



Department of Energy  
National Nuclear Security Administration  
Sandia Field Office  
P.O. Box 5400  
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MAR 18 2016  
CERTIFIED MAIL-RETURN RECEIPT REQUESTED



Mr. John E. Keiling  
Chief  
Hazardous Waste Bureau  
New Mexico Environment Department  
2905 Rodeo Park Drive East, Bldg. 1  
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Subject: Response to NMED Disapproval Letter, HWB-SNL-15-020, *Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern, September 2015, Sandia National Laboratories, EPA ID# NM5890110518*, dated December 3, 2015, and Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern

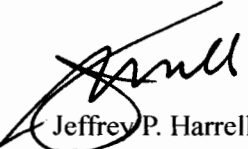
Dear Mr. Keiling:

The Department of Energy/National Nuclear Security Administration (DOE/NNSA) and Sandia Corporation (Sandia) are submitting the DOE/NNSA, Sandia Response to the New Mexico Environment Department's (NMED's) Disapproval Letter on the Treatability Study Work Plan (TSWP) for In-Situ Bioremediation (ISB) at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC), September 2015 (dated December 3, 2015), and a Revised TSWP for ISB at the TAVG AOC.

The NMED's comments from the Disapproval Letter are included verbatim in the enclosed DOE/NNSA, Sandia Response. The Response is in tabular form and provides each of the NMED's numbered comments, the specific DOE/NNSA, Sandia response to each NMED comment, and details where the DOE/NNSA, Sandia response is fully addressed in the Revised TSWP. Additional revisions to the TSWP not requested by the NMED Disapproval Letter are also detailed in the DOE/NNSA, Sandia Response. A redline version of the TSWP indicating all the changes to the September 2015 TSWP as well as a final version of the Revised TSWP are provided.

If you have questions, please contact me at (505) 845-6036 or David Rast of our staff at (505) 845-5349.

Sincerely,

  
Jeffrey P. Harrell  
Manager

Enclosure

cc: See Page 2

Mr. John E. Kieling

MAR 18 2016

2

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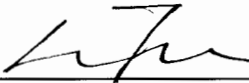
# CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

**Document Title:** Response to NMED Disapproval Letter, HWB-SNL-15-020, Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern, September 2015, Sandia National Laboratories, EPA ID# NM5890110518, dated December 3, 2015

and

Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern

**Document Author:** Jun Li, Department 06234



Signature

I certify under penalty of law that these documents were prepared under my direction or supervision according to a system designed to ensure 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. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

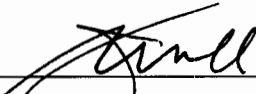


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3/3/16

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National Nuclear Security Administration  
Sandia Site Office  
Owner and Co-Operator

3/18/16

Date

**Response to NMED Disapproval Letter, HWB-SNL-15-020**  
**Treatability Study Work Plan for In-Situ Bioremediation**  
**at the Technical Area-V Groundwater Area of Concern, September 2015**  
**Sandia National Laboratories, EPA ID# NM5890110518**  
Disapproval dated December 3, 2015

#	Document Reference	NMED HWB Comment	DOE/Sandia Response
1	Section 4.2.2, KB-1 Primer, page 4-9	The purpose of adding soil cuttings from the injection well screened interval or septic tank amendments to the substrate solution is not mentioned. Describe the purpose of adding the soil core/cuttings or septic tank amendment into the first mixing tank in a revision to the Work Plan.	<p>The purpose of adding soil core/cuttings to the substrate solution are as follows:</p> <ol style="list-style-type: none"> <li>1) To inoculate the solution with native microorganisms.</li> <li>2) To create a diverse microbial community, which will more likely work synergistically with the bioaugmentation culture.</li> <li>3) To reduce the lag time for initiating biostimulation associated with utilization of the substrate in the subsurface.</li> </ol> <p>These explanations were added to Section 4.2.2.</p> <p>The septic tank amendment serves the same purposes if there is an insufficient amount of soil core/cuttings available.</p>
2	Section 5.2, Well Installation	There is no mention of well surveying in this section. A section must be added to the Work Plan in accordance with Section 8.10.2.5 of the Permit. The section must include language similar to the following: The new monitoring and injection wells will be surveyed relative to a U.S. Geological Survey (USGS) or other permanent benchmark. Survey data shall include northing, easting and elevation to the nearest hundredth of a foot or in accordance with the "Minimum Standards for Surveying in New Mexico" (12.8.2 NMAC). A survey elevation will be established at the top-of-casing, with a permanent marking indicating the point of survey. The survey will be completed and certified by a licensed New Mexico professional surveyor.	<p>A new section detailing the surveying of the new wells was added as Section 5.2.2 "Well Survey". The subsequent sections were renumbered.</p> <p>DOE/Sandia have consistently reported well coordinates relative to North American Datum of 1983 (NAD 83) and elevations relative to North American Vertical Datum of 1988 (NAVD 88).</p>

#	Document Reference	NMED HWB Comment	DOE/Sandia Response
3	Section 5.2.4, Well Construction, page 5-8	The filter pack, bentonite pellet seal, and bentonite grout must be emplaced by a tremie pipe to prevent bridging. Lifts must be no more than 100 feet. Revise the Work Plan accordingly.	<p>The TA-V injection wells and monitoring wells will be drilled using the Air-Rotary Casing Hammer (ARCH) drilling method. Tremie pipe is not typically used for ARCH drilling in the environmental field because the drive casing serves the dual purposes of keeping the borehole open while providing a direct conduit for emplacing the annular materials (filter pack, bentonite chips, and grout).</p> <p>To ensure that the annular materials have not bridged off, the field crew will:</p> <ol style="list-style-type: none"> <li>1) Tally the amount of emplaced materials to verify that the theoretical (planned) volume of each material corresponds to the actual volume installed.</li> <li>2) The materials will be poured by hand at a slow rate into the annulus at the top of the drive casing.</li> <li>3) A measuring tape will be used at approximately 3-foot intervals to verify that the materials have fallen to the proper depths.</li> <li>4) Before placing the bentonite chips and grout, the well casing will be surged to ensure that the filter pack has settled to the correct depth.</li> </ol> <p>The text in Section 5.2.5 (previously 5.2.4) was revised to include a discussion of the prevention of bridging.</p> <p>After the primary filter pack, the secondary filter pack, and the approximately 30-ft thick layer of bentonite chips are in place, the remaining annular space to ground surface will be filled with bentonite grout. The first lift of bentonite grout will be approximately 100-ft thick and will be allowed to set for a minimum of 24 hours. Subsequently, the annulus will be filled continuously with grout to within 10 ft below ground surface. Concrete will be used to complete the well installation. The text in Section 5.2.5 (previously 5.2.4) was revised accordingly.</p>

#	Document Reference	NMED HWB Comment	DOE/Sandia Response
4	Section 5.2.4, Well Construction, page 5-8	Cores and cuttings of the injection wells and monitoring wells should be kept in storage by the Permittees in order to allow further study, if needed, by the Permittees or NMED. Revise the Work Plan accordingly.	<p>As stated in Section 5.2.3 (previously 5.2.2), “Core Sampling at Injection Well Locations”, SNL staff plan to obtain cores only from approximately 20 ft above the water table to approximately 40 ft below the water table. Part of the core material will be used to inoculate the substrate solution as explained in the Response to Comment #1. Core material will also be used for soil sampling and chemical analyses, and possibly for sieve analysis (particle size distribution). The remainder of the cores will be stored on site for at least six months. SNL staff will take photographs of the entire core before segments are removed for inoculation and/or for sieve analysis. SNL staff will also retain cutting samples in chip boxes for three years after a well is installed. This text has been added in Section 5.2.3 (previously 5.2.2).</p> <p>Prior to the drilling activities, NMED will be notified so that their staff can observe the drilling and core extraction.</p>
5	Section 5.4.3, Push/Pull Test at TAV-INJ1, page 5-17	It is unclear if the results of the push/pull test and associated revisions will be submitted to NMED in written form. The Permittees must submit a written report to NMED that includes well construction, lithologic logs, documentation of field activities, and results of the push/pull test at least 60 days prior to starting the full Phase I activities of the Treatability Study. Revise the Work Plan accordingly.	<p>A <b>written</b> report on the push/pull test results, as well as well construction, lithologic logs, and documentation of field activities, will need to account for several items with long lead time: the laboratory turnaround time of the last performance monitoring sampling results, the time to compile the required graphics and materials, the required Sandia and DOE review cycles, and the formal approval/document release process. Much of the time is due to the logistics of document submittal. These items could lead to a delay in starting the full-scale injection phase if that is the conclusion of the push/pull test. In lieu of the initial report, DOE/Sandia propose that:</p> <p>1) DOE/Sandia will send an email to NMED that includes [a] a summary of the push/pull test results, [b] DOE/Sandia’s determination to proceed or not to proceed to full-scale injection, and [c] associated revisions to the testing protocol if needed. This email will be sent at least 60 days prior to starting the full-scale injection at TAV-INJ1. The email will allow for NMED to comment on the validity of proceeding to the full-scale injection.</p> <p>2) Within one year of the consensus reached about the push/pull test results, DOE/Sandia will prepare a <b>written</b> report that includes well construction, lithologic logs, documentation of field activities, and results of the push/pull test. Section 9.0 and Executive Summary were revised accordingly.</p>

#	Document Reference	Additional Revisions not Requested by the Disapproval Letter
1	Throughout	The two new groundwater monitoring wells will be installed first, followed by the installation of injection well TAV-INJ1. Text has been revised accordingly throughout the document.
2	Section 4.3.2	Updated text regarding controlling internal pressure in the injection well based on the new nested casing injection well design.
3	Sections 4.3.2, 5.4.2	Four, 5,000-gal tanks instead of two 10,000-gal tanks will be used for aboveground substrate solution mixing and deoxygenation. Sections 4.3.2 and 5.4.2 were revised accordingly.
4	Section 5.1	Submittal of a Discharge Permit Application is replaced by submittal of a Notice of Intent (NOI) and Discharge Permit Application if required by the NMED Ground Water Quality Bureau (GWQB), as suggested by the personnel from GWQB during recent communications. DOE/Sandia will follow NMED's guidance on the NOI and Discharge Permit.
5	Sections 5.2.5, 5.2.6 Figures 5-1, 5-2, 5-3	A new nested casing design (two PVC casings in one single borehole) for the injection wells was adopted. Subsequently, changes were made to the text and figures.
6	Section 5.4.1	Corrected the quantity of KB-1 Primer to be added to Tank 1 during the push/pull test from 1.5 kilograms (3.3 lbs) to 5.9 kilograms (13.1 lbs), to be consistent with the quantity presented in Table 4-1 (7.1 lbs per 1,000 gal water).
7	Sections 5.4.1, 5.4.2	Further evaluation of the field implementation of all downhole equipment led to decision to eliminate the sparge tubing. The purpose of the sparge tubing was to deoxygenate the water column in the casing. Considering the total volume to be injected (thousands of gallons) vs. the casing volume (<100 gallon), deoxygenation of the water column can be achieved by pre-injecting a small amount of deoxygenated substrate solution, thereby eliminating the sparge tubing and so simplifying field operation. Sections 5.4.1 and 5.4.2 were updated accordingly.
8	Section 5.5	The original content in Section 5.5 "New Groundwater Monitoring Wells" was redundant of Section 4.4. Therefore, the original content was replaced by "Impact on Groundwater and Additional Monitoring during Treatability Study". Additional monitoring of dissolved metals (iron, manganese, and arsenic) was proposed for eight wells to monitor and evaluate the impact of substrate discharge on groundwater in a broader area than the treatment zone. Table 6-1 was updated accordingly.
9	Table 5-4	Table 5-4 (previously Table 5-5) was revised to include alkalinity, more anions and cations for groundwater characterization purposes.
10	Throughout	Miscellaneous editorial corrections and clarifications.



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## **Sandia National Laboratories, New Mexico Environmental Restoration Operations**

### **Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern**

**March 2016**



United States Department of Energy  
Sandia Field Office

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## LIST OF APPENDICES

### Appendix

- A        Electron Donor Demand Calculation
- B        Safety Data Sheets



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## ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
AOC	Area of Concern
AOP	Administrative Operating Procedure
ARCH	Air-Rotary Casing-Hammer
bgs	below ground surface
CCM	Current Conceptual Model
<i>cis</i> -1,2-DCE	<i>cis</i> -1,2-dichloroethene
COC	constituent of concern
the Consent Order	the Compliance Order on Consent
CY	cubic yard
Dhc	<i>Dehalococcoides</i>
DO	dissolved oxygen
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FOP	Field Operating Procedure
Fe(III)	ferric iron
ft	foot or feet
ft/day	feet per day
ft/year	feet per year
g/mL	grams per milliliter
gpd	gallons per day
gpm	gallons per minute
GWQB	Ground Water Quality Bureau
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HWB	Hazardous Waste Bureau
ISB	in-situ bioremediation
KAFB	Kirtland Air Force Base
L	liter
lb(s)	pound(s)
LWDS	Liquid Waste Disposal System
MCL	maximum contaminant level
mg/L	milligrams per liter
mV	millivolts
NAD	North American Datum
NAVD	North American Vertical Datum
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NNSA	National Nuclear Security Administration
NPN	nitrate plus nitrite
NTU	Nephelometric Turbidity Units
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
psi	pounds per square inch
PVC	polyvinyl chloride

## ACRONYMS AND ABBREVIATIONS (Concluded)

RCRA	Resource Conservation and Recovery Act
Sandia	Sandia Corporation
SC	specific conductivity
SDS	Safety Data Sheet
SNL/NM	Sandia National Laboratories, New Mexico
SOP	standard operating procedure
SWMU	Solid Waste Management Unit
TA	Technical Area
TAVG	Technical Area-V Groundwater
TCE	trichloroethene
TOC	total organic carbon
vcrA	vinyl chloride reductase
VOC	volatile organic compound
WMP	Waste Management Plan
yr	year

## EXECUTIVE SUMMARY

This Work Plan presents the approach for conducting a phased Treatability Study to evaluate the effectiveness of in-situ bioremediation (ISB) as a potential technology for remediation of groundwater contamination at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC) at Sandia National Laboratories, New Mexico (SNL/NM). Trichloroethene (TCE) and nitrate have been identified as the two constituents of concern (COCs) for the TAVG AOC.

