe™ system, and/or the failure of the FLUTe™ to seal the open borehole between the conductor casing and bottom of the corehole. C-8 is being considered as an extraction well for the FSDF GWIM.	• Remove the FLUTe™ system. • Video log the upper 200 ft of corehole to identify visual changes in bedrock fracture conditions from its original installation and logging. • Packer test the corehole to identify potential intervals with TCE to see if C-8 is a candidate location for a GWIM pumping well. • Install blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary.
	RD-22, a DOE responsibility, is located west and downgradient of the FSDF TCE plume. Both the location and the well depth are appropriate for monitoring in this critical area. The FLUTe™ multi-port system is reported to have ruptured during or shortly after installation. The configuration of the currently-installed FLUTe™ system does not allow sampling of the shallowest fractures in this important area. The upgradient FSDF shallow wells are the most contaminated; data from the shallow bedrock zone at this location is needed.	• Review field data including visual, geophysical, and video logs. • Sample well intervals based on determination of fracture zones. • Monitor the response of TCE concentrations in the fracture zones during and following the GWIM. • Remove the FLUTe™ system. • Install blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary.
	RD-23, a DOE responsibility, is located downgradient of the FSDF ponds. TCE concentrations increased in RD-23 from first sampling until the FLUTe™ was installed. The FLUTe™ multi-port system is reported to have ruptured during pumping of RD-54B. Groundwater data suggest that Near-surface groundwater has not been isolated from the deeper Chatsworth Formation groundwater. Isolation failure may be the result of conductor casing not being extended deep enough into the unweathered Chatsworth Formation, the borehole remaining open between completion of drilling and installation of the FLUTe™ system, and/or failure of the FLUTe™ to seal the open borehole between the conductor casing and bottom of borehole. Because of the opportunity to extract Near-surface groundwater from this borehole, RD-23 has been identified as a candidate extraction well for the GWIM.	• Review field data including visual, geophysical, and video logs. • Remove FLUTe™ system. • Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary. • If necessary, perform borehole geophysics and video logging to clearly identify fractures and bedding plans. • Isolate the perched zone from the bedrock aquifer during sampling. • Evaluate the possibility of removal of groundwater from highest sandstone unit during GWIM at this location (above 280 ft bgs).

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
FSDF cont. (Section 4.1)	The RD-33 well cluster, a DOE responsibility, is located west and downgradient of the FSDF TCE plume. The shallow well RD-33A is important in defining and monitoring the horizontal and vertical extent of contamination. Historically, lower TCE concentrations were reported in samples from the FLUTe™ than the open borehole TCE concentration indicating that fractures that are transporting TCE are not sampled with the FLUTe™ system. RD-33B is an open borehole well open from 360 ft to 415 ft. The well is in hydraulic connection with other wells, but no TCE has been detected in this well. RD-33B defines the vertical extent of contamination. RD-33C is open from 480 to 520 ft bgs; no TCE has been detected. Because co-located RD-33B defines the vertical extent, RD-33C is not needed in this capacity.	RD-33A • Remove the FLUTe™ system. • Continue sampling as a downgradient monitoring point. RD-33B • Continue sampling as a downgradient monitoring point. RD-33C • No action for this well. Reserve for future consideration.
	The RD-54 well cluster, a DOE responsibility, is installed in the former pond area. RD-54A, the shallowest well, exhibited a sharp decrease in TCE concentrations when the FLUTe™ was installed in 2003. This suggests that the FLUTe™ system may not have been sampling the most contaminated fractures. However, when the FLUTe™ was removed the open borehole concentrations were low indicating that TCE concentrations decreased in the shallow groundwater during the period that the FLUTe™ was installed. Groundwater data suggest that Near-surface groundwater may not be isolated from the deeper Chatsworth Formation groundwater. Because of the opportunity to extract Near-surface groundwater from this borehole, RD-54A has been identified as a candidate extraction well for the GWIM. RD-54B is open from 379 to 437 ft bgs. RD-54B exhibited TCE contamination in 1993 and 2002 but not since. The well can be used to define the vertical extent of TCE in the FSDF pond area. The depth of RD-54C, the deepest well in the cluster, is uncertain, but (based on various sources) may be 520 ft, 557 ft, or 638 ft. TCE was detected at 1.1 µg/L in 2006, but has not been detected since that time.	RD-54A • Perform a packer test of RD-54A to determine which fracture zones are contributing TCE to the well. • Evaluate RD-54A as an extraction well pumping during the proposed FSDF GWIM targeting the highest sandstone unit. RD-54B • Continue sampling as vertical extent monitoring point. RD-54C • Monitor response in well during the proposed FSDF GWIM. • Confirm the total depth of borehole.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
	Although not in communication with the fractures in RD-54A, some communication with shallow fractures is indicated by the historic presence of TCE.	
FSDF cont. (Section 4.1)	Near-surface groundwater well RS-54, a DOE responsibility, is located at the RD-54(A,B,C) well cluster. Although frequently dry, when present groundwater is contaminated (1,600 µg/L TCE in 2013). RS-54 was planned to be the extraction well during the FSDF GWIM but cannot serve in that capacity due to the absence of water much of the time. A well suitable for pumping near-surface TCE-contaminated groundwater during GWIM pumping is needed.	• RS-54 cannot serve as a pumping well and candidate wells need to be identified for GWIM purposes. Data collection activities identified in the previous section should be considered to identify the pumping wells.
	RD-57, a DOE responsibility, is downgradient and north of the FSDF plume. TCE was detected one time (1.9 µg/L in 2000) in this 419-ft deep open borehole well. A FLUTe™ multi-port system installed in 2003 is still in the well. No fractures shallower than 228 ft have been sampled due to the FLUTe™ system. The presence or absence of TCE in fractures above the FLUTe™ ports or in intervals not sampled by FLUTe™ ports in RD-57 is not known.	• Review field data including visual, geophysical, and video logs. • Remove the FLUTe™ system to allow access to upper portion of well. • Sample depth intervals based on field log observations of fracture zones. • If appropriate, seal or otherwise abandon the deeper zone. • Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary. • Install a new deep Chatsworth Formation well between RD-57 and RD-57. Well will be used to investigate the Plume's northern extent.
	RD-64, a DOE responsibility, is located on the western edge of the FSDF ponds. Concentrations of TCE were increasing prior to the installation of the FLUTe™ in 2003. The FLUTe™ system did not sample the shallowest fractures. The presence of TCE breakdown product *cis*-1,2-DCE indicates that dechlorination/degradation may be occurring. RD-64 is currently equipped with the FLUTe™ multi-port system. Groundwater data suggest that Near-surface groundwater has not been isolated from the deeper Chatsworth Formation groundwater. Isolation failure may be the result of conductor casing not being extended deep enough into the unweathered Chatsworth formation, the borehole remaining open between completion of drilling and installation of the FLUTe™ system, and/or failure of the FLUTe™ to seal the open borehole between the conductor casing and bottom of borehole. Because of the opportunity to extract Near-surface groundwater from this borehole, RD-64 has been selected as an extraction well for the GWIM.	• Remove the FLUTe™ system. • Perform borehole geophysics and video and compare with C-8 logging to identify fractures and bedding planes. • Sample selected intervals to evaluate the vertical extent of TCE. • Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
FSDF cont. (Section 4.1)	RD-65, a DOE responsibility, is located downgradient of the FSDF. TCE at up to 960 µg/L was reported for RD-65 prior to installation of the FLUTe™ system in 2003. Concentrations decreased after the installation of the FLUTe™ suggesting that the highest TCE-contaminated fractures were not monitored with the FLUTe™ system. The FLUTe™ was removed in February 2013. The presence and concentrations of TCE in upper fractures of RD-65 and other specific fractures and features are not known. Prior to installation of the FLUTe™ the water chemistry suggested that dechlorination was occurring.	• Perform geophysical and video logging of well. • Perform a packer test to collect groundwater from the perched groundwater zone. • Continue sampling as downgradient monitoring point.
	PZ-098 is located downgradient of the FSDF and is a DOE responsibility. It is typically dry but should be assessed each quarter for the presence of water to measure and sample. TCE has been measured previously (29 µg/L). When groundwater is present this piezometer provides data used to evaluate presence of shallow TCE.	• Install a monitoring well (near PZ-098) capable of collecting Chatsworth Formation groundwater. • Collect Near-surface water elevation data and sample when water is present.
	RD-21, a joint Boeing-DOE responsibility, is downgradient of ESADA and upgradient of FSDF. TCE has been reported for RD-21 but the vertical distribution of contamination in RD-21 is not understood. The shallow fractures in RD-21 have not been sampled. The impact of a relatively shallow shale bed identified in RD-21 with respect to transmission of TCE contamination is not known.	• Perform borehole geophysics (oriented acoustic logging) and video logging to identify fractures and bedding planes. • Perform packer testing on RD-21 to identify zones of contamination based on fracture data. • Confirm completion in the Upper Burro Flats member with analysis of water quality type (calcium bicarbonate) as part of RD-50 fault data. Install Blank FLUTe™ or packers to isolate non-impacted from impacted zones, if necessary.
	Bedrock well RD-50, a joint Boeing-DOE responsibility, is installed to a depth of 195 feet. Located in close proximity to the Burro Flats Fault and may be in the Santa Susana formation (somewhat uncertain). The well is upgradient of ESADA (and FSDF) and low levels of TCE (2.2 µg/L) have been detected in RD-50 in the past. Water levels in RD-50 have not responded to pumping of RD-54B or RD-21, indicating that there is not a strong hydraulic connection between RD-50 and RD-21 and RD-54B. The pathway for TCE to enter RD-50 is not known. The location of fractures and bedding planes in RD-50 are not known.	• Perform borehole geophysics and video logging to identify fractures and bedding planes. • Monitor RD-50 response during FSDF GWIM. • Confirm Lower Burro Flats member and water quality type (calcium bicarbonate). • Remove the FLUTe™ system. • Note: installation of Blank FLUTe™ or packers to isolate non-impacted from impacted zones is not recommended because TCE is just above detection limits and well location is upgradient of FSDF and ESADA.
Building 4100 Trench (Section 4.2)	No groundwater issues exist for the Building 4100 area.	• No further action.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
Building 56 Landfill (Section 4.3)	RD-07 is identified as a DOE responsibility. No source for the TCE found in RD-07 has been identified. The FLUTe™ ports with the highest TCE concentrations correlate to bedding plane fractures; therefore, the source of TCE is expected to be along geologic strike from RD-07. Groundwater pumping at RD-24, RD-25, and RD-28 (located along strike to the northwest) lowered water levels in RD-07 and may have drawn contaminated groundwater from the southeast (along strike.). RD-91 (Building 4100) may be the source of TCE in RD-07. Under static (non-pumping) conditions, groundwater flow is to the northwest. The downgradient extent of contamination has not been defined as the downgradient well and piezometers (RD-74 and PZ-124) are too shallow to intersect the contaminated fractures found in RD-07. Both are frequently dry.	• RD-07 should be geophysically logged to identify water bearing and transmissive fractures. • VOC concentrations in groundwater in individual fractures are not known and data are necessary for extent of groundwater impact. The fractures in RD-07 should be individually sampled for VOCs to determine which are contributing significantly to the present VOC contamination. Identification of the most contaminated fractures will allow a focused approach to remediation. • Install a new Chatsworth Formation groundwater monitoring well near PZ-124 to investigate the plumes northern extent in this area.
	RD-74 is identified as a DOE responsibility. RD-74 (101 ft deep) is too shallow to intersect the bedding plane fractures that contain TCE in RD-07. These fractures are present at 110 to 120 and 130 to 140 ft bgs in RD-07.	• The downgradient extent of contamination is not defined because the downgradient monitoring well, RD-74 (101 ft deep), is too shallow to intersect the bedding plane fractures previously identified as most contaminated in RD-07. This data gap can be filled through the installation of a new well deep enough to intersect the same fractures formerly monitored by RD-07 ports 4 and 5 or fractures identified as most contaminated during the testing of RD-07 described above.
Buildings 4057/4059/4626 (Section 4.4)	Buildings 4057/4059/4626 are a DOE responsibility. The source of the PCE detected in the Near-surface groundwater at PZ-109 (Building 4057) is assumed to be contaminated soil near Building 4626, and potentially 4057. The Near-surface groundwater and the Chatsworth Formation groundwater are connected. Pumping of the Chatsworth Formation at RD-24, RD-25, and RD-28, located northwest (and downgradient) of PZ-109, pulled PCE contamination in that direction. PCE has been detected in RD-25 and RD-28; both are now abandoned and are no longer available to monitor the downgradient migration and extent of the PCE plume.	• Install a new Near-surface groundwater monitoring well along the southern perimeter of Building 4059 to investigate if this building is a PCE source area. • Install a new Chatsworth Formation groundwater monitoring well between RD-25 and RD-28 to investigate vertical extent of PCE in this area.
Hazardous Material Storage Area (HMSA) (Section 4.5)	The HMSA is a DOE responsibility. TCE contamination is found in an area of perched Near-surface groundwater. PZ-108 and PZ-120 are impacted. The area is underlain at depth by the fine-grained ELV Member of the Chatsworth Formation. The HMSA sits on a groundwater divide although a slight southwesterly component of flow in the perched groundwater	• The HMSA TCE plume is well delineated in the Near-surface groundwater. Continue annual monitoring at PZ-109, as well as PZ-108, PZ-120, PZ-121, PZ-122, and RS-27. • Groundwater is monitored by RD-29 and RD-24. Continue annual monitoring of these two wells.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
	zone can be discerned from the generally (not exclusively) higher water levels measured at PZ-108 compared to those in PZ-120. Generally decreasing concentrations of TCE in PZ-108, with generally increasing concentrations in PZ-120, indicate a general migration of contamination to the southwest. The downgradient extent of TCE in the Chatsworth Formation groundwater is bound by RD-24 and RD-29. The vertical extent of TCE at the source area in the deep groundwater system has not been defined.	• TCE-contaminated groundwater is candidate for a groundwater interim measure through dewatering of the contaminated Near-surface groundwater via pumping of PZ-120. Water level and quality of near-surface water would need to be monitored following the dewatering effort. • Install a new deep Chatsworth Formation well between PZ-108 and PZ-120 in the source area.
Tritium Plume (Section 4.6)	The Tritium plume is a DOE responsibility. Tritium activity in wells defining the tritium plume exhibit decreasing concentrations at rates consistent with or faster than the tritium half-life of 12.5 years. The decay rates include some tritium diffusing from the groundwater in bedrock fractures into the rock matrix. In the matrix the tritium will continue to decay at its half-life rate.	• Continue monitoring of tritium in groundwater at RD-96 and RD-97 at 2-year intervals (Buildings 4057/4059/4626). • Advance soil boring to confirm or eliminate possible tritium source at Building 4614 Hold Up Pond (Tritium Plume). • Continue to monitor Tritium Plume wells RD-87, RD-88, RD-89, RD-90, RD-93, RD-94, RD-95, and SP-T02A, SP-T02B, SP-T02C, and SP-T02D at 2-year intervals (Tritium Plume). • Continue monitoring RD-34A, RD-34B, and RD-34C at 2-year intervals (RMHF). • Continue to monitor off-site wells RD-59A, RD-59B, and RD-59C at 5-year intervals (Off-Site Wells).
RMHF (Section 4.7)	The RMHF, a RCRA permitted facility, is a DOE responsibility. The RMHF leach field is the apparent source of TCE and Sr-90 found in the drainage north of the RMHF. The leach field and underlying contaminated rock were removed in 1978; however, Sr-90 remains. In addition, EPA sampling indicates that surrounding soils may also still contain Sr-90 contamination. RD-98, located adjacent to the RMHF leach field, is open in the upper 68 feet of the Chatsworth Formation. Sr-90 activities in RD-98 increase with increasing water elevations, i.e., during periods of more precipitation. This pattern is indicative of a remaining shallow Sr-90 source that has not migrated into the deeper bedrock. Sr-90 is moderately soluble in water compared with other radionuclides. The groundwater surface elevation map indicates that groundwater flow in the area is to the northwest. However, the migration of TCE indicates flow in the area is to the west. A potential fracture zone, expressed as an east-west oriented aerial photographic lineament, may be providing the hydraulic connections that provide the westward migration pathway.	• An additional monitoring well northwest of RD-98 will be installed to provide groundwater flow control. • The new well will be sampled for VOCs and Sr-90. • Continue sampling RD-98, RS-28, RD-30, RD-34A, and RD-63 for TCE and Sr-90 on an annual basis.

Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
	While Sr-90 migration to the west has been confirmed, there is not an existing well to the north of RD-98 to monitor groundwater in the northwest direction.	
Old Conservation Yard (OCY) (Section 4.8)	The OCY is a DOE responsibility. There is no confirmed source of groundwater contamination in the OCY. Two bedrock wells, RD-14 (30 to 125 ft) and WS-07 (700 ft) have been used for monitoring groundwater. WS-07 is a former water supply well sampled in the past. TCE was detected at a concentration below the MCL in WS-07 in 1985. In RD-14 TCE was reported at 13 µg/L in 1990; since then concentrations have been below MCL and non-detect.	• No further investigation is warranted at OCY GIA as concentration of contaminants are below MCLs, and with one spurious exception, have been for many years. • Water levels should be measured at RD-14 to be used with the data from other site wells in producing accurate potentiometric surface maps.
Metals Clarifier Laboratory Building 4065/DOE Leach Fields 3 (Section 4.9)	The Metals Clarifier Laboratory area is a DOE responsibility. There are several leach fields and the Metals Clarifier building that could have been sources of the TCE detected in PZ-005, PZ-104, PZ-105, and PZ-103. The size of the TCE plume is decreasing. In February 2014 only PZ-105 contained TCE above the MCL. Groundwater quality parameters in 2013 indicated reducing conditions that would be conducive to dechlorination.	• Given the generally low concentrations of TCE found in the Near-surface groundwater, the existing monitoring well network is considered adequate to monitor the Metals Clarifier/DOE Leach field 3 TCE plume. Continued annual monitoring of TCE and other VOCs in PZ-005, PZ-104, and PZ-105 is recommended. Less frequent monitoring is recommended for PZ-005 and PZ-104 if TCE concentrations remain below the MCL of 5 µg/L. • Install a new deep Chatsworth Formation well next to PZ-104 to investigation water conditions in the Chatsworth Formation.
Building 4064 Leach field (Section 4.10)	Building 4064 is a DOE responsibility. Soils in the area are thin and no Near-surface groundwater is expected. The soils in the area are fine-grained and would be expected to inhibit downward migration of any contaminants released in the leach field. RD-92 is used to monitor the Chatsworth Formation groundwater. No contamination (other than low level laboratory contamination) has been found in samples from RD-92.	• • Continued use of RD-92 as a groundwater level control point for this location of Area IV. • Install a new Near-surface groundwater monitoring well between Building 4064 and Building 4064 leach field to investigate if this leach field is a VOC source area.
Building 4030 and Building 4093 Leach fields (Section 4.10)	Buildings 4030 and 4093 are a DOE responsibility. There are no indications that TCE was used in the buildings and facilities associated with these leach fields. Soils are thin and the presence of Near-surface groundwater is uncertain. PZ-112 screened from 24 to 34 ft is frequently dry. Chatsworth Formation groundwater is monitored by RD-17. Low levels of TCE have been consistently detected in RD-17 (as high as 7.6 µg/L; 1 µg/L in 2014).	• Due to the low concentrations of TCE found in groundwater and lack of known source areas, only sampling of RD-17 for TCE is warranted. • RD-17 should be used as a water level monitoring point. • Install a new Near-surface groundwater monitoring well at the leach field to investigate if this leach field is a VOC source area.
Building 4133/Building 4029 Hazardous Waste Management Facility (Section 4.11)	Buildings 4029 and 4133 are a DOE responsibility. The Near-surface groundwater at Building 4133 is monitored by RS-25; RS-25 is frequently dry. The Chatsworth Formation groundwater is monitored by RD-19, location downgradient of Building 4133. In the four most recent	• The recommendations pertaining to groundwater listed in the DTSC-approved RCRA Closure Plan should be implemented. These recommendations include the collection of groundwater from the Near-surface groundwater (if it is found) from the building footprint