Historical discharges of industrial wastewater and sanitary waste to drain field (Solid Waste Management Unit [SWMU 5]) and seepage pits (SWMU 275) between approximately 1962 and 1992 are considered the most likely sources of TCE and nitrate contamination at the site. Concentrations in groundwater are above the Maximum Contaminant Levels of 5 micrograms per liter ( $\mu\text{g/L}$ ) for TCE and 10 milligrams per liter ( $\text{mg/L}$ ) for nitrate, with the highest detected TCE and nitrate concentration in October/November 2014 being 16.9  $\mu\text{g/L}$  and 13.1  $\text{mg/L}$ , respectively.

The technical approach for this Treatability Study is to induce biodegradation of TCE and nitrate by gravity injecting a nutrient-amended substrate solution and a microbial bioaugmentation culture into groundwater at three locations of highest COC concentrations. The intent of this action is to reduce nitrate concentrations through denitrification followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids in the aquifer.

Up to three injection wells will be installed in the vicinity of the highest contaminant concentrations to facilitate effective and thorough delivery of substrate solution and bioaugmentation culture. In total, a substrate solution consisting of approximately 530,000 gallons of potable water mixed with approximately 4,700 pounds of ethyl lactate amended with nutrients and pH buffer will be injected into each injection well along with over 200 pounds of a dechlorinating microbial culture including *Dehalococcoides*. Each full-scale injection is estimated to take approximately six months. The estimated delivery area extends to a radius of 60 feet (ft) surrounding the injection well to a depth of approximately 25 ft below the static water level.

ISB performance will be monitored at the injection wells and at nearby groundwater monitoring wells. An inert tracer will be included with the injection stream to help evaluate delivery and the effect of dilution from the injected potable water. Because contaminant concentrations are initially very low, several lines of evidence will be evaluated to assess the effectiveness of ISB, including injection rate and volume, changes in dissolved oxygen and redox potential, evidence of sequential redox reactions, establishment of a dechlorinating microbial population, contaminant and tracer concentrations, and production of degradation daughter products.

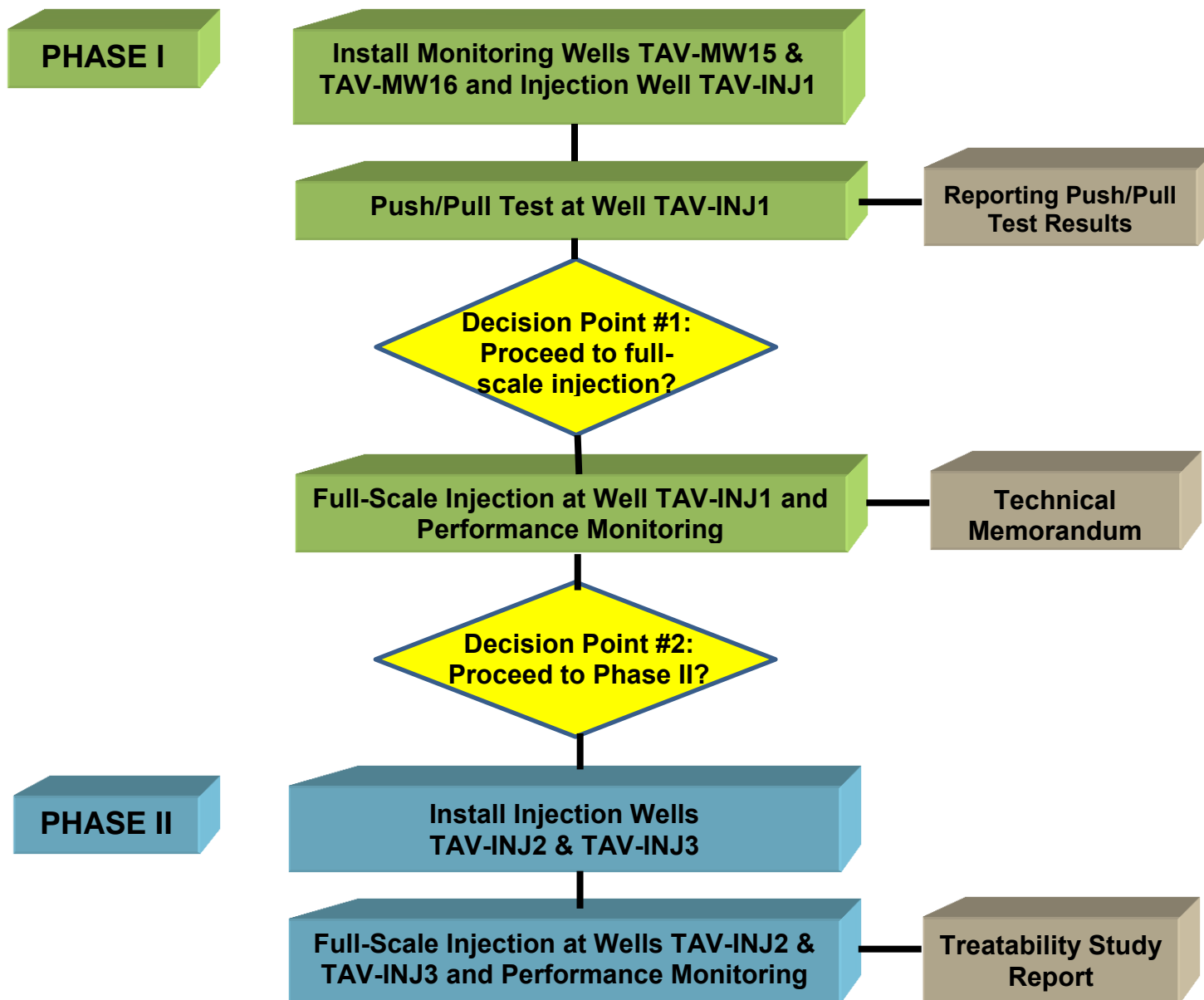
The overall sequence of Treatability Study work is described below, followed by a process flow diagram.

## Phase I

1. Installation of groundwater monitoring wells TAV-MW15 and TAV-MW16 south of Technical Area-V, and injection well TAV-INJ1 near SWMU 5.
2. Proof of concept push/pull test by mixing a substrate solution using extracted groundwater and reinjecting it along with bioaugmentation culture to affect a 5-ft radius treatment area around well TAV-INJ1. Post-injection performance monitoring for four months.
3. Submittal of push/pull test results and well installation report on TAV-MW15 and TAV-MW16 to New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB).
4. Full-scale injection with substrate solution and bioaugmentation culture to affect a 60-ft radius treatment area around well TAV-INJ1. Post-injection performance and rebound monitoring for 24 months.
5. Submittal of a Phase I Technical Memorandum to the NMED HWB, summarizing Phase I work.

## Phase II

1. Installation of injection wells TAV-INJ2 and TAV-INJ3 near SWMU 275 and monitoring well LWDS-MW1, respectively. Submittal of well installation report on TAV-INJ2 and TAV-INJ3 to NMED HWB.
2. Full-scale injection with substrate solution and bioaugmentation culture to affect 60-ft radius treatment areas around wells TAV-INJ2 and TAV-INJ3. Post-injection performance and rebound monitoring for 24 months.
3. Submittal of a Treatability Study Report to the NMED HWB, including recommendations for a path forward for TAVG AOC.



Technical Area-V Treatability Study Process Flow Diagram

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## 1.0 INTRODUCTION

Sandia National Laboratories, New Mexico (SNL/NM) is a government-owned, contractor-operated, multi-program facility overseen by the U.S. Department of Energy (DOE), National Nuclear Security Administration (NNSA) through the Sandia Field Office in Albuquerque, New Mexico. Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation, manages and operates SNL/NM under Contract No. DE AC04-94AL85000. SNL/NM is located on Kirtland Air Force Base (KAFB), in Albuquerque, New Mexico (Figure 1-1). Sandia personnel mostly operate in five technical areas (TAs) (TA-I, TA-II, TA-III, TA-IV, and TA-V) on KAFB.

The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) implements and enforces the Resource Conservation and Recovery Act hazardous waste regulatory program. In April 2004, a Compliance Order on Consent (the Consent Order) became effective between the NMED, DOE, and Sandia (NMED April 2004) to govern environmental investigation and corrective action requirements at SNL/NM.

The Consent Order specified TA-V as an area of groundwater contamination, and trichloroethene (TCE) and nitrate were identified as constituents of concern (COCs) requiring corrective measures based on detections above the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) in samples collected from monitoring wells. As specified in section VI.K.1 of the Consent Order, the EPA MCLs for drinking water contaminants, if available, should be used for groundwater cleanup levels. The EPA MCLs for TCE and nitrate are 5 micrograms per liter ( $\mu\text{g/L}$ ) and 10 milligrams per liter ( $\text{mg/L}$ ) (as nitrogen), respectively. Therefore, the HWB will enforce these MCLs for remediation. This is more stringent than the human health standard that the NMED Ground Water Quality Bureau (GWQB) has adopted for TCE in groundwater ( $0.1 \text{ mg/L}$  or  $100 \mu\text{g/L}$ ). The human health standard for nitrate in groundwater is also  $10 \text{ mg/L}$  (as nitrogen).

This document presents a work plan for conducting a phased Treatability Study to evaluate the effectiveness of in-situ bioremediation (ISB) as a potential technology for remediation of the COCs at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC). The Current Conceptual Model (CCM) document (SNL/NM September 2015) provides detailed information on site history, hydrogeology, the nature and extent of contamination, and the fate and transport of contaminants in groundwater at TA-V.

### 1.1 Overview of the Treatability Study

The technical approach for this Treatability Study is to induce biodegradation of TCE and nitrate by gravity injecting a nutrient-amended substrate solution and a microbial bioaugmentation culture into groundwater at up to three locations of highest COC concentrations. The intent of this action is to reduce nitrate concentrations through denitrification followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids in the aquifer. Biodegradation will ultimately convert these contaminants into innocuous breakdown products.



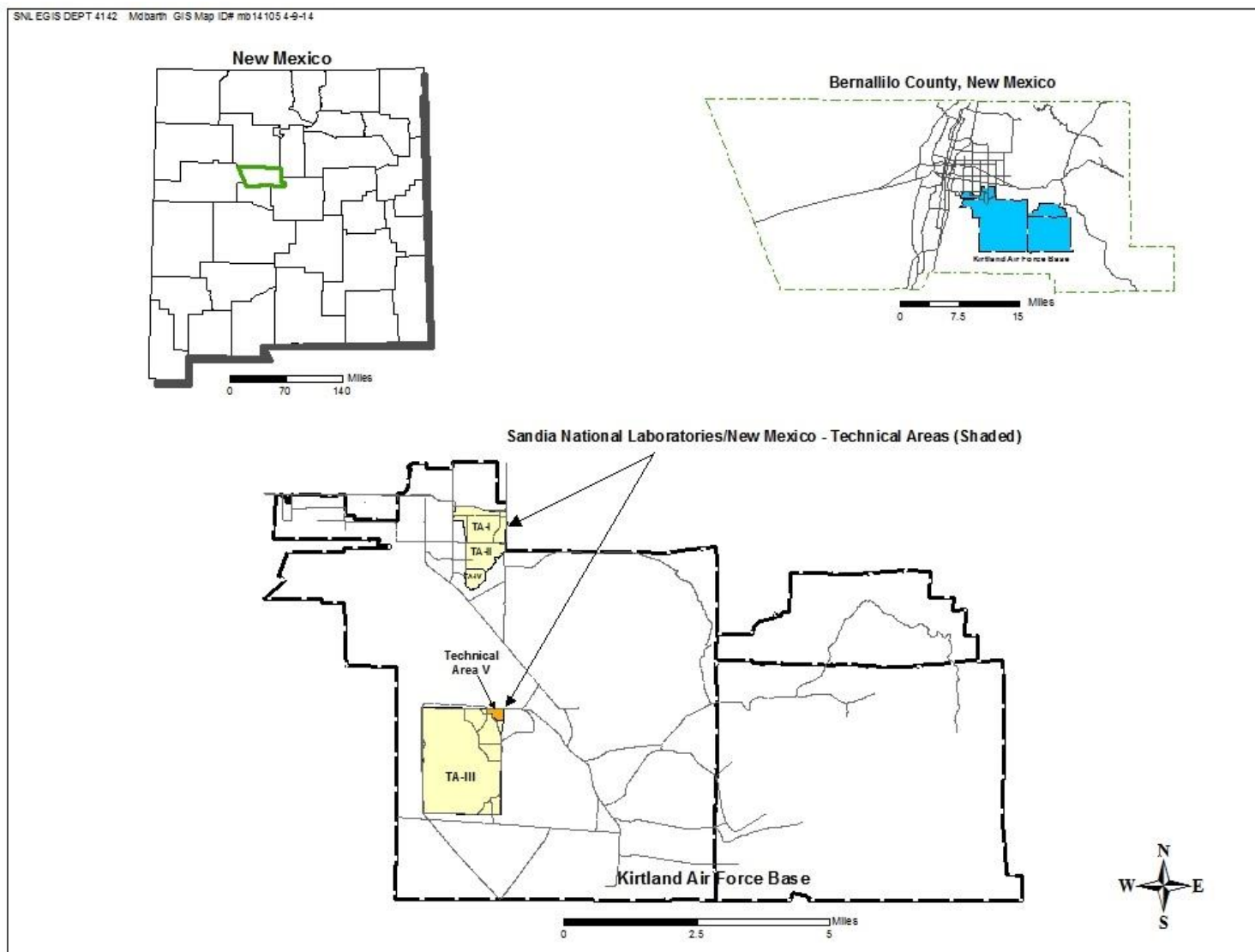


Figure 1-1  
Location of Sandia National Laboratories, New Mexico Technical Area-V

Treatability Study implementation will be conducted in two phases:

1. Phase I will be conducted at one injection location starting with a short-term push/pull test to evaluate proof of concept. Groundwater will be extracted from the injection well and mixed with a nutrient-amended substrate solution that will facilitate biostimulation and creation of an anaerobic and reducing environment in groundwater. An inert tracer will be added and this substrate solution will be reinjected into the well in parallel with a bioaugmentation culture. Subsequent sampling of the injection well and nearest groundwater monitoring wells will be conducted over a 4-month period to establish proof of concept. If the results of the push/pull test are favorable, a full-scale injection will be implemented over a 6-month period. After full-scale injection is completed, performance and rebound monitoring will be conducted for a 24-month period consisting of three monthly sampling events followed by quarterly sampling.
2. Phase II consists of implementing a full-scale injection at each of the two remaining locations of highest COC concentrations. Implementation design and procedures for each injection will incorporate lessons learned from previous activities. Performance and rebound monitoring will be conducted for 24 months following each of the two full-scale injections as described above for Phase I.