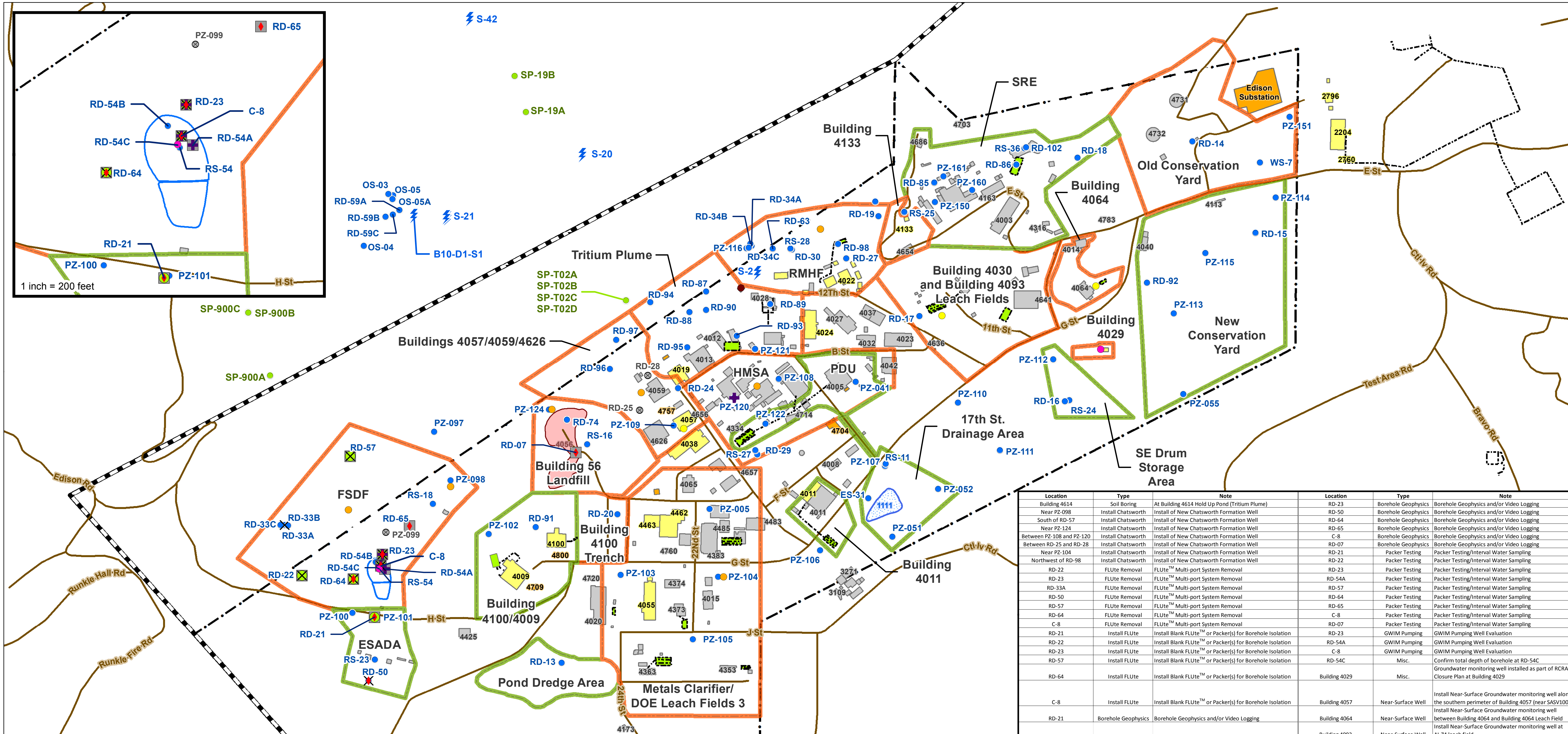
Table 9-1. Groundwater Characterization Data Gaps Summary

Groundwater Investigation Area (Work Plan Section)	Identified Data Gap/Rationale	Field Activities to Fill Data Gaps
	sampling events no contamination has been reported for the well. There is no groundwater monitoring well in the Building 4029 area.	following building removal. • To be conducted as part of the RCRA Closure Plan, a new monitoring well will be installed at or near Building 4029 to characterize bedrock groundwater. The monitoring well will be sampled in accordance to the closure plan.
Fault Investigation	Fault investigations within Area IV are joint Boeing-DOE responsibilities. An aerial photo lineament, the SRE/Lineament may be impacting the direction of groundwater flow, and therefore the direction of contaminant migration, downgradient of the RMHF Leach field. Regional groundwater flow data suggests a northward flow direction; however, the TCE plume seems to have a westward component. Data are needed to understand the nature of the lineament (does it represent a fracture zone?) and to assess the potential impact on groundwater flow direction. The Burro Flats Fault, the boundary between the Chatsworth Formation and the Santa Susana Formation, appears to be a hydraulic barrier to the migration of TCE. However, this conceptual model is based on the findings from RD-50. RD-50 did not respond to pumping during a regional aquifer test indicating that it is not well connected to other wells. In addition, only low concentrations of TCE have been detected in the past. The relationship of RD-50 to the fault is not known.	• Installation of a well to the north of the RMHF leach field to monitor for contaminant migration in the direction of regional groundwater flow. The well will provide additional potentiometric data to define the direction of flow. The borehole will be logged with geophysical instruments and video logged to look for fracturing indicative of a fault zone. • Collect geochemical data from RD-50 (carbonate) to determine in which geologic formation the well is completed. Conduct geophysical and video logging to look for a high density of fractures that may indicate that the well may be completed in a fracture zone. • Monitor water levels during the GWIM pumping to determine if RD-50 is hydraulically connected to wells in the FSDF and ESADA area.

Notes:
µg/L – microgram per liter
Boeing – The Boeing Company
C-8 – Corehole-8
DOE – Department of Energy
EPA – United States Environmental Protection Agency
ESADA – Empire State Atomic Development Authority
FLUTe™ – Flexible Liner Underground Technologies
FSDF – Former Sodium Disposal Facility
ft – feet
ft bgs – feet below ground surface
GWIM – groundwater interim measure
HMSA – Hazardous Material Storage Area
MCL – maximum contaminant level
MNA – monitored natural attenuation
OCY – Old Conservation Yard
PCE – tetrachloroethylene
RCRA – Resource Conservation Recovery Act
RMHF – Radioactive Material Handling Facility
Sr-90 – Strontium 90
SRE – Sodium Reactor Experiment
TCE – trichloroethene
U – Uranium
VOCs – volatile organic compounds

---

[i] Based on the 2007 Consent Order



Location	Type	Note	Location	Type	Note
Building 4614	Soil Boring	At Building 4614 Hold Up Pond (Tritium Plume)	RD-23	Borehole Geophysics	Borehole Geophysics and/or Video Logging
Near PZ-098	Install Chatsworth	Install of New Chatsworth Formation Well	RD-50	Borehole Geophysics	Borehole Geophysics and/or Video Logging
South of RD-57	Install Chatsworth	Install of New Chatsworth Formation Well	RD-64	Borehole Geophysics	Borehole Geophysics and/or Video Logging
Near PZ-124	Install Chatsworth	Install of New Chatsworth Formation Well	RD-65	Borehole Geophysics	Borehole Geophysics and/or Video Logging
Between PZ-108 and PZ-120	Install Chatsworth	Install of New Chatsworth Formation Well	C-8	Borehole Geophysics	Borehole Geophysics and/or Video Logging
Between RD-25 and RD-28	Install Chatsworth	Install of New Chatsworth Formation Well	RD-07	Borehole Geophysics	Borehole Geophysics and/or Video Logging
Near PZ-104	Install Chatsworth	Install of New Chatsworth Formation Well	RD-21	Packer Testing	Packer Testing/Interval Water Sampling
Northwest of RD-98	Install Chatsworth	Install of New Chatsworth Formation Well	RD-22	Packer Testing	Packer Testing/Interval Water Sampling
RD-22	FLUte Removal	FLUte™ Multi-port System Removal	RD-23	Packer Testing	Packer Testing/Interval Water Sampling
RD-23	FLUte Removal	FLUte™ Multi-port System Removal	RD-54A	Packer Testing	Packer Testing/Interval Water Sampling
RD-33A	FLUte Removal	FLUte™ Multi-port System Removal	RD-57	Packer Testing	Packer Testing/Interval Water Sampling
RD-50	FLUte Removal	FLUte™ Multi-port System Removal	RD-64	Packer Testing	Packer Testing/Interval Water Sampling
RD-57	FLUte Removal	FLUte™ Multi-port System Removal	RD-65	Packer Testing	Packer Testing/Interval Water Sampling
RD-64	FLUte Removal	FLUte™ Multi-port System Removal	C-8	Packer Testing	Packer Testing/Interval Water Sampling
C-8	FLUte Removal	FLUte™ Multi-port System Removal	RD-07	Packer Testing	Packer Testing/Interval Water Sampling
RD-21	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	RD-23	GWIM Pumping	GWIM Pumping Well Evaluation
RD-22	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	RD-54A	GWIM Pumping	GWIM Pumping Well Evaluation
RD-23	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	C-8	GWIM Pumping	GWIM Pumping Well Evaluation
RD-57	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	RD-54C	Misc.	Confirm total depth of borehole at RD-54C
RD-64	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	Building 4029	Misc.	Groundwater monitoring well installed as part of RCRA Closure Plan at Building 4029
C-8	Install FLUte	Install Blank FLUte™ or Packer(s) for Borehole Isolation	Building 4057	Near-Surface Well	Install Near-Surface Groundwater monitoring well along the southern perimeter of Building 4057 (near SASV1007)
RD-21	Borehole Geophysics	Borehole Geophysics and/or Video Logging	Building 4064	Near-Surface Well	Install Near-Surface Groundwater monitoring well between Building 4064 and Building 4064 Leach Field
			Building 4093	Near-Surface Well	Install Near-Surface Groundwater monitoring well at AI-Z4 leach field

LEGEND

- Seep Well
- Seep
- Install Chatsworth Well
- Misc
- Install Shallow Well
- Soil Boring
- Borehole Geophysics
- FLUte Removal
- GWIM Pumping
- Install FLUte
- Packer Testing
- Abandoned Well
- Well/Piezometer
- Road Centerline

Groundwater Investigation Area
- Boeing
- DOE

- Existing Landfill
- Existing Structure
- Existing Substation
- Former Pond
- Demolished Structure
- Former FSDF Pond
- Area IV Boundary
- SSFL Property Boundary

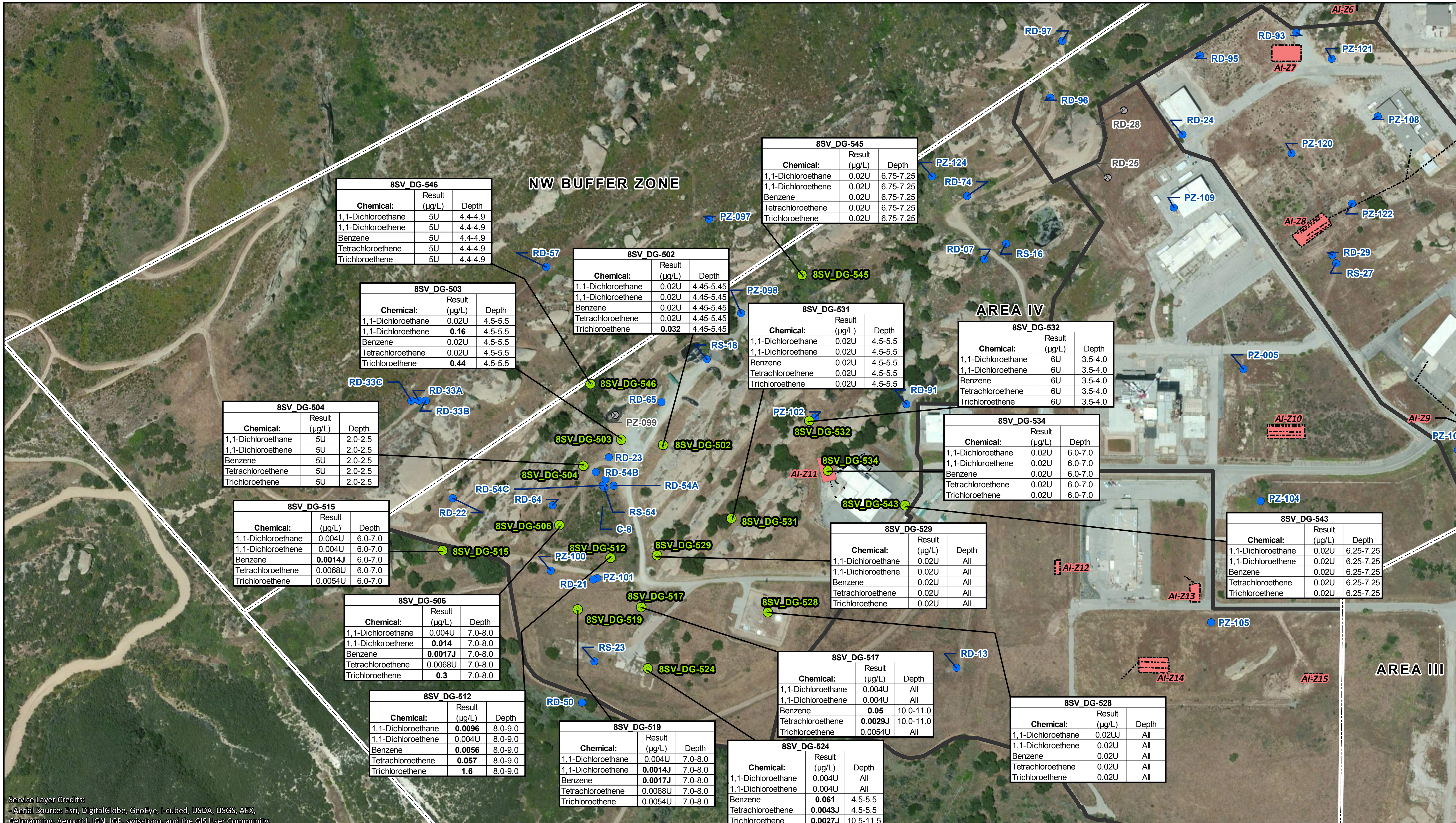
0 275 550 Feet

Notes:
- GIS Layers provided by MWH/Boeing.
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_GW_FieldWork_Activities_20151110.mxd 11/10/2015

CDM Smith

FIGURE 9-1
Area IV Groundwater Field Work



8SV_DG-546

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.4-4.9
1,1-Dichloroethene	5U	4.4-4.9
Benzene	5U	4.4-4.9
Tetrachloroethene	5U	4.4-4.9
Trichloroethene	5U	4.4-4.9

8SV_DG-503

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	**0.16**	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	**0.44**	4.5-5.5

8SV_DG-502

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.45-5.45
1,1-Dichloroethene	0.02U	4.45-5.45
Benzene	0.02U	4.45-5.45
Tetrachloroethene	0.02U	4.45-5.45
Trichloroethene	**0.032**	4.45-5.45

8SV_DG-545

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.75-7.25
1,1-Dichloroethene	0.02U	6.75-7.25
Benzene	0.02U	6.75-7.25
Tetrachloroethene	0.02U	6.75-7.25
Trichloroethene	0.02U	6.75-7.25

8SV_DG-531

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

8SV_DG-532

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	3.5-4.0
1,1-Dichloroethene	6U	3.5-4.0
Benzene	6U	3.5-4.0
Tetrachloroethene	6U	3.5-4.0
Trichloroethene	6U	3.5-4.0

8SV_DG-504

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.0-2.5
1,1-Dichloroethene	5U	2.0-2.5
Benzene	5U	2.0-2.5
Tetrachloroethene	5U	2.0-2.5
Trichloroethene	5U	2.0-2.5

8SV_DG-534

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

8SV_DG-515

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	6.0-7.0
1,1-Dichloroethene	0.004U	6.0-7.0
Benzene	**0.0014J**	6.0-7.0
Tetrachloroethene	0.0068U	6.0-7.0
Trichloroethene	0.0054U	6.0-7.0

8SV_DG-529

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

8SV_DG-543

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.25-7.25
1,1-Dichloroethene	0.02U	6.25-7.25
Benzene	0.02U	6.25-7.25
Tetrachloroethene	0.02U	6.25-7.25
Trichloroethene	0.02U	6.25-7.25

8SV_DG-506

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	**0.014**	7.0-8.0
Benzene	**0.0017J**	7.0-8.0
Tetrachloroethene	0.0068U	7.0-8.0
Trichloroethene	**0.3**	7.0-8.0

8SV_DG-517

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.05**	10.0-11.0
Tetrachloroethene	**0.0029J**	10.0-11.0
Trichloroethene	0.0054U	All

8SV_DG-512

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	**0.0096**	8.0-9.0
1,1-Dichloroethene	0.004U	8.0-9.0
Benzene	**0.0056**	8.0-9.0
Tetrachloroethene	**0.057**	8.0-9.0
Trichloroethene	**1.6**	8.0-9.0

8SV_DG-528

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02UJ	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

8SV_DG-519

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	**0.0014J**	7.0-8.0
Benzene	**0.0017J**	7.0-8.0
Tetrachloroethene	0.0068U	7.0-8.0
Trichloroethene	0.0054U	7.0-8.0

8SV_DG-524

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.061**	4.5-5.5
Tetrachloroethene	**0.0043J**	4.5-5.5
Trichloroethene	**0.0027J**	10.5-11.5