In addition to the Treatability Study performed in the center of TA-V, two additional groundwater monitoring wells will be installed to define the lateral extent of TCE to the south of TA-V.

## **1.2 Objectives of the Treatability Study**

The specific objectives of the Treatability Study are to determine the following:

- Effectiveness of gravity injection as a delivery mechanism for substrate solution and bioaugmentation culture.
- Ability of the substrate solution to establish and maintain anaerobic groundwater conditions conducive to nitrate denitrification and reductive dechlorination (biostimulation).
- Magnitude and timeframe of COC concentrations reduction and rebound after ISB treatment.
- Effectiveness of the injected bioaugmentation culture (*Dehalococcoides* bacteria) to fully dechlorinate TCE and its daughter products.
- If measures are needed to mitigate the effect of metal (iron and manganese) and metalloid (arsenic) solubilization potentially caused by changes in oxidation reduction (redox) conditions.

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## **2.0 SUMMARY OF CONCEPTUAL SITE MODEL**

This section presents a summary of the conceptual site model for TA-V, focusing on the Treatability Study area. A schematic conceptual site model cross-section is presented in Figure 2-1. Detailed information on the regional geology and hydrogeology as well as the geology and hydrogeology of TA-V may be found in the CCM document (SNL/NM September 2015).

### **2.1 Site Conditions**

TA-V is located at the northeast corner of TA-III in the west-central portion of KAFB and occupies approximately 35 acres (Figure 1-1). Research operations at TA-V began in the 1960s. TA-V facilities are used to test radiation effects on various weapon and reactor components. Historical operations involved use of the Sandia Engineering Reactor Facility, the Sandia Pulsed Reactor, the High Energy Radiation Megavolt Electron Source, and the PROTO I Facility. Active facilities include the Annular Core Research Reactor, the Gamma Irradiation Facility, and the Auxiliary Hot Cell Facility.

The majority of the fenced area of TA-V is paved. There is no significant vegetation within the fenced area and no wetlands are present.

Currently, the land use at TA-V is industrial, with potential future construction and demolition activities. It is anticipated the area will remain industrial through continued use by SNL/NM and land use will not change in the foreseeable future.

### **2.2 Sources of Contamination**

The Liquid Waste Disposal System (LWDS) drain field (Solid Waste Management Unit [SWMU] 5) and the TA-V seepage pits (SWMU 275) are considered the most probable sources of TCE and nitrate contamination in the groundwater at TA-V based on the location of the historical releases with respect to contaminated groundwater. Discharges of wastewater and sanitary waste disposal began in approximately 1962 and were discontinued in 1992. The locations of these SWMUs are shown in Figures 2-1 and 2-2.

### **2.3 Vadose Zone**

The vadose zone at TA-V consists of a thin veneer of soil overlying approximately 500 feet (ft) of interbedded, heterogeneous alluvial-fan sediments that are mostly clay-rich sands deposited in anastomosing stream channels with predominantly east-west trends. Relatively coarse-grained sands extend from the ground surface to a depth of approximately 340 ft below ground surface (bgs). The underlying fine-grained sands extend to a depth exceeding 650 ft bgs (see Figure 2-1). Occasional discontinuous layers of gravel and clay are present in both sand units. No laterally continuous perching horizons have been identified in the vadose zone or saturated sediments.

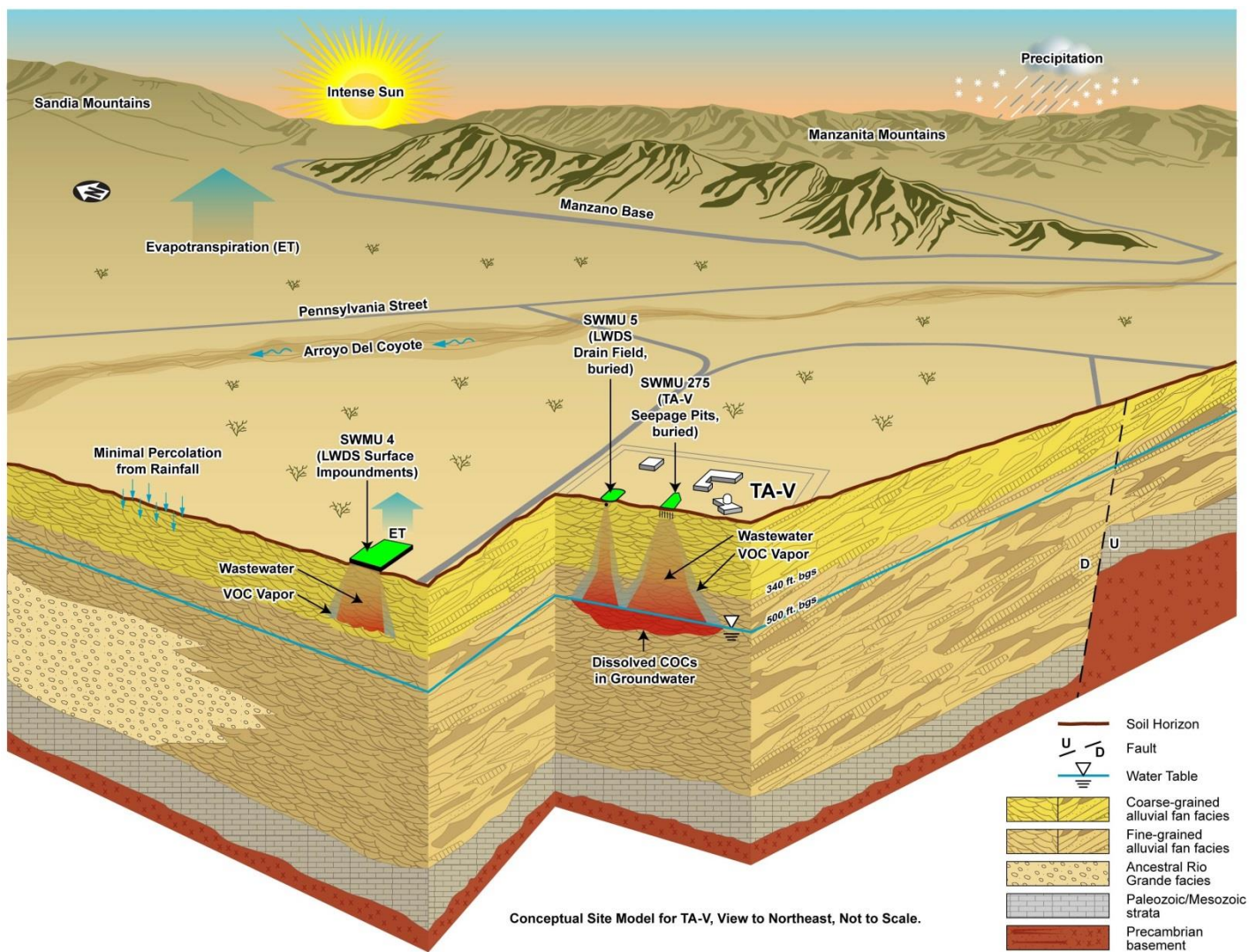


Figure 2-1  
Conceptual Site Model for Technical Area-V



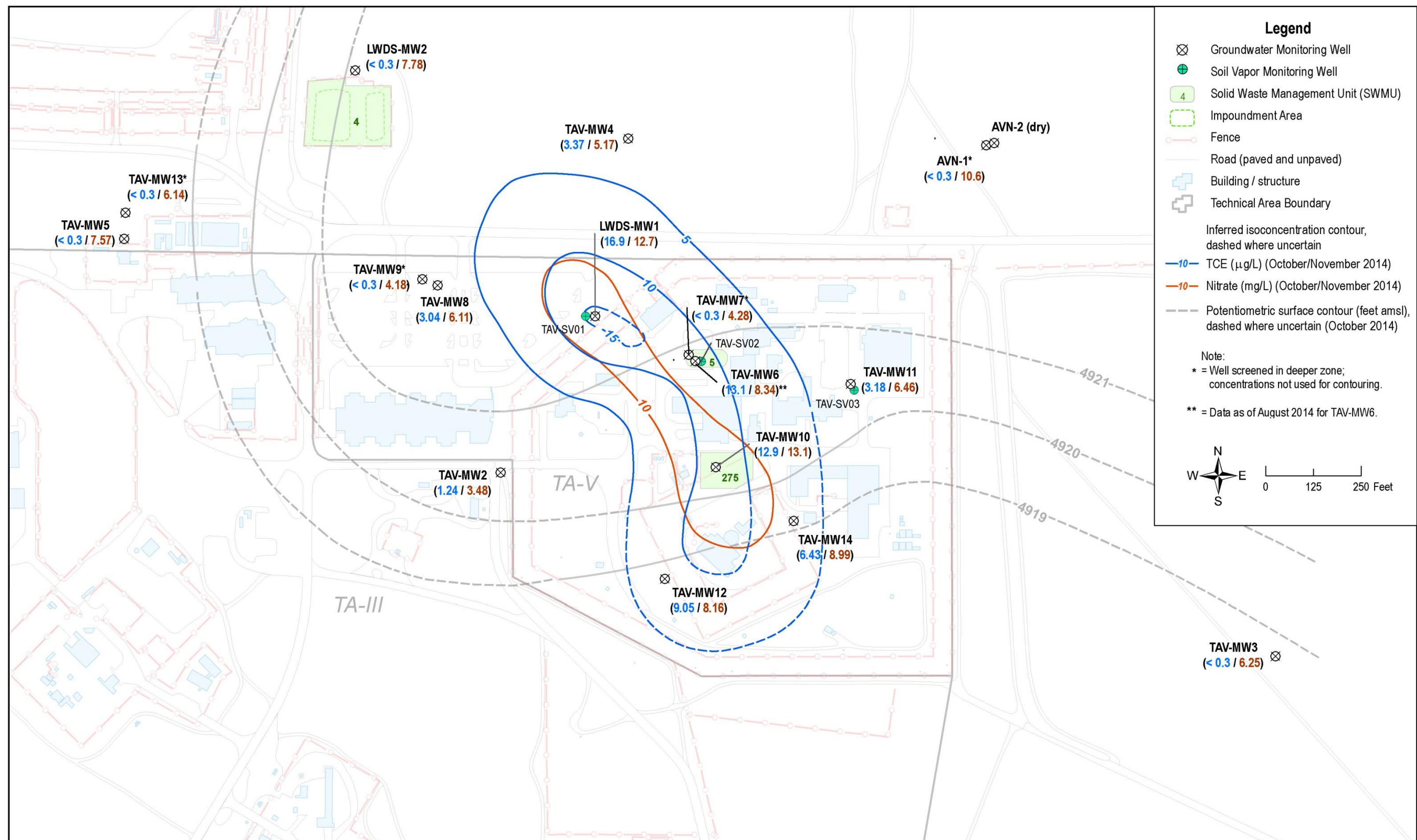


Figure 2-2  
Trichloroethene and Nitrate Distribution in Groundwater, October/November 2014



## **2.4 Groundwater Flow**

Water levels measured in October 2014 in the current 16 monitoring wells were used to construct a map of the groundwater potentiometric surface at TA-V (Figure 2-2). The aquifer is under unconfined conditions. Groundwater flow beneath TA-V is generally to the west, with localized flow to the south and southwest. The horizontal hydraulic gradient at TA-V ranged from approximately 0.002 to 0.008.

The horizontal groundwater flow velocity at TA-V can be calculated from the range of horizontal hydraulic conductivities (0.04 to 30.8 feet per day [ft/day]), the average horizontal hydraulic gradient of 0.005, and an assumed effective porosity of 0.25. The estimates for groundwater flow velocity at TA-V range from 0.29 to 225 feet per year (ft/yr), although the local flow velocity in the Treatability Study area is estimated to be less than 30 ft/yr. The wide range of hydraulic conductivity estimates at TA-V are derived from monitoring well slug tests and attributed to the textural heterogeneities associated with the alluvial-fan lithofacies. Vertical hydraulic conductivity is typically estimated to be one to two orders of magnitude lower than the horizontal hydraulic conductivity.

Groundwater levels have steadily declined at all TA-V monitoring wells due to the pumping of the regional aquifer by the KAFB and the Albuquerque Bernalillo County Water Utility Authority. The rates of decline at TA-V range from 0.55 to 0.88 ft/yr with an average declining rate of 0.77 ft/yr. The decreases in water level elevations are expected to persist as long as pumping of water supply wells in the regional aquifer continues.

## **2.5 Nature and Extent of Contamination in Vadose Zone**

No significant concentrations of TCE were found in soil vapor or soil samples collected during subsurface drilling investigations of the SWMUs at TA-V (SNL/NM January 2000 and October 2001).

Three soil-vapor monitoring wells (TAV-SV01, TAV-SV02, and TAV-SV03) were installed adjacent to groundwater monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW11, respectively (Figure 2-2), to a total depth of 500 ft bgs (close to the groundwater table). Volatile organic compound (VOC) concentrations in soil vapor were measured for eight quarters from April 2011 to March 2013. At each well, soil-vapor samples were collected from ten 1-foot long stainless steel screens set at intervals from 50 to 500 ft bgs and analyzed for VOCs. All eight quarters' analytical results were reported in Attachment 5D of the Calendar Year 2013 Annual Groundwater Monitoring Report (SNL/NM June 2014). TCE is the most prevalent VOC in the vadose zone. The soil-vapor results show that the TCE vapor concentrations have stabilized in the vadose zone at TA-V and the TCE in soil vapor is not considered a significant source to groundwater.