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

Area IV Soil Vapor Results
Subarea 8 North

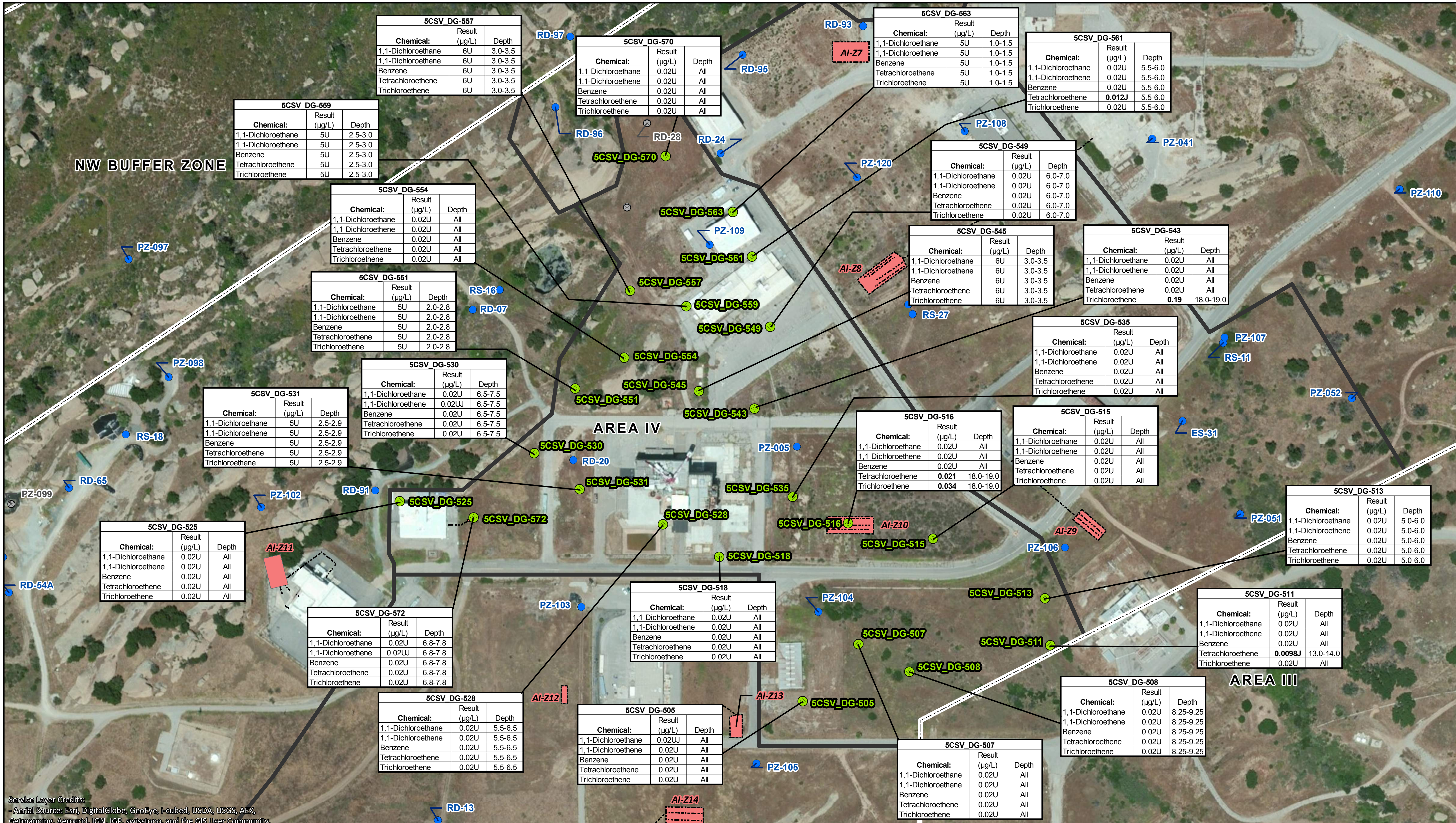
N

0 125 250 500 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure A-1

CDM Smith

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA8N_11x17_20150615.mxd 6/15/2015



5CSV_DG-557

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	3.0-3.5
1,1-Dichloroethene	6U	3.0-3.5
Benzene	6U	3.0-3.5
Tetrachloroethene	6U	3.0-3.5
Trichloroethene	6U	3.0-3.5

5CSV_DG-570

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-563

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.0-1.5
1,1-Dichloroethene	5U	1.0-1.5
Benzene	5U	1.0-1.5
Tetrachloroethene	5U	1.0-1.5
Trichloroethene	5U	1.0-1.5

5CSV_DG-561

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.5-6.0
1,1-Dichloroethene	0.02U	5.5-6.0
Benzene	0.02U	5.5-6.0
Tetrachloroethene	**0.012J**	5.5-6.0
Trichloroethene	0.02U	5.5-6.0

5CSV_DG-559

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.5-3.0
1,1-Dichloroethene	5U	2.5-3.0
Benzene	5U	2.5-3.0
Tetrachloroethene	5U	2.5-3.0
Trichloroethene	5U	2.5-3.0

5CSV_DG-549

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

5CSV_DG-554

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-545

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	3.0-3.5
1,1-Dichloroethene	6U	3.0-3.5
Benzene	6U	3.0-3.5
Tetrachloroethene	6U	3.0-3.5
Trichloroethene	6U	3.0-3.5

5CSV_DG-543

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	**0.19**	18.0-19.0

5CSV_DG-551

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.0-2.8
1,1-Dichloroethene	5U	2.0-2.8
Benzene	5U	2.0-2.8
Tetrachloroethene	5U	2.0-2.8
Trichloroethene	5U	2.0-2.8

5CSV_DG-535

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-530

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.5-7.5
1,1-Dichloroethene	0.02UJ	6.5-7.5
Benzene	0.02U	6.5-7.5
Tetrachloroethene	0.02U	6.5-7.5
Trichloroethene	0.02U	6.5-7.5

5CSV_DG-531

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.5-2.9
1,1-Dichloroethene	5U	2.5-2.9
Benzene	5U	2.5-2.9
Tetrachloroethene	5U	2.5-2.9
Trichloroethene	5U	2.5-2.9

5CSV_DG-516

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	**0.021**	18.0-19.0
Trichloroethene	**0.034**	18.0-19.0

5CSV_DG-515

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-513

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5CSV_DG-525

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-518

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-511

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	**0.0098J**	13.0-14.0
Trichloroethene	0.02U	All

5CSV_DG-572

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.8-7.8
1,1-Dichloroethene	0.02UJ	6.8-7.8
Benzene	0.02U	6.8-7.8
Tetrachloroethene	0.02U	6.8-7.8
Trichloroethene	0.02U	6.8-7.8

5CSV_DG-528

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.5-6.5
1,1-Dichloroethene	0.02U	5.5-6.5
Benzene	0.02U	5.5-6.5
Tetrachloroethene	0.02U	5.5-6.5
Trichloroethene	0.02U	5.5-6.5

5CSV_DG-505

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02UJ	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5CSV_DG-508

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	8.25-9.25
1,1-Dichloroethene	0.02U	8.25-9.25
Benzene	0.02U	8.25-9.25
Tetrachloroethene	0.02U	8.25-9.25
Trichloroethene	0.02U	8.25-9.25

5CSV_DG-507

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

Area IV Soil Vapor Results
Subarea 5C

N

0 100 200 400 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure A-2

CDM Smith

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA5C_11x17_20150615.mxd 6/15/2015

5ASV_DG-504

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.04U	25.0-26.0
1,1-Dichloroethene	0.04U	25.0-26.0
Benzene	**0.014J**	25.0-26.0
Tetrachloroethene	**0.032**	5.0-6.0
Trichloroethene	0.054U	25.0-26.0

5ASV_DG-509

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.019**	10.0-11.0
Tetrachloroethene	**0.0043J**	20.0-21.0
Trichloroethene	**0.036**	10.0-11.0

5ASV_DG-512

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	5.5-6.5
1,1-Dichloroethene	0.004U	5.5-6.5
Benzene	**0.0013J**	5.5-6.5
Tetrachloroethene	**0.005J**	5.5-6.5
Trichloroethene	0.0054U	5.5-6.5

5ASV_DG-522

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.5-8.5
1,1-Dichloroethene	0.004U	7.5-8.5
Benzene	0.0032U	7.5-8.5
Tetrachloroethene	0.0068U	7.5-8.5
Trichloroethene	0.0054U	7.5-8.5

5ASV_DG-565

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	**0.0018J**	5.0-6.0
1,1-Dichloroethene	**0.011J**	5.0-6.0
Benzene	**0.00076J**	5.0-6.0
Tetrachloroethene	**0.16J**	5.0-6.0
Trichloroethene	**0.018J**	5.0-6.0

5ASV_DG-566

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	3.0-3.5
1,1-Dichloroethene	6U	3.0-3.5
Benzene	6U	3.0-3.5
Tetrachloroethene	6U	3.0-3.5
Trichloroethene	6U	3.0-3.5

5ASV_DG-568

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

5ASV_DG-570

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.0-8.0
1,1-Dichloroethene	0.02U	7.0-8.0
Benzene	0.02U	7.0-8.0
Tetrachloroethene	0.02U	7.0-8.0
Trichloroethene	0.02U	7.0-8.0

5ASV_DG-576

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.5-3.0
1,1-Dichloroethene	5U	2.5-3.0
Benzene	5U	2.5-3.0
Tetrachloroethene	5U	2.5-3.0
Trichloroethene	5U	2.5-3.0

5ASV_DG-560

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.0012J**	10.5-11.5
Tetrachloroethene	**0.0014J**	10.5-11.5
Trichloroethene	0.0054U	All

5ASV_DG-582

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5ASV_DG-630

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.5-2.0
1,1-Dichloroethene	5U	1.5-2.0
Benzene	5U	1.5-2.0
Tetrachloroethene	5U	1.5-2.0
Trichloroethene	5U	1.5-2.0

5ASV_DG-574

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	1.5-2.0
1,1-Dichloroethene	6U	1.5-2.0
Benzene	6U	1.5-2.0
Tetrachloroethene	6U	1.5-2.0
Trichloroethene	6U	1.5-2.0

5ASV_DG-629

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	0.004U	7.0-8.0
Benzene	**0.00067J**	7.0-8.0
Tetrachloroethene	0.0068U	7.0-8.0
Trichloroethene	0.0054U	7.0-8.0

5ASV_DG-521

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.001J**	5.0-6.0
Tetrachloroethene	**0.002J**	5.0-6.0
Trichloroethene	0.0054U	All

5ASV_DG-571

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.5-3.0
1,1-Dichloroethene	5U	2.5-3.0
Benzene	5U	2.5-3.0
Tetrachloroethene	5U	2.5-3.0
Trichloroethene	5U	2.5-3.0

5ASV_DG-626

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.5-6.5
1,1-Dichloroethene	0.02U	5.5-6.5
Benzene	0.02U	5.5-6.5
Tetrachloroethene	0.02U	5.5-6.5
Trichloroethene	0.02U	5.5-6.5

5ASV_DG-622

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	6.0-7.0
1,1-Dichloroethene	0.004U	6.0-7.0
Benzene	**0.005**	6.0-7.0
Tetrachloroethene	**0.0031J**	6.0-7.0
Trichloroethene	**0.024**	6.0-7.0

5ASV_DG-529

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.0-4.5
1,1-Dichloroethene	5U	4.0-4.5
Benzene	5U	4.0-4.5
Tetrachloroethene	5U	4.0-4.5
Trichloroethene	5U	4.0-4.5

5ASV_DG-528

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	**0.049**	9.0-10.0
Tetrachloroethene	**0.0044J**	9.0-10.0
Trichloroethene	0.027U	5.0-6.0

5ASV_DG-546

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

5ASV_DG-627

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	3.0-3.5
1,1-Dichloroethene	5U	3.0-3.5
Benzene	5U	3.0-3.5
Tetrachloroethene	5U	3.0-3.5
Trichloroethene	5U	3.0-3.5

5ASV_DG-537

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

5ASV_DG-619

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	4.5-5.5
1,1-Dichloroethene	0.004U	4.5-5.5
Benzene	**0.00085J**	4.5-5.5
Tetrachloroethene	0.0068U	4.5-5.5
Trichloroethene	0.0054U	4.5-5.5

5ASV_DG-552

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.5-2.0
1,1-Dichloroethene	5U	1.5-2.0
Benzene	5U	1.5-2.0
Tetrachloroethene	5U	1.5-2.0
Trichloroethene	5U	1.5-2.0

5ASV_DG-547

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

5ASV_DG-543

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5ASV_DG-540

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5ASV_DG-618

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	5.0-6.0
1,1-Dichloroethene	0.004U	5.0-6.0
Benzene	0.0032U	5.0-6.0
Tetrachloroethene	**0.0027J**	5.0-6.0
Trichloroethene	0.0054U	5.0-6.0

5ASV_DG-611

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.35-1.85
1,1-Dichloroethene	5U	1.35-1.85
Benzene	5U	1.35-1.85
Tetrachloroethene	5U	1.35-1.85
Trichloroethene	5U	1.35-1.85

5ASV_DG-554

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.5-2.0
1,1-Dichloroethene	5U	1.5-2.0
Benzene	5U	1.5-2.0
Tetrachloroethene	5U	1.5-2.0
Trichloroethene	5U	1.5-2.0

5ASV_DG-609

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	0.004U	7.0-8.0
Benzene	0.0032U	7.0-8.0
Tetrachloroethene	0.0068U	7.0-8.0
Trichloroethene	0.0054U	7.0-8.0

5ASV_DG-616

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	6.5-7.5
1,1-Dichloroethene	0.004U	6.5-7.5
Benzene	**0.0019J**	6.5-7.5
Tetrachloroethene	0.0068U	6.5-7.5
Trichloroethene	0.0054U	6.5-7.5

5ASV_DG-592

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5ASV_DG-595

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	5.0-6.0
1,1-Dichloroethene	0.004U	5.0-6.0
Benzene	0.0032U	5.0-6.0
Tetrachloroethene	0.0068U	5.0-6.0
Trichloroethene	0.0054U	5.0-6.0

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

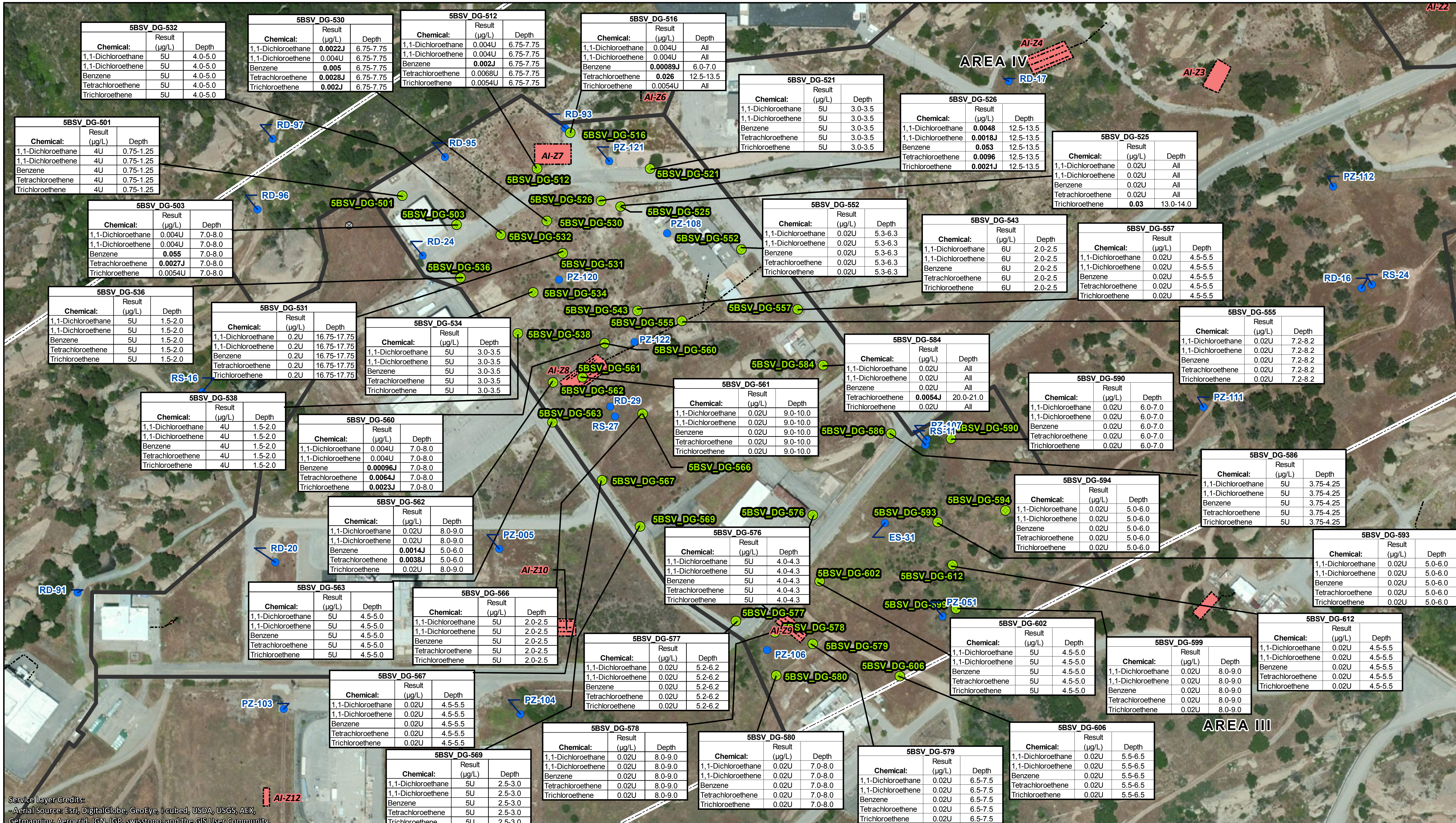
Area IV Soil Vapor Results
Subarea 5A

Santa Susana Field Laboratory
Ventura County, California
Figure A-3

0 100 200 400 Feet

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA5A_11x17_20150615.mxd 6/15/2015



5BSV_DG-532

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.0-5.0
1,1-Dichloroethene	5U	4.0-5.0
Benzene	5U	4.0-5.0
Tetrachloroethene	5U	4.0-5.0
Trichloroethene	5U	4.0-5.0

5BSV_DG-530

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	**0.0022J**	6.75-7.75
1,1-Dichloroethene	0.004U	6.75-7.75
Benzene	**0.005**	6.75-7.75
Tetrachloroethene	**0.0028J**	6.75-7.75
Trichloroethene	**0.002J**	6.75-7.75

5BSV_DG-512

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	6.75-7.75
1,1-Dichloroethene	0.004U	6.75-7.75
Benzene	**0.002J**	6.75-7.75
Tetrachloroethene	0.0068U	6.75-7.75
Trichloroethene	0.0054U	6.75-7.75

5BSV_DG-516

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	All
1,1-Dichloroethene	0.004U	All
Benzene	**0.00089J**	6.0-7.0
Tetrachloroethene	**0.026**	12.5-13.5
Trichloroethene	0.0054U	All

5BSV_DG-521

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	3.0-3.5
1,1-Dichloroethene	5U	3.0-3.5
Benzene	5U	3.0-3.5
Tetrachloroethene	5U	3.0-3.5
Trichloroethene	5U	3.0-3.5

5BSV_DG-526

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	**0.0048**	12.5-13.5
1,1-Dichloroethene	**0.0018J**	12.5-13.5
Benzene	**0.053**	12.5-13.5
Tetrachloroethene	**0.0096**	12.5-13.5
Trichloroethene	**0.0021J**	12.5-13.5

5BSV_DG-525

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	**0.03**	13.0-14.0

5BSV_DG-501

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	4U	0.75-1.25
1,1-Dichloroethene	4U	0.75-1.25
Benzene	4U	0.75-1.25
Tetrachloroethene	4U	0.75-1.25
Trichloroethene	4U	0.75-1.25

5BSV_DG-503

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	0.004U	7.0-8.0
Benzene	**0.055**	7.0-8.0
Tetrachloroethene	**0.0027J**	7.0-8.0
Trichloroethene	0.0054U	7.0-8.0

5BSV_DG-552

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.3-6.3
1,1-Dichloroethene	0.02U	5.3-6.3
Benzene	0.02U	5.3-6.3
Tetrachloroethene	0.02U	5.3-6.3
Trichloroethene	0.02U	5.3-6.3