Nitrate occurs primarily in the dissolved phase. It typically does not exchange onto sediment surfaces and is not sorbed to sediments in the subsurface. Therefore, nitrate in excess of background concentrations was most likely transported through the vadose zone with the wastewater discharges.



## **2.6 Nature and Extent of Contamination in Groundwater**

TCE has been consistently detected above the MCL of 5 µg/L in samples from a number of wells in the area. Figure 2-2 shows TCE isoconcentration contours in groundwater for the fourth quarter of calendar year 2014, except that the TCE concentration from the August sampling event is shown for TAV-MW6 (TCE was anomalously not detected in the fourth quarter).

While TCE has been detected in wells screened across the groundwater table, it has not been detected in wells screened approximately 90 ft deeper.

Figure 2-2 shows the 10 mg/L nitrate isoconcentration contour for the fourth quarter of calendar year 2014. The 10 mg/L nitrate contour is located within the 5 µg/L TCE contour. The general configuration of the 10 mg/L contour has not changed significantly over the past several years.

Nitrate has also been detected in groundwater monitoring wells upgradient of TA-V at concentrations exceeding the MCL, indicating a contribution of nitrate from other unidentified KAFB sources and/or locally elevated background conditions.

## **2.7 Contaminant Transport Mechanisms in Groundwater**

Contaminant transport mechanisms in groundwater include advection, dispersion, diffusion, sorption, and biodegradation. Groundwater monitoring results over the past two decades indicate that advection is not the main force driving contamination migration at TA-V, likely due to the low groundwater flow velocities especially in the center of TA-V (i.e., the Treatability Study area). Dispersion and diffusion are the more important transport mechanisms at TA-V.

While nitrate does not tend to sorb to sediment surfaces, TCE is a hydrophobic organic compound and sorbs to the organic matter in the aquifer matrix. Sorption is a reversible process. As the dissolved contaminant concentration in groundwater decreases due to advection, dilution, or biodegradation, the sorbed TCE portion will tend to desorb and reenter the aqueous phase. The relatively stable TCE concentration in TA-V groundwater can be attributed to the relatively slow processes of dispersion, diffusion, and reversible sorption.

Biodegradation of TCE was evaluated during preparation of the 2005 CME Report (SNL/NM July 2005). The assessment indicated that anaerobic reductive dechlorination is not occurring in groundwater at TA-V, nor is biologically mediated transformation of nitrate. This is likely due to the relatively high concentration of dissolved oxygen (DO) and low concentration of dissolved organic carbon as carbon and energy sources. A study of denitrification parameters and isotopic signatures conducted in 2013 also indicated that natural denitrification was insignificant at TA-V (Madrid et al. June 2013).

### 3.0 TECHNICAL APPROACH OF IN-SITU BIOREMEDIATION

The Treatability Study uses a phased approach to increase the scale of ISB injections based on key data-driven decision points starting with a proof of concept push/pull test, followed by a full-scale injection at one location and if successful, full-scale injections at two other locations near the highest COC concentrations in groundwater. These decision points provide the opportunity to incrementally evaluate the degree of success and to optimize procedures and the use of resources. An overview of the technical approach is described below.

An electron donor (ethyl lactate), nutrients, pH buffer, and an inert tracer (sodium bromide) will be mixed in aboveground tanks with extracted groundwater for the push/pull test and with potable water for the full-scale injections. KB-1<sup>®</sup> Primer (produced by SiREM, Guelph, Ontario, Canada) will be used in the first batch of solution to accelerate deoxygenation within the mixing tanks prior to parallel injection with the bioaugmentation culture. Subsequent batches will replace the KB-1<sup>®</sup> Primer with a mixture of ethyl lactate as the electron donor and diammonium phosphate and yeast extract as nutrients and pH buffer. This deoxygenated substrate solution and bioaugmentation culture will be delivered to the groundwater via injection wells.

To mitigate potential biofouling of the injection well during the full-scale injection periods, each daily injection of the substrate solution and bioaugmentation culture will be followed by injection of unamended potable water of sufficient volume to displace water in the static water column and surrounding filter pack. This unamended water will be deoxygenated with argon gas prior to injection.

Once the injection is completed, the effect of biostimulation and bioaugmentation within the treatment area is expected to be relatively rapid, on the order of months, thereby reducing overall contaminant mass and concentrations in groundwater. Performance monitoring will be conducted at nearby groundwater monitoring wells and compared to results from the injection well. Analyzing groundwater for concentrations of the inert tracer over time at both the injection well and monitoring wells will support evaluation of the size of the treatment area and the degree of dilution caused by the injected water.

Biodegradation is intended to initially reduce nitrate concentration through denitrification eventually followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids within the aquifer.

Reductive dechlorination occurs through microbially mediated reactions whereby microorganisms obtain energy through redox reactions. Electron donors, such as ethyl lactate, are used by microbes to reduce various electron acceptors such as oxygen, nitrate, manganese (IV), ferric iron (Fe[III]), sulfate, and carbon dioxide to obtain energy. Bacteria obtain the greatest energy yield by using oxygen as the electron acceptor because it is highly oxidized and can therefore be easily reduced. During the first stages of the Treatability Study, biodegradation of the injected electron donor will deplete the aquifer of DO and other terminal electron acceptors and will lower the oxidation-reduction potential (ORP) of the groundwater. This produces conditions conducive to anaerobic degradation. When DO is depleted in an uncontaminated aquifer, bacteria sequentially use the less oxidized electron acceptors in the following order (ITRC June 2008):

- |                           |  |
|---------------------------|--|
| 1. Nitrate:               | Denitrification to molecular nitrogen.       |
| 2. Manganese (IV):        | Reduction to $\text{MnO}_2/\text{Mn}^{+2}$ . |
| 3. Ferric iron (Fe[III]): | Reduction to ferrous iron (Fe[II]).          |
| 4. Sulfate:               | Reduction to sulfide.                        |
| 5. Carbon dioxide:        | Methanogenic respiration.                    |

Chlorinated VOCs, such as TCE, can also be used as electron acceptors by specific microorganisms such as *Dehalococcoides* and thereby be degraded to innocuous end products. As less oxidized electron acceptors are utilized, the ORP is lowered to a point favorable for reductive dechlorination. Injection of the electron donor to groundwater overcomes terminal electron acceptor sinks (such as DO, nitrate, and sulfate) and creates sulfate-reducing and/or methanogenic conditions throughout the saturated zone. Either of these conditions will promote the transfer of electrons first to nitrate and then to chlorinated solvents, which will reduce their concentrations.

During reductive dechlorination, chlorine ions are successively replaced with hydrogen, degrading TCE to *cis*-1,2-dichloroethene (*cis*-1,2-DCE), followed by vinyl chloride, and finally to innocuous ethene and ethane. TCE can be reduced under ferric iron-reducing conditions (Chapelle, September 1996), *cis*-1,2-DCE under sulfate-reducing or methanogenic conditions (Chapelle, September 1996; Vogel et al., August 1987) and the degradation of vinyl chloride occurs under highly reducing methanogenic conditions (Ballapragada et al., 1997, Freedman and Gosset, 1989; Maymó-Gatell et al., July 1999; Vogel and McCarthy, May 1985). TCE dechlorination can begin to occur at an ORP of approximately 50 millivolts (mV), but a value closer to negative 100 mV is significantly more favorable as iron would be competing for electrons above this ORP value.

A primary objective of the Treatability Study is to create these reducing and methanogenic subsurface conditions to sustain a population of introduced and possible naturally occurring *Dehalococcoides* that will induce complete dechlorination of TCE to ethene. Aerobic conditions found at TA-V, are not favorable for establishing a population of *Dehalococcoides*. Additionally, concentrations of TCE are very low, and therefore may not facilitate rapid *Dehalococcoides* population growth after anaerobic reducing conditions are established. Fully dechlorinating TCE (while preventing a degradation stall at either *cis*-1,2-DCE or at vinyl chloride) at the site based solely on developing a potential native microbe population, would either take a very long time, or may not even occur. Therefore, the Treatability Study includes injecting a bioaugmentation culture (KB-1<sup>®</sup> Dechlorinator, produced by SIREM) along with the substrate solution to establish a robust *Dehalococcoides* population and thereby increase the rate and extent of anaerobic reductive dechlorination. KB-1<sup>®</sup> Dechlorinator includes specific strains of *Dehalococcoides* that possess the vinyl chloride reductase gene needed to fully dechlorinate TCE through vinyl chloride to ethene.

The process of developing strongly anaerobic redox conditions is likely to result in solubilization and mobilization of some naturally occurring oxidized metals and metalloids as a result of direct reduction and mineral dissolution, most particularly iron, manganese, and arsenic. However, the solubilization of these metals is generally a transient phenomenon and is limited to the treatment area. Solubilized metals and metalloids will precipitate into solid form once they leave the anaerobic treatment zone or after the aquifer returns to aerobic conditions in the treatment zone. Active management can be employed, such as direct injection of oxygen or other electron acceptors, but most sites do not require such actions (ITRC June 2008). This Treatability Study includes monitoring changes in iron, manganese, and arsenic concentrations before, during, and after injections are conducted to ascertain if active management of these

constituents will be necessary to return them to background concentrations after groundwater treatment is completed.

Quantifying the effects of denitrification and dechlorination relative to the effect of dilution caused by the substrate solution is complicated by the low initial concentrations of both COCs. Their respective daughter products (nitrite and nitrogen gas for nitrate and *cis*-1,2-DCE, vinyl chloride, and ethene for TCE) may not be produced at readily detectable concentrations. Conclusions about nitrate are further complicated by the fact that background concentrations will rebound with advection over time due to upgradient nitrate sources or possibly elevated background concentration. Therefore, several lines of evidence will be used to make conclusions about the degree of dilution versus denitrification and dechlorination including:

- Attenuation of inert tracer concentrations and any correlation to COC concentration trends,
- Temporary increases in iron, manganese, and arsenic concentrations, and
- Measurement of redox parameters, indicating a reducing environment.

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## 4.0 TREATABILITY STUDY DESIGN

The Treatability Study will be performed in two phases:

### Phase I: Installation of Injection Well TAV-INJ1 Followed by a Push/Pull Test and Full-Scale Injection

Injection well TAV-INJ1 will be installed near SWMU 5 with a screen extending approximately 25 ft below the water table. A small-scale proof of concept push/pull test will then be conducted by preparing a substrate solution using groundwater extracted from well TAV-INJ1 and reinjecting it along with the bioaugmentation culture to deliver a 5-ft radius treatment area. Post-injection performance monitoring will be conducted for 4 months.

Contingent on successful results from the push/pull test, Phase I will continue with full-scale injection using potable water for mixing and delivery of the substrate solution and bioaugmentation culture throughout a 60-ft radius treatment area. Post-injection performance monitoring will be conducted for 24 months.

### Phase II: Installation of Injection Wells TAV-INJ2 and TAV-INJ3 Followed by Successive Full-Scale Injections

Phase II expands the Treatability Study to two additional locations. The objectives of Phase II are the same as the full-scale injection conducted in Phase I with the added objectives of determining performance at locations with different hydraulic conductivities and whether injection(s) at these locations would be sufficient to meet cleanup standards site-wide within a reasonable timeframe. Post-injection performance monitoring will be conducted for 24 months.

The primary components of the Treatability Study design are:

- ISB treatment areas and injection volume.
- Substrate solution and bioaugmentation culture.
- Injection wells for substrate solution delivery.
- Additional groundwater monitoring wells.

## 4.1 ISB Treatment Area and Volume of Injection

Three areas with the highest COC concentrations are targeted for ISB treatment under this Treatability Study:

- Vicinity of SWMU 5.
- Vicinity of SWMU 275.
- Vicinity of monitoring well LWDS-MW1.

Due to the depth of groundwater (over 500 ft), direct-push drilling and injection technology used for shallow plumes is not feasible. Therefore, injections must be performed through injection wells screened within contaminated groundwater. The scope of this Treatability Study includes installing up to three injection wells (TAV-INJ1, TAV-INJ2, and TAV-INJ3) as shown in Figure 4-1. These well locations correspond to the three areas of highest COC concentrations.

Figure 4-2 shows the conceptual treatment area at each injection location. To eliminate a variable in the Treatability Study, the targeted delivery area was kept consistent for each injection location. A 60-ft delivery radius was selected because it covers an area approximately equal to the footprint of the largest release source, SWMU 275. This is a large enough area to provide evaluation of injection performance and, if successful, will eliminate the highest concentrations of COCs without being so large as to take an unreasonable length of time to perform and evaluate the injections.

The volume of substrate solution to be injected for the full-scale test at each of the three locations is based on replacing one pore volume of the aquifer within a radius of approximately 60 ft and a thickness of 25 ft below static water level centered around each injection well. Assuming an effective porosity of 25 percent, the total target volume of substrate solution to be injected per injection well is approximately 530,000 gallons, as shown in the calculation below. The actual areal extent of delivery is difficult to estimate due to preferential flowpaths and lithologic heterogeneities. Actual injected volume may be less if achievable injection rates preclude full injection within a reasonable time frame. Actual injected volume and measurements at monitoring wells near the injection wells will be incorporated into the assessment of radius of influence and delivery area.

#### Substrate Solution Volume Calculation (per injection well)

Delivery radius	60 ft
Area	11,310 square feet (ft <sup>2</sup> )
Thickness	25 ft
Total Volume	282,743 cubic feet (ft <sup>3</sup> )
Effective porosity	25 percent
Effective pore volume (target injection volume)	70,688 ft <sup>3</sup>
Effective pore volume ( <b>target injection volume</b> )	<b>528,783 gallons (rounded to 530,000 gallons)</b>

The volume of the substrate solution components (see section 4.2.1) relative to the potable water is negligible and therefore not included in the total injected volume calculation.