5BSV_DG-543

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	2.0-2.5
1,1-Dichloroethene	6U	2.0-2.5
Benzene	6U	2.0-2.5
Tetrachloroethene	6U	2.0-2.5
Trichloroethene	6U	2.0-2.5

5BSV_DG-557

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

5BSV_DG-536

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.5-2.0
1,1-Dichloroethene	5U	1.5-2.0
Benzene	5U	1.5-2.0
Tetrachloroethene	5U	1.5-2.0
Trichloroethene	5U	1.5-2.0

5BSV_DG-531

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.2U	16.75-17.75
1,1-Dichloroethene	0.2U	16.75-17.75
Benzene	0.2U	16.75-17.75
Tetrachloroethene	0.2U	16.75-17.75
Trichloroethene	0.2U	16.75-17.75

5BSV_DG-534

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	3.0-3.5
1,1-Dichloroethene	5U	3.0-3.5
Benzene	5U	3.0-3.5
Tetrachloroethene	5U	3.0-3.5
Trichloroethene	5U	3.0-3.5

5BSV_DG-555

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.2-8.2
1,1-Dichloroethene	0.02U	7.2-8.2
Benzene	0.02U	7.2-8.2
Tetrachloroethene	0.02U	7.2-8.2
Trichloroethene	0.02U	7.2-8.2

5BSV_DG-584

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	**0.0054J**	20.0-21.0
Trichloroethene	0.02U	All

5BSV_DG-590

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.0-7.0
1,1-Dichloroethene	0.02U	6.0-7.0
Benzene	0.02U	6.0-7.0
Tetrachloroethene	0.02U	6.0-7.0
Trichloroethene	0.02U	6.0-7.0

5BSV_DG-538

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	4U	1.5-2.0
1,1-Dichloroethene	4U	1.5-2.0
Benzene	4U	1.5-2.0
Tetrachloroethene	4U	1.5-2.0
Trichloroethene	4U	1.5-2.0

5BSV_DG-560

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.004U	7.0-8.0
1,1-Dichloroethene	0.004U	7.0-8.0
Benzene	**0.00096J**	7.0-8.0
Tetrachloroethene	**0.0064J**	7.0-8.0
Trichloroethene	**0.0023J**	7.0-8.0

5BSV_DG-561

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	9.0-10.0
1,1-Dichloroethene	0.02U	9.0-10.0
Benzene	0.02U	9.0-10.0
Tetrachloroethene	0.02U	9.0-10.0
Trichloroethene	0.02U	9.0-10.0

5BSV_DG-586

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	3.75-4.25
1,1-Dichloroethene	5U	3.75-4.25
Benzene	5U	3.75-4.25
Tetrachloroethene	5U	3.75-4.25
Trichloroethene	5U	3.75-4.25

5BSV_DG-594

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5BSV_DG-562

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	8.0-9.0
1,1-Dichloroethene	0.02U	8.0-9.0
Benzene	**0.0014J**	5.0-6.0
Tetrachloroethene	**0.0038J**	5.0-6.0
Trichloroethene	0.02U	8.0-9.0

5BSV_DG-576

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.0-4.3
1,1-Dichloroethene	5U	4.0-4.3
Benzene	5U	4.0-4.3
Tetrachloroethene	5U	4.0-4.3
Trichloroethene	5U	4.0-4.3

5BSV_DG-593

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02U	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5BSV_DG-563

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.5-5.0
1,1-Dichloroethene	5U	4.5-5.0
Benzene	5U	4.5-5.0
Tetrachloroethene	5U	4.5-5.0
Trichloroethene	5U	4.5-5.0

5BSV_DG-566

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.0-2.5
1,1-Dichloroethene	5U	2.0-2.5
Benzene	5U	2.0-2.5
Tetrachloroethene	5U	2.0-2.5
Trichloroethene	5U	2.0-2.5

5BSV_DG-602

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.5-5.0
1,1-Dichloroethene	5U	4.5-5.0
Benzene	5U	4.5-5.0
Tetrachloroethene	5U	4.5-5.0
Trichloroethene	5U	4.5-5.0

5BSV_DG-599

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	8.0-9.0
1,1-Dichloroethene	0.02U	8.0-9.0
Benzene	0.02U	8.0-9.0
Tetrachloroethene	0.02U	8.0-9.0
Trichloroethene	0.02U	8.0-9.0

5BSV_DG-612

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

5BSV_DG-577

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.2-6.2
1,1-Dichloroethene	0.02U	5.2-6.2
Benzene	0.02U	5.2-6.2
Tetrachloroethene	0.02U	5.2-6.2
Trichloroethene	0.02U	5.2-6.2

5BSV_DG-567

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

5BSV_DG-569

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	2.5-3.0
1,1-Dichloroethene	5U	2.5-3.0
Benzene	5U	2.5-3.0
Tetrachloroethene	5U	2.5-3.0
Trichloroethene	5U	2.5-3.0

5BSV_DG-578

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	8.0-9.0
1,1-Dichloroethene	0.02U	8.0-9.0
Benzene	0.02U	8.0-9.0
Tetrachloroethene	0.02U	8.0-9.0
Trichloroethene	0.02U	8.0-9.0

5BSV_DG-580

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.0-8.0
1,1-Dichloroethene	0.02U	7.0-8.0
Benzene	0.02U	7.0-8.0
Tetrachloroethene	0.02U	7.0-8.0
Trichloroethene	0.02U	7.0-8.0

5BSV_DG-579

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	6.5-7.5
1,1-Dichloroethene	0.02U	6.5-7.5
Benzene	0.02U	6.5-7.5
Tetrachloroethene	0.02U	6.5-7.5
Trichloroethene	0.02U	6.5-7.5

5BSV_DG-606

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.5-6.5
1,1-Dichloroethene	0.02U	5.5-6.5
Benzene	0.02U	5.5-6.5
Tetrachloroethene	0.02U	5.5-6.5
Trichloroethene	0.02U	5.5-6.5

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

Area IV Soil Vapor Results
Subarea 5B

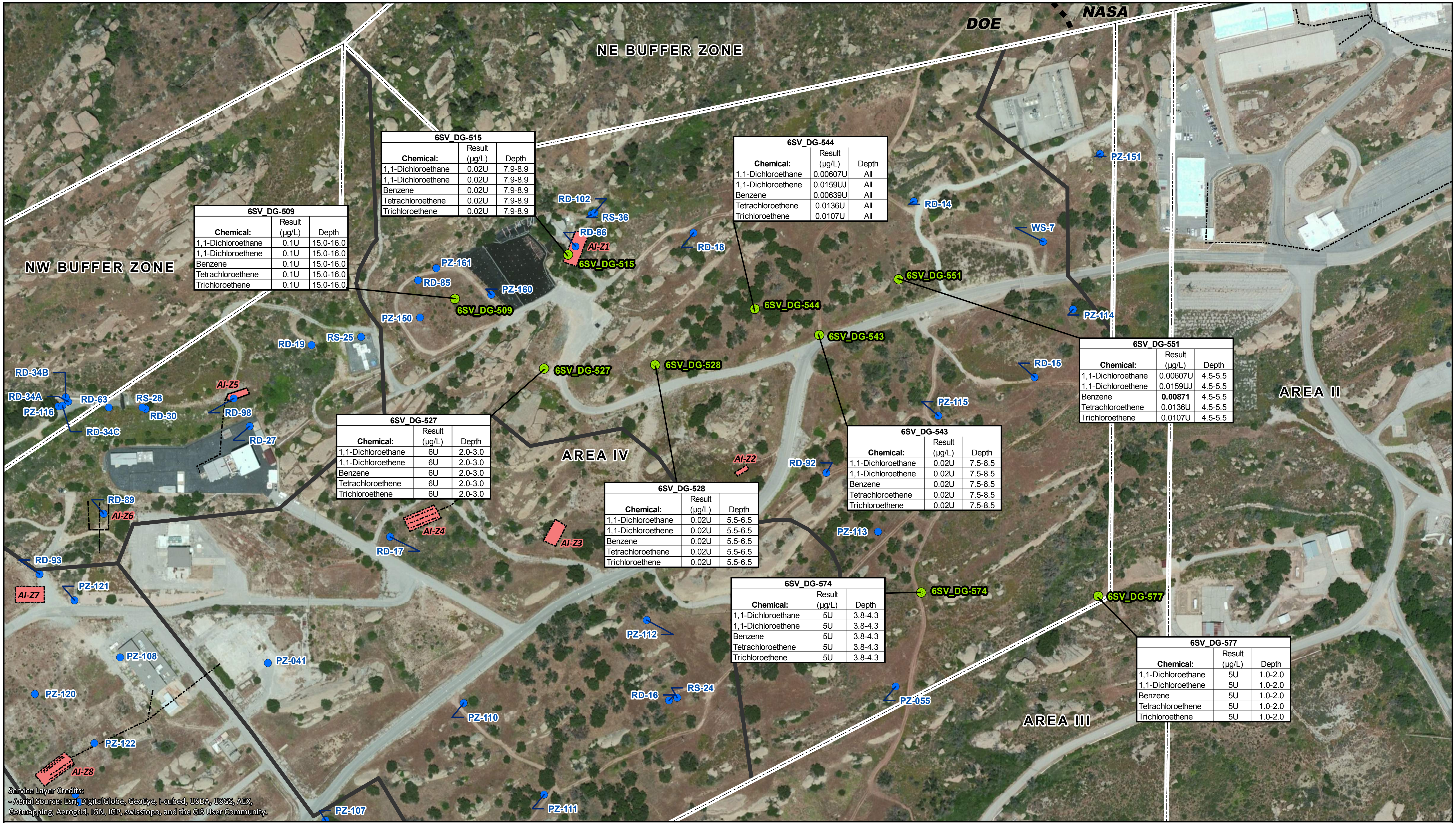
N

0 100 200 400 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure A-4

CDM Smith

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA5B_11x17_20150615.mxd 6/15/2015