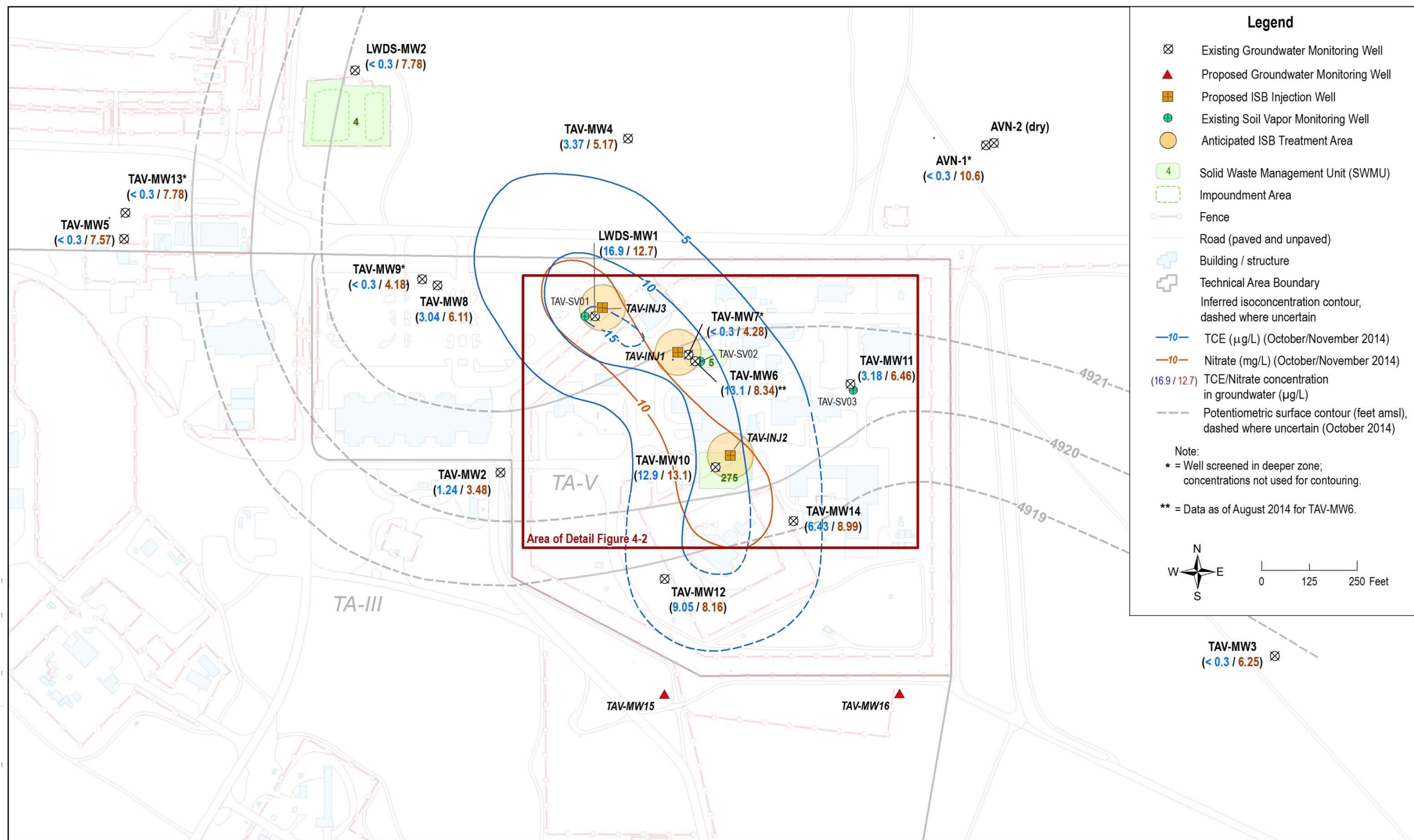


Figure 4-1  
Proposed Injection Wells and Additional Groundwater Monitoring Wells





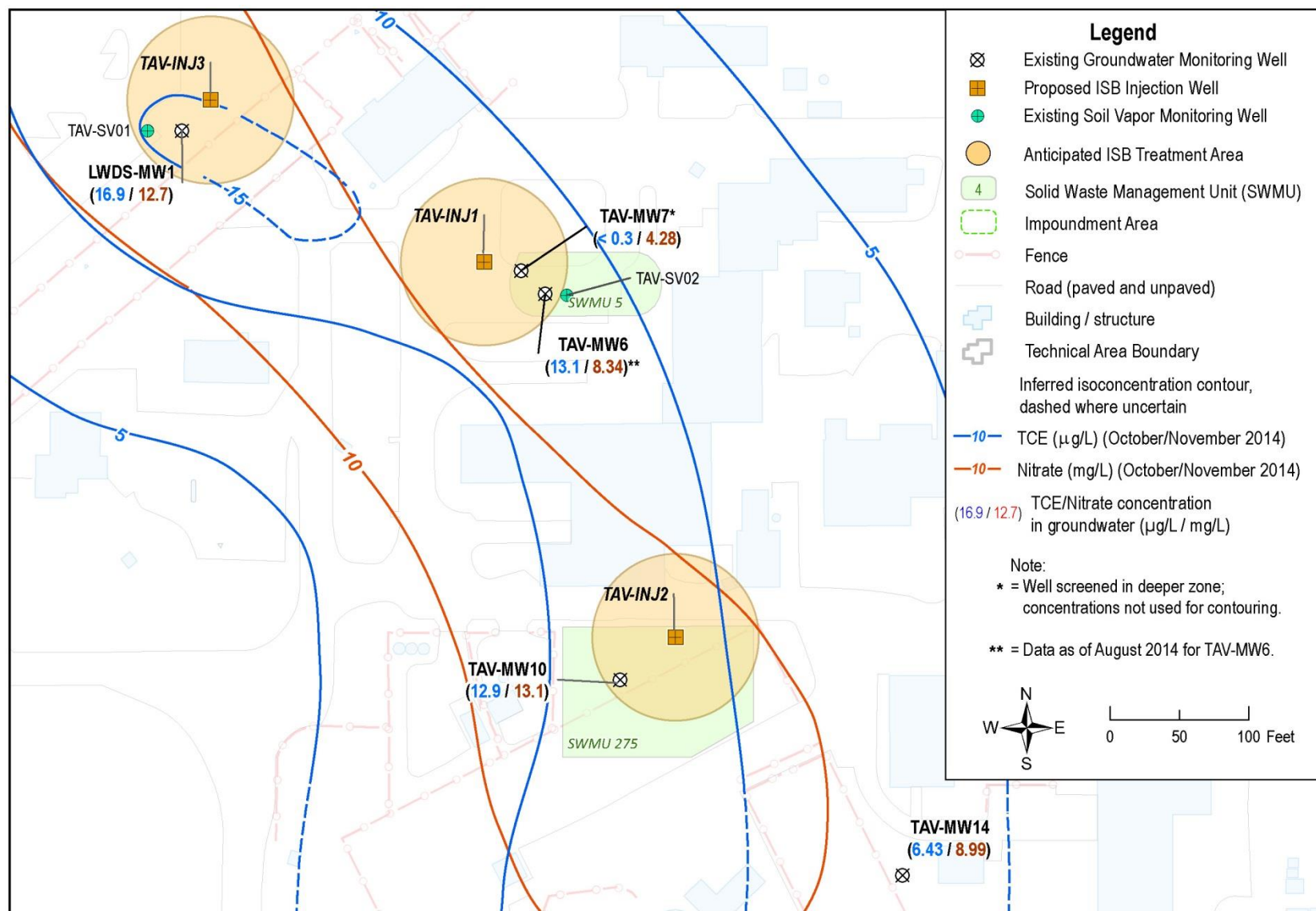


Figure 4-2  
Treatability Study In-Situ Bioremediation Treatment Areas

## 4.2 Substrate Solution and Bioaugmentation Culture

The injected substrate solution and bioaugmentation culture will include several components, each serving a specific purpose. The following section discusses each of these components and the dosage and mixing ratio.

### 4.2.1 Components of Substrate Solution

#### Electron Donor

Ethyl lactate has been selected as the electron donor or substrate for this Treatability Study. Ethyl lactate has high water solubility, a low retardation factor, low viscosity, and lacks particulates, all of which ensure a high degree of transportability within the treatment area. These physical and chemical properties are appropriate for conditions at TA-V.

Ethyl lactate has been shown to be very effective at stimulating microbial growth that produces conditions conducive to anaerobic degradation of contaminants. It also has other favorable properties compared to other electron donors (Jayaraj et al. 2004). It is fully utilizable by microbes, unlike substrates such as sodium lactate where the sodium is not utilized. Ethyl lactate yields the same hydrogen equivalent as dextrose (12:1) and is comprised of ester-linked carbons that break apart to form lactate and ethanol. The ethanol produced during dissolution acts as a co-solvent aiding in desorption of chlorinated solvents, such as TCE, from the aquifer matrix. The ethanol is also highly transportable, as is the lactate that is generated upon dissolution. Both of these components are then utilized by the bacteria, creating the desired anaerobic conditions.

Ethyl lactate is also very effective at reducing nitrate. During a recent pilot study at Lawrence Livermore National Laboratory (LLNL March 2014), ethyl lactate injection reduced nitrate concentrations to below reporting limits within 1-2 months.

From a practical standpoint, ethyl lactate is supplied in a liquid concentrate that will not spoil or freeze, providing a longer shelf life when compared with simple sugars such as glucose or dextrose. Because it is provided as a liquid, ethyl lactate can also be easily blended with other components in the tank prior to injection. To prevent oxidation, the ethyl lactate is supplied under a nitrogen or argon blanket. After opening the container, the product will be stored under inert conditions by purging the container head space with inert gas.

The Treatability Study is designed to deliver one pore volume (based on estimated effective porosity) of potable water mixed with a sufficient mass of electron donor to treat the contaminant mass within that treatment area. Appendix A shows the calculations for the total electron donor demand based on treatment area dimensions (radius and thickness), effective porosity, and concentration of terminal electron acceptors. These calculations use stoichiometric ratios of ethyl lactate (the electron donor) to electron acceptors including chlorinated VOCs to estimate the total electron donor demand.

The desired mass of electron donor to be delivered is determined by:

1. Estimating electron donor demand from the competing terminal electron acceptors.
2. Estimating electron donor demand from chlorinated VOC mass in groundwater.

3. Estimating electron donor demand from chlorinated VOC mass sorbed to the solid matrix within the aquifer.
4. Totaling the above three subsets.
5. Applying utilization and safety factors (described below).

Observations from numerous site implementations across the United States show that the theoretical stoichiometric value is often not sufficient to create the desired conditions at a site. Research (Lee et al. March 2004) shows that only 30 percent of the electron donor is utilized for dechlorination (referred to as the 'McCarty' factor). The McCarty factor was applied to calculate the electron donor demand based on stoichiometry. A safety factor of 10 was then applied based on full-scale field experience and to account for low hydraulic conductivity of the saturated sediments at TA-V.

The final calculated total mass of ethyl lactate to be injected during each full-scale test is 4,690 pounds (lbs) per injection well. Ethyl lactate is supplied as a liquid and has an approximate density of 1.03 grams per milliliter (g/mL) (8.60 lbs/gallon). Therefore, approximately a total of 545 gallons of ethyl lactate will be used to mix with the 530,000 gallons of potable water to be injected at each well. This is approximately equivalent to a 0.10 percent ethyl lactate solution.

### Nutrients

Diammonium phosphate and yeast extract will be added as nutrients to support microbial growth. They will be blended with the ethyl lactate at a weight ratio of approximately 80 percent ethyl lactate, 17 percent diammonium phosphate, and 3 percent yeast extract. This will provide a solution that is very similar to that used at wastewater treatment plants where for every 100 parts of carbon, 10 parts of nitrogen and 1 part of phosphorus are required for bacterial growth (Metcalf and Eddy 1991). Without the addition of these nutrients, bacteria will enter nutrient-limited kinetic rates that are much more ineffective at reducing contaminant concentrations. The nitrogen and phosphorus will be mixed with the ethyl lactate before being injected into the subsurface to facilitate utilization by bacteria.

Ammonia and phosphate concentrations will rise as the solution is injected to the saturated zone. However, once the bacteria begin to grow on the substrate, they will rapidly utilize the nitrogen and phosphorus, reducing the ammonia and phosphate concentration to background concentrations. The nitrogen and phosphorus are converted to microorganism biomass, and will not be a concern for downgradient migration.

### pH Buffer

It is important to maintain a relatively neutral pH in the aquifer to support a robust microbial community that can fully dechlorinate TCE to ethene. Therefore, addition of a pH buffer is included to offset pH reduction that can occur as a result of volatile fatty acid production during fermentation of the electron donor. The diammonium phosphate added as a nutrient will also serve as the pH buffer; thereby eliminating the need for an additional component specific to buffering. *Dehalococcoides* optimally dechlorinates in a pH range between 6.9 and 7.5 (Löffler et al. April 2012), although keeping the pH between 6.0 and 8.5 is common practice for

bioremediation. Maintaining a neutral pH also mitigates the degree of metals and metalloid solubilization.

### Tracer

Sodium bromide will be used as an inert tracer added to the substrate solution during the initial push/pull test and in subsequent full-scale injections. In the push/pull test where native groundwater will be extracted, amended, and re-injected, the bromide tracer concentration will be monitored over time after injection to normalize sampling data to account for surrounding groundwater flowing into the re-injected area. Under full-scale injections, where potable water is used to deliver the substrate solution and bioaugmentation culture, bromide concentration data will be used to evaluate the degree of initial dilution caused at the injection location, the rate at which this dilution effect attenuates as a result of mixing with the surrounding groundwater, and delivery of the injected solution to the nearby monitoring well(s).

Background bromide concentrations in groundwater at TA-V are less than 1 mg/L. Assuming that the hydraulic conductivity at each injection well is comparable to that measured in nearby monitoring wells, a bromide concentration of approximately 20 mg/L would be a suitable tracer concentration. This translates to approximately 0.2 lbs of sodium bromide per 1,000 gallons of injected potable water. If significantly higher hydraulic conductivity is encountered at the injection well, the bromide concentration can be increased to as much as 200 mg/L to counter dilution effects from local groundwater advection.

### Component Mixing

The substrate and other components will be mixed in aboveground tanks with water (extracted groundwater for the push/pull test and potable water for the full-scale injections). Table 4-1 lists the components of the substrate solution, their respective roles, and mixing ratio. The estimated amount of sodium bromide tracer is also shown. The final mixing ratios may vary based on data acquired from injection well sampling. The Safety Data Sheet (SDS) for each component is included in Appendix B.

Each batch of mixed solution will be deoxygenated in the tank prior to gravity injection into the well to protect the anaerobic bioaugmentation culture that will be co-injected with the substrate solution. KB-1<sup>®</sup> Primer (slurry) will initially be used to accelerate the conversion from aerobic to anaerobic in the tank, typically within a few hours. Subsequent batches will rely on the ethyl lactate substrate to develop anaerobic conditions.

#### 4.2.2 KB-1<sup>®</sup> Primer

KB-1<sup>®</sup> Primer is a proprietary mixture of amino acids, potassium bicarbonate, and sodium sulfite that is used to accelerate deoxygenation of water inorganically (sodium sulfite) while still providing an electron donor (amino acids) and buffer (potassium bicarbonate). It can therefore be used as a substitute for ethyl lactate, diammonium phosphate, and yeast extract, although it is significantly more costly and therefore, not suitable for the large volumes planned under full-scale injection.

Table 4-1  
Substrate Solution Components

Substrate Solution Component	Function	Mixing Ratio (by weight)	Weight per 1,000 gal Water
<b>Primary Components</b>			
Ethyl lactate	Electron donor (substrate)	80%	8.9 lbs (1.0 gal)
Diammonium phosphate	Nutrient and pH buffer	17%	1.9 lbs
Yeast extract	Nutrient	3%	0.3 lbs
<b>Primary components per 1,000 gal potable water</b>		<b>100%</b>	<b>11.1 lbs</b>
<b>Additional Component Mixed with Substrate Solution</b>			
Sodium bromide	Inert tracer (as bromide)	Not applicable; adjusted per field condition	0.2 lbs
<b>Initial batch of Substrate Solution (to accelerate deoxygenation)</b>			
KB-1 <sup>®</sup> Primer <sup>a</sup>	Substitute for ethyl lactate, diammonium phosphate, and yeast extract to accelerate deoxygenation in push/pull test and initial full-scale injection batches	100%	7.1 lbs

<sup>a</sup> KB-1<sup>®</sup> Primer is a product manufactured and supplied by SiREM, Guelph, Ontario, Canada.

% = Percent.

gal = Gallon(s).

lbs = Pounds.

The groundwater extracted for push/pull test will be stored in approximately equal proportions in two tanks. One tank will be inoculated with a small amount of soil core/cuttings from the injection well screened interval and have KB-1<sup>®</sup> Primer added. The purposes of adding soil core/cuttings to the substrate solution are to (1) inoculate the solution with native microorganisms, (2) create a diverse microbial community that will more likely work synergistically with the bioaugmentation culture, and (3) reduce the lag time for initiating biostimulation associated with utilization of the substrate in the subsurface. If sufficient core/cuttings are not recovered during drilling, a commercial lyophilized bacterial septic tank amendment (e.g., Rid-X<sup>®</sup> Septic System Treatment or equivalent) may be substituted at a mass/volume based on manufacturer recommendations.

As water in the first tank turns anaerobic, water from the second tank will be transferred into the first tank and mixed with proportional amounts of the substrate solution components, as outlined in section 4.2.1. Although addition of groundwater from the second tank is likely to increase the DO and ORP initially, the combined water volume is expected to return to sufficiently decreased DO and ORP within one to two days and ready for gravity injection back into the well as one batch.

A similar process will be applied to the full-scale injections. Two pairs of tanks will be used for full-scale injection (see section 4.3.2). Both pairs of tanks will be filled halfway with potable water, inoculated, and have KB-1<sup>®</sup> Primer added. After turning anaerobic, the tanks will be filled with potable water and mixed with proportional amounts of the substrate solution components. As with the push/pull test, deoxygenation of the entire tank volume is expected within one to two days. Once anaerobic conditions are restored, half of the tank contents (from each pair) will be injected. This pair of tanks will then be refilled with potable water and mixed with proportional amounts of the substrate solution components. Provided that approximately half a tank of the

deoxygenated solution remains in each tank, this accelerated deoxygenation schedule is expected to continue without further use of KB-1<sup>®</sup> Primer during the remainder of the injection period. By alternating two pair of tanks, injection would not be interrupted while waiting for the substrate solution to turn anaerobic.

Approximately 7.1 lbs of KB-1<sup>®</sup> Primer is needed per 1,000 gallons of water based on manufacturer recommendations.

#### 4.2.3 KB-1<sup>®</sup> Dechlorinator

To expedite growth of a microbial population capable of fully dechlorinating TCE to ethene, a bioaugmentation culture, KB-1<sup>®</sup> Dechlorinator, will be injected in conjunction with the substrate solution. KB-1<sup>®</sup> Dechlorinator is a naturally occurring, non-hazardous, non-pathogenic, microbial culture that contains a consortium of anaerobic microorganisms that promote dechlorination of chlorinated solvents. It includes *Dehalococcoides* that has a strain possessing the gene capable of producing enzymes that reduce vinyl chloride to non-toxic ethene (vinyl chloride reductase). *Dehalococcoides* can be found naturally in the environment. However, these bacteria are not ubiquitous, and an aerobic environment, such as that present at TA-V, is not favorable for establishing a population. With concentrations of TCE being very low at the site, development of a robust *Dehalococcoides* population without bioaugmentation either may not be possible or would require a very long time if relying solely on an indigenous population.

Typical dosing of KB-1<sup>®</sup> Dechlorinator for sites with TCE concentrations one or more orders of magnitude higher than that present at TA-V is approximately 0.24 lbs KB-1<sup>®</sup> Dechlorinator per 1,000 gallons of water. The low concentrations of TCE at TA-V would result in a slower microbial population growth rate. Therefore, the KB-1<sup>®</sup> Dechlorinator dosing will be doubled to 0.5 lbs KB-1<sup>®</sup> Dechlorinator per 1,000 gallons of water to facilitate population development within a reasonable timeframe.

To effectively deliver the KB-1<sup>®</sup> Dechlorinator to the treatment area, it will be injected simultaneously with the substrate solution. Waiting to deliver the bioaugmentation culture until after the initial injection of substrate solution alone would require additional injection volumes to reach the same treatment area and would have to be delayed long enough to ensure the groundwater had been deoxygenated.

KB-1<sup>®</sup> Dechlorinator is a liquid and is shipped by the supplier to the site in stainless steel containers. KB-1<sup>®</sup> Dechlorinator has a shelf life of approximately two weeks, so shipments will be sized and delivered as needed to match the pace of injections without compromising the product shelf life.

KB-1<sup>®</sup> Dechlorinator injection will be performed in accordance with the supplier's procedure and be mixed in-line with the substrate solution via a connection placed between the substrate solution mixing tank and the wellhead. The KB-1<sup>®</sup> Dechlorinator is purged from its vessel into the aboveground injection line with inert gas (argon) under sufficient pressure to ensure proper mixing with the substrate solution injection stream.

Concentrations of solubilized metals and metalloids and the pH in groundwater will also be evaluated prior to adding *Dehalococcoides* to determine if adjustments in buffering amendment are required over the course of the full-scale injection period.

## 4.3 Injection Locations and Injection Rate

### 4.3.1 Location of Injection Wells

Injection well locations are shown in Figure 4-2. Each injection well will be paired with an existing groundwater monitoring well and installed at a distance so that evidence of substrate delivery can be observed within the 24-week active injection period. The detailed derivation of the 24-week active injection period is presented in Appendix A. Placing the injection wells in slightly closer proximity to the monitoring wells accelerates the data collection timeframe and helps offset uncertainties regarding subsurface heterogeneity. However, the injection well cannot be placed too close to the existing monitoring well because well construction might damage the existing monitoring well due to gradual deviation of the drill stem during drilling or due to inaccurate/undesirable placement of grout in the borehole annulus during well construction. Well pairings are as follows:

- TAV-INJ1 is paired with monitoring well TAV-MW6 and deeper monitoring well TAV-MW7.
- TAV-INJ2 is paired with monitoring well TAV-MW10.
- TAV-INJ3 is paired with monitoring well LWDS-MW1.

Modeling of substrate solution injection using MODFLOW 2000 was used to guide the location of injection wells with respect to existing monitoring well locations. Each injection well is located at a distance from its paired monitoring well that modeling indicates the substrate solution will travel during the 24-week active injection period. Delivery will continue for several weeks after active injection ceases as the residual mound dissipates, returning water levels to pre-injection elevations.

Modeling, using the anticipated injection rate and hydraulic conductivity, indicates that substrate solution injected into TAV-INJ1 and TAV-INJ2 would travel approximately 50 ft during the 24-week active injection period and approximately 10 ft farther as the residual mound dissipates. Therefore, these two wells will be installed at approximately 50 ft from the paired monitoring wells (TAV-MW6 and TAV-MW10, respectively). Modeling of injection at TAV-INJ3, where hydraulic conductivity is expected to be much lower, results in placing the well approximately 30 ft away from monitoring well LWDS-MW1. Delivery to the remaining 30 ft of the treatment area radius would be achieved as the residual mound dissipates.

Injection wells will be installed upgradient of their respective monitoring wells to the degree logistically possible. Prior to drilling, available engineering drawings will be reviewed, a utility location survey will be performed, and facility and security operations management will be involved throughout project planning activities. Figure 4-2 takes into account known access limitations, but final well locations will be determined in the field and modified as needed due to proximity to buildings, fencing, secured nuclear facility buffer zones, underground utilities, and other obstructions. If an appropriate upgradient location is not accessible, an alternative location proximal to the paired monitoring well(s) will be selected. The groundwater gradient is relatively low (averaging approximately 0.005) throughout TA-V and will be overwhelmed by the temporary mounding effect induced during injection. Therefore, the relative lateral proximity to the neighboring monitoring well is more important than orientation with respect to the hydraulic gradient.



### 4.3.2 Injection Rate

The target injection rate is approximately 5,000 gallons per 8-hour work day (i.e., approximately 10.4 gallons per minute [gpm]). The achievable injection rate is controlled by two factors: (1) the time required to deoxygenate each batch of substrate solution prior to injection, and (2) controlling the pressure exerted by the height of the substrate solution column within the well during injection to prevent damage to well casing and well screen.

#### Deoxygenation of Substrate Solution

Two pairs of 5,000-gallon tanks will be used for substrate solution mixing and deoxygenation. After the initial total of 10,000 gallons of substrate solution (in two tanks) are mixed and deoxygenated, 5,000 gallons (2,500 gallons from each tank) will be gravity-injected along with the bioaugmentation culture (KB-1<sup>®</sup> Dechlorinator) into the injection well, leaving 2,500 gallons of deoxygenated solution in each tank. This remaining volume will facilitate the accelerated deoxygenation of the refilled water (2,500 gallons for each tank) after mixing with commensurate substrate solution components. It is anticipated that the entire tank volume will turn anaerobic in one to two days. Two pairs of 5,000-gallon tanks will be used, alternating injection of 5,000-gallon batch while waiting for the other 5,000-gallon batch to be deoxygenated. At this rate, and allowing time to optimize injection procedures, it will take approximately 24 weeks at each injection well to inject the total target volume of 530,000 gallons substrate solution.

If deoxygenation takes longer than anticipated, procedures may be modified based on site conditions and implementation feasibility. Modifications may include, but are not limited to adding inorganic constituents in the tanks to help scavenge oxygen and accelerate the process, sparging the solution with argon gas, modifying injection schedules, and modifying total injection volumes.

#### Controlling Internal Pressure in the Injection Wells

The planned injection well design detailed in section 5.2.5 consists of two equally deep, nested polyvinyl chloride (PVC) well casings installed in a single borehole. A 1.5-inch nominal diameter injection casing will be connected to the mixing tanks and used to convey the substrate solution and bioaugmentation culture to the subsurface. A 5-inch nominal diameter monitoring casing will be used for groundwater sample collection and field parameter measurements. During the injection process the height of the fluid column in the monitoring casing will rise. Controlling the height of the substrate solution column in the casing during injection is necessary to prevent bursting of the well casing or well screen. The manufacturer's specification for bursting strength of the 5-inch diameter casing is 145 pounds per square inch (psi). This pressure would be generated by a water column of approximately 335 ft above the static water level. The elevation of the substrate solution in the monitoring casing will be monitored during injection to ensure the internal pressure does not exceed this height.

The bursting strength of the 1.5-inch diameter casing is 235 psi, which corresponds to a water column of approximately 545 ft. This is above the ground surface and the height of the connected mixing tanks. Therefore, there is no concern with respect to casing integrity of the injection casing during gravity injection.

Additionally, MODFLOW 2000 was used to estimate the injection rate (and resulting water column height) that could be maintained without the internal pressure exceeding the bursting pressure of the casing. Of the three injection well locations, the hydraulic conductivity is lowest in the vicinity of well TAV-INJ3; therefore, for a given injection rate the height of the column in this well should be greater than at the other two locations where hydraulic conductivities are higher. The modeling estimates a maximum safe constant injection rate of approximately 15 gpm in well TAV-INJ3, which would result in approximately 7,200 gallons of substrate solution being delivered per 8-hour working day. This is over 40 percent greater than the target delivery rate of 5,000 gallons per day (gpd). Additionally, the manufacturer's specification for casing bursting strength incorporates a 50 percent safety factor. Therefore, damage due to excessive pressure in injection well TAV-INJ3 should not be of concern.

The estimated hydraulic conductivity at the proposed locations of TAV-INJ1 and TAV-INJ2 is much higher than in the TAV-INJ3 area. Thus, the expected height of the water column in these wells would be much lower, and internal well pressure would not be of concern at these locations either. Therefore, higher injection rates at these two wells may be accommodated. Water levels will be monitored during injections to ensure the height of the water column does not exceed 335 ft above the static water level.