6SV_DG-515

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.9-8.9
1,1-Dichloroethene	0.02U	7.9-8.9
Benzene	0.02U	7.9-8.9
Tetrachloroethene	0.02U	7.9-8.9
Trichloroethene	0.02U	7.9-8.9

6SV_DG-509

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.1U	15.0-16.0
1,1-Dichloroethene	0.1U	15.0-16.0
Benzene	0.1U	15.0-16.0
Tetrachloroethene	0.1U	15.0-16.0
Trichloroethene	0.1U	15.0-16.0

6SV_DG-544

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.00607U	All
1,1-Dichloroethene	0.0159UJ	All
Benzene	0.00639U	All
Tetrachloroethene	0.0136U	All
Trichloroethene	0.0107U	All

6SV_DG-551

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.00607U	4.5-5.5
1,1-Dichloroethene	0.0159UJ	4.5-5.5
Benzene	**0.00871**	4.5-5.5
Tetrachloroethene	0.0136U	4.5-5.5
Trichloroethene	0.0107U	4.5-5.5

6SV_DG-527

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	6U	2.0-3.0
1,1-Dichloroethene	6U	2.0-3.0
Benzene	6U	2.0-3.0
Tetrachloroethene	6U	2.0-3.0
Trichloroethene	6U	2.0-3.0

6SV_DG-543

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.5-8.5
1,1-Dichloroethene	0.02U	7.5-8.5
Benzene	0.02U	7.5-8.5
Tetrachloroethene	0.02U	7.5-8.5
Trichloroethene	0.02U	7.5-8.5

6SV_DG-528

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.5-6.5
1,1-Dichloroethene	0.02U	5.5-6.5
Benzene	0.02U	5.5-6.5
Tetrachloroethene	0.02U	5.5-6.5
Trichloroethene	0.02U	5.5-6.5

6SV_DG-574

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	3.8-4.3
1,1-Dichloroethene	5U	3.8-4.3
Benzene	5U	3.8-4.3
Tetrachloroethene	5U	3.8-4.3
Trichloroethene	5U	3.8-4.3

6SV_DG-577

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.0-2.0
1,1-Dichloroethene	5U	1.0-2.0
Benzene	5U	1.0-2.0
Tetrachloroethene	5U	1.0-2.0
Trichloroethene	5U	1.0-2.0

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

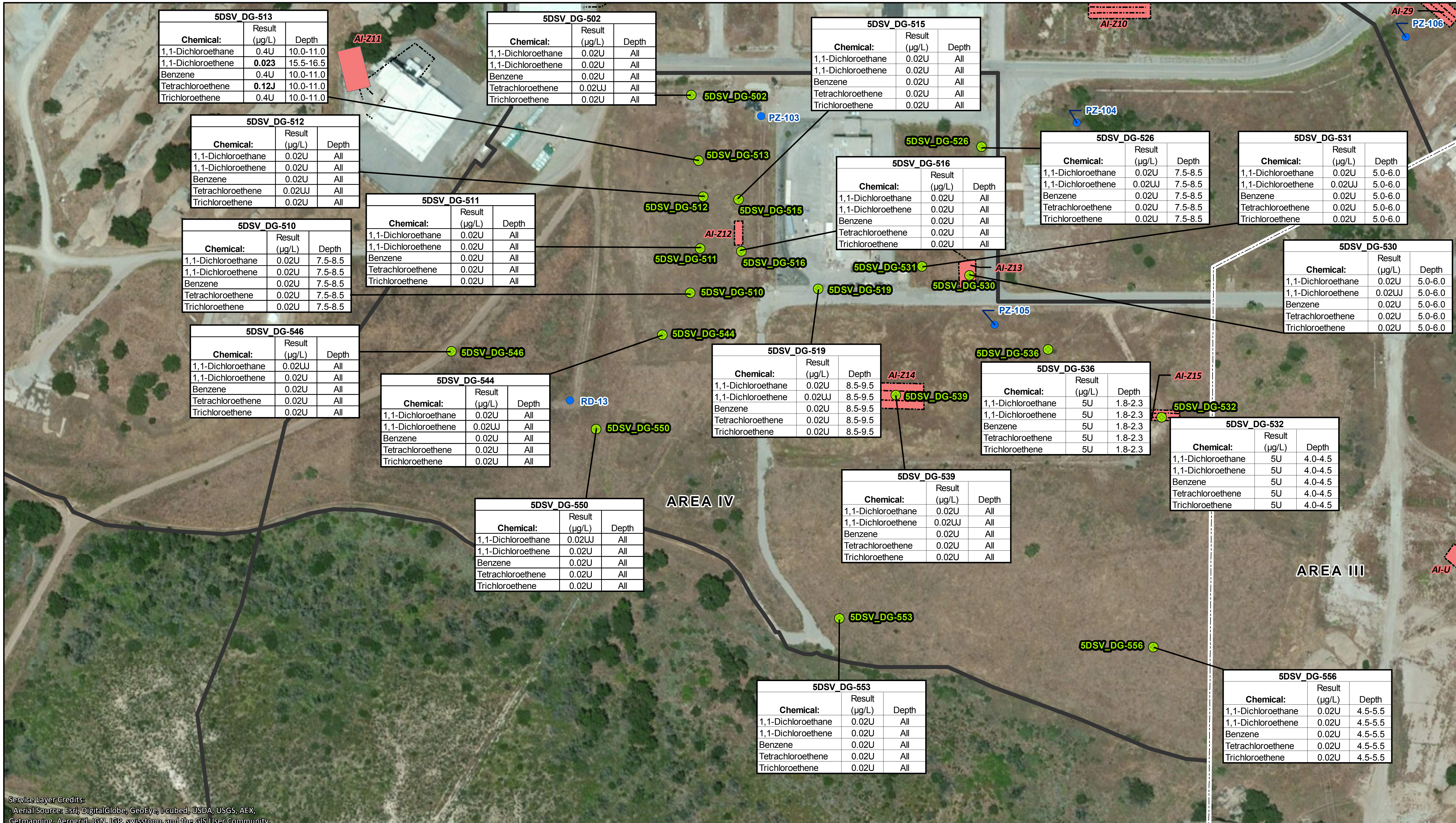
Area IV Soil Vapor Results
Subarea 6

0 125 250 500 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure A-5

CDM Smith

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA6_11x17_20150615.mxd 6/15/2015



5DSV_DG-513

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.4U	10.0-11.0
1,1-Dichloroethene	**0.023**	15.5-16.5
Benzene	0.4U	10.0-11.0
Tetrachloroethene	**0.12J**	10.0-11.0
Trichloroethene	0.4U	10.0-11.0

5DSV_DG-502

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02UJ	All
Trichloroethene	0.02U	All

5DSV_DG-515

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-512

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02UJ	All
Trichloroethene	0.02U	All

5DSV_DG-526

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.5-8.5
1,1-Dichloroethene	0.02UJ	7.5-8.5
Benzene	0.02U	7.5-8.5
Tetrachloroethene	0.02U	7.5-8.5
Trichloroethene	0.02U	7.5-8.5

5DSV_DG-531

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02UJ	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5DSV_DG-516

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-511

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-510

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	7.5-8.5
1,1-Dichloroethene	0.02U	7.5-8.5
Benzene	0.02U	7.5-8.5
Tetrachloroethene	0.02U	7.5-8.5
Trichloroethene	0.02U	7.5-8.5

5DSV_DG-530

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	5.0-6.0
1,1-Dichloroethene	0.02UJ	5.0-6.0
Benzene	0.02U	5.0-6.0
Tetrachloroethene	0.02U	5.0-6.0
Trichloroethene	0.02U	5.0-6.0

5DSV_DG-546

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02UJ	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-519

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	8.5-9.5
1,1-Dichloroethene	0.02UJ	8.5-9.5
Benzene	0.02U	8.5-9.5
Tetrachloroethene	0.02U	8.5-9.5
Trichloroethene	0.02U	8.5-9.5

5DSV_DG-536

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	1.8-2.3
1,1-Dichloroethene	5U	1.8-2.3
Benzene	5U	1.8-2.3
Tetrachloroethene	5U	1.8-2.3
Trichloroethene	5U	1.8-2.3

5DSV_DG-544

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02UJ	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-532

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	5U	4.0-4.5
1,1-Dichloroethene	5U	4.0-4.5
Benzene	5U	4.0-4.5
Tetrachloroethene	5U	4.0-4.5
Trichloroethene	5U	4.0-4.5

5DSV_DG-539

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02UJ	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-550

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02UJ	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-553

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	All
1,1-Dichloroethene	0.02U	All
Benzene	0.02U	All
Tetrachloroethene	0.02U	All
Trichloroethene	0.02U	All

5DSV_DG-556

Chemical:	Result (µg/L)	Depth
1,1-Dichloroethane	0.02U	4.5-5.5
1,1-Dichloroethene	0.02U	4.5-5.5
Benzene	0.02U	4.5-5.5
Tetrachloroethene	0.02U	4.5-5.5
Trichloroethene	0.02U	4.5-5.5

Legend

- Soil Vapor Location
- Abandoned Well/Piezometer
- Well/Piezometer
- AI-Zxx Leach Field*
- NE Buffer Zone Cleanup Responsibility
- Area IV Subarea
- Site Area

Notes:
- * - Leach Fields labeled using unique ID (AI-Zxx).Service Layer Credits:

Area IV Soil Vapor Results
Subarea 5D North

0 100 200 400 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure A-6

CDM Smith

C:_projects\SantaSusana\GIS\MXD\Groundwater\WP\SSFL_AreaIV_SoilVapor_Results_SA5D_11x17_20150615.mxd 6/15/2015