The magnitude of rise of injected substrate solution into the vadose zone adjacent to the injection wells is uncertain, but would likely be significantly less than the modeled pressure head because hydraulic conductivity in anisotropic sedimentary deposits is typically an order of magnitude higher horizontally than vertically.

#### **4.4 Additional Groundwater Monitoring Wells**

Two additional groundwater monitoring wells (TAV-MW15 and TAV-MW16) will be installed south of the TA-V boundary, as shown in Figure 4-1. These wells will help define the extent of TCE concentrations and the potentiometric surface along the southern boundary of TA-V. Long-term sampling from these locations, along with other TAVG monitoring wells, will provide data to evaluate the long-term effectiveness of remedial actions.

Well screens for these two monitoring wells will extend from approximately 2 ft above the water table to 23 ft below the water table to be consistent with other monitoring wells at the site. Actual screen placement will be based on the observed lithology of the aquifer material.

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## 5.0 TREATABILITY STUDY IMPLEMENTATION AND PERFORMANCE MONITORING

Treatability Study implementation will occur in the following order.

1. Pre-field activities.
2. Two groundwater monitoring well installations.
3. Phase I injection well installation and background sampling.
4. Phase I push/pull test and performance monitoring.
5. Phase I full-scale injection and performance monitoring.
6. Phase II injection well installations and background sampling.
7. Phase II full-scale injection and performance monitoring.

Applicable Sandia Field Operating Procedures (FOPs) and Administrative Operating Procedures (AOPs) are listed in Table 5-1. Most current versions will be used. Specific procedures for activities that are not currently described under existing FOPs or AOPs are either incorporated into this work plan or will be prepared prior to Treatability Study implementation.

Table 5-1  
Applicable Sandia National Laboratories, New Mexico Operating Procedures.

Procedure Number	Procedure Title
FOP 03-02	Groundwater Level Data Acquisition and Management
FOP 05-01	Groundwater Monitoring Well Sampling and Field Analytical Measurements
FOP 05-02	Groundwater Monitoring Equipment Field Check for Water Quality Measurements
FOP 05-03	General Sampling Equipment Decontamination
FOP 05-04	Groundwater Monitoring Waste Management
FOP 09-05	Conducting Slug Test Using Pressure Transducer & Data Logger
FOP 10-01	Borehole and Downhole Well Video Inspection
FOP 12-11	Drilling Methods, Designing, and Installing Groundwater Monitoring Wells
FOP 94-01	Safety Meetings, Inspections, and Pre-Entry Briefings
FOP 94-05	Borehole Lithologic Logging
FOP 94-25	Documentation of Field Activities
FOP 94-28	Health and Safety Monitoring of Organic Vapors (FID and PID)
FOP 94-41	Well Development
FOP 94-43	Decommissioning of Wells
FOP 94-44	Monitoring Well Inspection, Assessment, and Rehabilitation
FOP 94-57	Decontaminating Drilling and Associated Field Equipment
FOP 94-68	Field Change Control
FOP 94-69	Personnel Decontamination (Level D, C, and B Protection)
AOP 00-03	Data Validation Procedure for Chemical and Radiochemical Data
AOP 08-05	Monitoring Well Installation, Decommissioning, and Planning
AOP 95-16	Sample Management and Custody
AOP 97-01	Well Registry and Tracking System

FID = Flame ionization detector.

PID = Photoionization detector.

## **5.1 Pre-Field Activities**

Activities that must be completed prior to implementing the Treatability Study include:

- Approval of this Work Plan by NMED HWB.
- Submittal to and review and approval from the DOE-Sandia Field Office of the National Environmental Policy Act checklist.
- Submittal to and approval from the New Mexico Office of the State Engineer (NMOSE) of the well installation permit application.
- Submittal of the Notice of Intent and Discharge Permit Application if required by the NMED GWQB.
- Completion of the SNL Institutional Biosafety Committee Project Registration.
- Request and approval of the SNL/NM excavation permit.
- Preparation and approval of the SNL/NM site-specific Health and Safety Plan (HASP).
- Preparation of the SNL/NM Engineered Safety Review.
- Preparation of the Contract-Specific Safety Plans by contractors.
- Preparation of the SNL/NM Primary Hazard Screening document.
- Preparation of the SNL/NM Technical Work Document.
- Preparation of the SNL/NM Waste Management Plan (WMP).
- Preparation of the SNL/NM Statement of Work for drilling and well installation.
- Preparation of the SNL/NM Statement of Work for substrate preparation and injection contractor.
- Coordinate sampling with the SNL/NM Sample Management Office.
- Completion, review, and approval of the SNL/NM field work punch list.
- Conduct the SNL/NM readiness review meeting.

## **5.2 Well Installation**

Phase I will include installation of three wells: two groundwater monitoring wells (TAV-MW15 and TAV-MW16) and one injection well (TAV-INJ1). If implemented, Phase II will include installation of two additional injection wells (TAV-INJ2 and TAV-INJ3). The following procedures are applicable to both monitoring and injection wells, except where noted.

### 5.2.1 Mobilization and Site Setup

Work areas will be set up in accordance with the HASP and coordinated with facility management personnel, including but not limited to, exclusion zone delineation and signage, applicable alternative routes for traffic and pedestrians, eye wash, and sanitation facilities.

SNL/NM personnel will ensure that waste containers for cuttings, development water, and trash have been obtained and are ready for drilling operations.

### 5.2.2 Well Survey

The new monitoring and injection wells will be surveyed relative to North American Datum of 1983 (NAD 83) and elevations surveyed relative to North American Vertical Datum of 1988 (NAVD 88). Survey data will include northings, eastings, and elevations to the nearest hundredth of a foot. Survey elevations will be established at top-of-casing and ground surface, with a permanent marker indicating the point of survey. Well survey will be completed and certified by a licensed New Mexico professional surveyor.

### 5.2.3 Borehole Drilling

Based on local topography, recent groundwater level measurements at TA-V, and the lithology recorded during installation of the nearest groundwater monitoring wells, boreholes for the two new groundwater monitoring wells and the three injection wells are anticipated to be drilled to approximately 535 to 560 ft bgs.

Boreholes for the new monitoring and injection wells will be drilled using Air-Rotary Casing-Hammer (ARCH) drilling methods. It is anticipated that a telescoped borehole will be drilled and temporarily cased to reduce friction between the steel drive casing and borehole during drilling. The borehole will be advanced with 11.75-inch nominal diameter drive casing from ground surface to approximately 200 ft bgs and cased. The remaining borehole from 200 ft bgs to total depth will be advanced with a 9.625-inch nominal diameter drive casing and cased. The ARCH drilling method will use environmentally friendly lubricants and will be able to penetrate highly variable lithologies such as cobbles, boulders, gravel, sand, clay, and caliche. The borehole lithology will be logged by the Sandia field geologist during drilling. SNL staff will retain cutting samples in chip boxes for three years after each well is installed. The depth of the first encounter with regional groundwater and any perched groundwater will be noted and recorded during drilling. Standby time will be used as needed for determining the accurate water level.

Minimal water (but no other foams/liquids) in the form of mist may be introduced into the drive casing to aid in the removal of cuttings. Borehole cuttings and core will be stored within an area adjacent to the well. Water produced from the well during drilling or development will be contained in 55-gallon polypropylene drums and placed on spill control pallets. Management and final disposition of cuttings, core, and water will be performed according to applicable state and federal regulations, as specified in the project-specific WMP to be prepared as part of the pre-field activities.

### Core Sampling at Injection Well Locations

To optimize the injection well construction design, continuous core will be collected from approximately 20 ft above the anticipated static water table to approximately 40 ft below the observed water table to allow detailed lithologic logging of the saturated zone and the overlying capillary fringe. Core will be obtained by advancing an acetate-lined, 4-inch inner diameter core barrel (or functional equivalent) ahead of the ARCH drill bit. The total depth of each borehole will be determined by the Sandia field geologist based on observed lithology and injection well design objectives. Lithology from coring will be used to refine the final well screen and filter pack placement to ensure injection wells are completed at the proper depth to optimize substrate delivery. The field crew will take photographs of the entire core before segments are removed for laboratory analysis, inoculation, or sieve analysis. The rest of the core material will be stored onsite in core boxes for at least six months.

Unsaturated and saturated soil samples will be collected from the most permeable observed sediment layers within the core at a minimum of one per 10-ft interval. Soil samples will be analyzed for VOCs on overnight turnaround. Samples will also be analyzed for total organic carbon (TOC) to compare against values used in calculating substrate demand for TCE sorbed to soil. Sieve analysis may also be conducted on the core samples for lithological composition.

The injection well screen will be set at least deep enough to intersect any significant detection of VOCs in soil below the water table. If VOCs are not detected in any of the soil samples, the injection well screen completion interval will default to the injection well design detailed in section 5.2.5. Because detected VOC concentrations have been historically very low at TA-V, lack of VOC detection in the soil samples does not preclude their presence at low concentrations in groundwater. The purposes of VOC analysis of soil samples are to confirm historical results of negligible contaminants in soil samples and to determine if significant concentrations are present in a deeper horizon than is monitored by the current groundwater monitoring network.

### 5.2.4 Geophysical Logging

Geophysical logging of the new monitoring and injection wells will be performed. Neutron and gamma logging will be performed through the steel drive casing, before well construction for injection wells, for optimum placement of the injection casing screens. Neutron logging will be contingent upon receiving access permission from TA-V radiological control administration. Drill rig standby time up to two calendar days will be used to allow for completion of neutron and gamma logging. However, waiting longer risks getting the drive casing lodged in the borehole due to swelling clays. Removal of drive casing would be costly and risk compromising the borehole for proper completion of the well. If neutron and gamma logging cannot be performed within two calendar days after the borehole total depth has been reached, and the drilling supervisor determines that getting the drive casing stuck is likely if standby is continued, the well screen length and vertical placement will be based on field geologist observations of lithologic and hydrologic characteristics and analytical data.

### 5.2.5 Well Construction

The new monitoring and injection wells will be installed through the temporary steel drive casing and completed with flush-threaded, PVC Schedule-80 water well casing. No petroleum-based

solvents, cleaners, or lubricants will be used for well construction. The casing and screen will be delivered pre-cleaned and bagged, or steam-cleaned on site prior to installation. To preserve the structural integrity of well materials, the casing and screen will be suspended in the drive casing while the primary filter pack, bentonite chips seal, and annular seal are installed. PVC centralizers might be placed at the bottom and top of the well screen, and at intervals not to exceed 100 ft along the well casing up to the ground surface.

### Groundwater Monitoring Well Design

The locations of groundwater monitoring wells TAV-MW15 and TAV-MW16 are shown in Figure 4-1. The well screen and filter pack will either be 0.010-inch slot with #20/40 sand or 0.020-inch slot with #10/20 silica sand as the primary filter pack material depending on the degree of fines in the surrounding sediments. The well screen will be 25-ft long and extend 23 ft below and 2 ft above the static water level. Table 5-2 shows the anticipated design specifications. The configuration and construction of the monitoring well casing and screen will follow the same process as for the injection well described below.

Table 5-2  
Anticipated Groundwater Monitoring Well Design Specifications

<b>Well Name</b>	<b>Estimated Depth to Water 2016-2017 (ft bgs)</b>	<b>Screen Interval (ft bgs)</b>	<b>Filter Pack Interval (ft bgs)</b>	<b>Total Casing Depth (ft bgs)</b>
TAV-MW15	519	517 – 542	507 – 547	547
TAV-MW16	535 <sup>a</sup>	533 – 558	523 – 563	563

<sup>a</sup> Assumes TAV-MW16 ground surface elevation is approximately 12 ft higher and water table is 2 ft lower than at TAV-MW15.

bgs = Below ground surface.

ft = Feet.

Previously installed groundwater monitoring wells at TA-V currently extend approximately 15 ft below the water table. Water levels have been declining at a rate of approximately 0.8 ft/year at TA-V. The additional 8 ft of screen for these new wells is intended to allow a longer useful lifespan. The final monitoring well construction design will be determined based on lithology and geophysics.

The planned locations for groundwater monitoring wells TAV-MW15 and TAV-MW16 are not in areas requiring at-grade completion. The well casing will extend approximately 30 inches above ground surface with a water-tight cap. The borehole will be grouted to within 5 ft of the ground surface, allowed to cure, followed by placing another 2-foot lift of bentonite chips to serve as a firm base for the stovepipe. The wellhead will be protected with a steel stovepipe with locking hinged lid, set in a reinforced concrete pad and surrounded by three concrete-filled guard posts. Each concrete pad will be affixed with a brass well identification plate.



## Injection Well Design

A nested casing design will be used for injection wells, which consists of two separate casings in one borehole: a 5-inch nominal diameter monitoring casing and screen with an adjacent 1.5-inch nominal diameter injection casing and screen, as shown in Figure 5-1. This nested casing design allows the separation of downhole substrate injection from the deployment and retrieval of a sampling pump and downhole measurement tools, which are operated in the monitoring casing. This design streamlines substrate injection and avoids equipment restrictions and tangling in a single casing design.

The two separate, equally deep casings will be installed simultaneously in the borehole and affixed to each other with straps placed at appropriate intervals determined by driller's. The injection casing screen will be 20 ft long with its top placed approximately 5 ft below the water table to facilitate submerged placement of the injected solution. The monitoring casing screen will be 30 ft long extending from approximately 5 ft above to 25 ft below the water table. This is longer than existing groundwater monitoring wells at TA-V, but is intended to help facilitate vertical distribution of the injected substrate in the subsurface. The monitoring casing screen will extend 5 ft above the static water table to allow for distribution to the capillary fringe above the water table. Each casing will have a 5-ft long blank sump casing at the bottom to mitigate long term silting up of the wells. The monitoring casing screen will have a 0.020-inch slot and the injection casing screen will have a 0.040-inch slot size to enhance injection rates.

To enhance injection rate and lessen chance of biofouling, a relatively coarse-grained filter pack material, #8/12 sand or equivalent, will be used as the primary filter pack material extending from the bottom of the sumps to at least 5 ft above the top of the monitoring casing screen. An additional 5 ft of #60 silica sand will be placed on top of the primary filter pack. Each filter pack interval will be tagged to verify the depth setting. Swabbing using a surge block will be performed to help settle the filter pack and reduce possible bridging of the sand.

An approximately 30-ft thick lift of 3/8-inch grade bentonite chips will be placed above the filter pack in 5-ft lifts. Each lift will be hydrated with 5 gallons of potable water and tagged prior to emplacement of the next lift. The first lift of bentonite chips will be allowed to hydrate for at least one hour to facilitate sufficient hydration.

The remaining annular space to ground surface will then be filled with bentonite grout. To prevent overloading, the first lift of bentonite grout will be approximately 100-ft thick and will be allowed to set for a minimum of 24 hours. Subsequently, the annulus will be filled continuously with grout to within 10 ft below ground surface. To prevent bridging inside the annular space, during well construction the field crew will (1) tally the amount of emplaced materials to verify that the theoretical (planned) volume of each material corresponds to the actual volume installed, (2) pour the materials by hand at a slow rate into the annulus at the top of the drive casing, and (3) use a measuring tape at approximately 3-foot intervals to verify that the materials have fallen to the proper depths. Concrete will be used to complete the well installation.

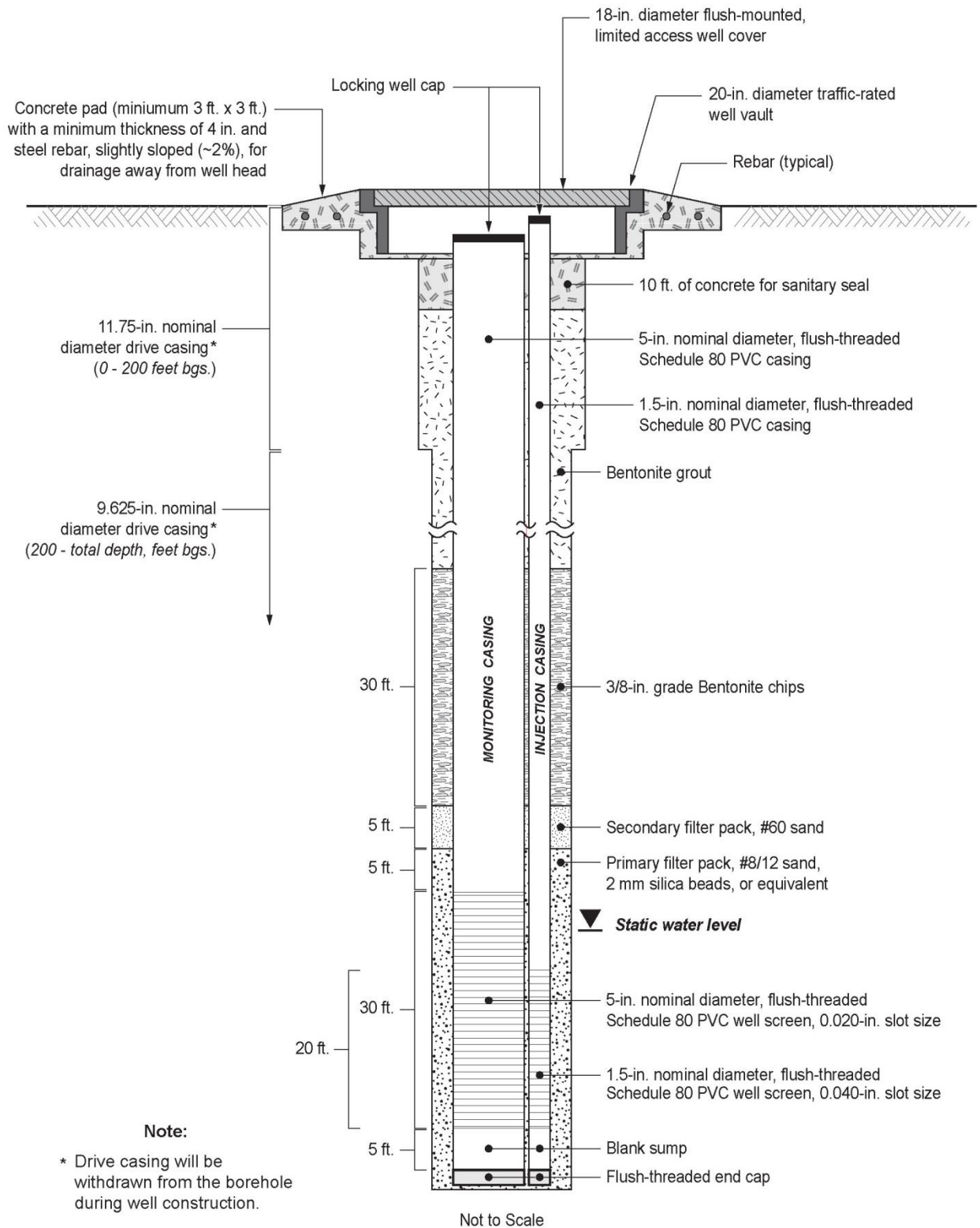


Figure 5-1  
Injection Well Design: Nested Casing

The planned locations for injection wells TAV-INJ1, TAV-INJ2, and TAV-INJ3 will require at-grade completions. The PVC well casing for these wells will be cut off below grade, and fitted with a water-tight cap and a lock. The well casing and well cap will be protected by installing an 18-inch diameter by approximately 18-inch deep traffic-rated steel vault centered over the PVC casing. The vault will be set in concrete, rebar-reinforced, constructed to surround the upper portion of each vault that slopes evenly away from the vault, to meet the surrounding ground surface to direct water away from the top of the vaults. A brass well identification marker will be fastened to each vault.

Table 5-3 shows the planned design for the three injection wells based on their paired groundwater monitoring wells and the anticipated static depth to water in 2016-2017 (the anticipated timeframe for well construction).

Table 5-3  
Anticipated Injection Well Design Specifications

Treatment Area and Well Description	Well Name	Estimated Depth to Water 2016-2017 (ft bgs)	Monitoring Casing Screen Interval <sup>a</sup> (ft bgs)	Filter Pack Interval (ft bgs)	Total Casing Depth (ft bgs)
<b>SWMU 5 Area</b>					
Planned Injection Well	TAV-INJ1	513	508 - 538	498 - 543	543
Existing Monitoring Well	TAV-MW6	513	507 - 527	498 - 534	532
<b>SWMU 275 Area</b>					
Planned Injection Well	TAV-INJ2	519	514 - 544	504 - 549	549
Existing Monitoring Well	TAV-MW10	519	508 - 528	494 - 539	533
<b>LWDS-MW1 Area</b>					
Planned Injection Well	TAV-INJ3	505	500 - 530	490 - 535	535
Existing Monitoring Well	LWDS-MW1	505	495 - 515	495 - 525 <sup>b</sup>	520.3

<sup>a</sup> Screen interval shown is for the monitoring casing screen. Top of adjacent injection casing screen is 10 ft lower with same bottom depth as the monitoring casing.

<sup>b</sup> LWDS-MW1 well log indicates "plug back" beneath well casing from 520.3-525 ft bgs, but does not specify material. Material is assumed to be a combination of filter pack sand and slough.

bgs = Below ground surface.

ft = Feet.

A single casing injection well design will be retained as the contingent injection well design if the nested casing design is not successful, as shown in Figure 5-2. A larger diameter well casing and screen may be used to facilitate operations of all necessary downhole equipment including substrate injection hose, sampling pump, and downhole parameter measurement device. The configuration and construction of the well casing and screen will follow the same process as the monitoring casing of the nested casing injection well.



### 5.2.6 Well Development

Well development will begin after at least 48 hours following final grout placement. Development of groundwater monitoring wells will consist of bailing, surging, swabbing, and/or pumping techniques. Development of the nested casing injection wells will consist of pumping the 5-inch casing only to limit the amount of fine-grained material being forced into the well screen slots. Small amounts of potable water may be poured into the 1.5-inch casing during pumping to facilitate development. During development, groundwater field parameters (pH, specific conductivity [SC], temperature, and turbidity) will be continuously monitored, and development will continue until these parameters have stabilized. Development water will be contained in polyethylene drums and not allowed to discharge to the ground surface. The development water will either be re-purposed or disposed of as waste. All waste will be disposed of according to applicable state and federal regulations, and in accordance with the site-specific WMP. The method of development, the volume of water added or removed, the parameters measured, the results of the measurements, and the time these activities take place will be documented on field forms. If addition of water is necessary during development of a low yielding well, only potable water will be used.

During well development, a minimum of five well bore volumes of groundwater will be removed. One bore volume is calculated as the interior casing volume from static water level to the bottom of screen, plus the estimated porosity of the saturated filter pack. After the minimum volume has been removed, development will continue until representative groundwater is obtained. Representative water is assumed to be obtained when pH, SC, and temperature readings stabilize (less than 10 percent variability over three consecutive well bore volumes) and the water is visually clear of suspended solids with a target turbidity of less than 5 Nephelometric Turbidity Units (NTU).

### 5.2.7 Hydraulic Testing

Slug tests will be performed on each newly installed well in accordance with FOP 09-05 "Conducting Slug Test Using Pressure Transducer & Data Logger." Water-level changes induced in the wells will be measured using a Solinst electronic pressure transducer (or equivalent) and data logger software. The "slug out" (removal of the slug from the water column) portion of the test for each well will be recorded and analyzed. The slug test data will be analyzed by the AquiferTest™ Software developed by Waterloo Hydrogeologic, Inc. (Waterloo Hydrogeologic 2001). The hydraulic conductivities calculated from the slug tests performed on each well will be presented in the Treatability Study Report.

### 5.2.8 Equipment Decontamination

The drill rig and related equipment, including development and slug test equipment, will be decontaminated at the decontamination pad in TA-III prior to beginning of drilling operations. Decontamination of equipment will also be required after completing each well. Decontamination waste will be kept to a minimum and contained in drums placed on spill control pallets at the decontamination pad, consistent with the WMP.

### 5.3 Groundwater Sampling

Groundwater samples will be collected from each new injection well and analyzed for the constituents listed in Table 5-4 to establish baseline conditions prior to substrate injection. These analyses will also be performed on the paired groundwater monitoring wells. Analytical results from groundwater monitoring wells obtained during the most recent quarterly groundwater monitoring event could be used to reduce redundancy for baseline sampling. Table 5-4 also shows analyses to be conducted during performance and rebound monitoring.

Table 5-4  
Analytical Parameters for Groundwater Samples

Analytical Group/Analyte	Analytical Method	Reference
Alkalinity (total, bicarbonate, and carbonate)	SM2320B	Standard Methods Online <sup>a</sup>
Ammonia (as Nitrogen)	EPA 350.1	EPA 1983
Anions (bromide, chloride, fluoride, nitrite, and sulfate)	SW846-9056	EPA 1986 (and updates)
<i>Dehalococcoides</i> (Dhc) and, if Dhc is present, vinyl chloride reductase (vcrA).	Gene-Trac-Dhc Gene-Trac-VC	Proprietary methods of SiREM, Guelph, Ontario, Canada.
Dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, and sodium)	SW846-3005/6020	EPA 1986 (and updates)
Methane/ethane/ethene	RSK-175 SOP	Laboratory dependent <sup>b</sup>
Nitrate plus nitrite (NPN)	EPA 353.2	EPA 1983
Orthophosphate (as P)	EPA 300.0	EPA 1983
Total organic carbon	SW846-9060	EPA 1986 (and updates)
Sulfide	SW846-9034	EPA 1986 (and updates)
Volatile organic compounds	SW846-8260	EPA 1986 (and updates)

<sup>a</sup> Standard Methods for the Examination of Water and Wastewater. <http://standardmethods.org/>

<sup>b</sup> RSK-175 is not an analytical method, it is a standard operating procedure (SOP). Each laboratory adopts a procedure that is consistent with the quality controls of the SOP, but may have different specific processes.

EPA = U.S. Environmental Protection Agency.

SOP = Standard Operating Procedure.

The following field parameter measurements will also be collected:

- pH, SC, temperature, and turbidity to comply with pre-sampling purging protocols. Monitoring the pH is also necessary for maintaining optimal ISB conditions.
- DO and ORP to evaluate how effectively biodegradation is affecting groundwater conditions in the treatment area.

Groundwater sampling will be conducted in accordance with the requirements specified in section IX.A of the Consent Order (NMED April 2004).

A portable Bennett sampling system will be used to collect the groundwater samples. The sampling pump and tubing bundle will be decontaminated prior to installation into each well according to procedures described in FOP 05-03 "General Sampling Equipment

Decontamination.” After decontamination, the pump intake will be set near the bottom of the screened interval.

In accordance with procedures described in FOP 05-01 “Groundwater Monitoring Well Sampling and Field Analytical Measurements,” all wells will be purged a minimum of one saturated casing volume (the volume of one length of the saturated screen plus the porosity of the saturated filter pack around the saturated screen interval). The saturated casing volume of a nested casing injection well will be the volume of one length of the saturated screens of monitoring casing and injection casing, plus the porosity of the saturated filter pack around the two casings. After the minimum volume is removed, purging will continue until four consecutive measurements of water quality parameters (pH, SC, temperature, and turbidity) exhibit stabilized conditions. Groundwater stability is considered acceptable for sample collection when consecutive measurements are within 1.0 degrees Celsius, 0.1 pH units, within 5 percent for SC, and turbidity is less than 5 NTU or within 10 percent for turbidity higher than 5 NTU. If these parameters do not stabilize within removal of three saturated casing volumes, purging will cease and samples will be collected. Additional field parameters to be collected for all wells will include DO, ORP, and water level measurements.

Samples will be analyzed by off-site analytical laboratories accredited by the National Environmental Laboratory Accreditation Program. Quality Control samples will include duplicate samples, equipment blanks, field blanks, and trip blanks.

Groundwater samples will be collected directly from the sample discharge tubing into laboratory-prepared sample containers. If chemical preservatives are required, the analytical laboratories will add the preservatives to the sample containers prior to shipping. Immediately after collection, all sample containers will be custody-taped, sealed in plastic bags, and placed on blue ice in shipping containers. Analytical Request/Chain-of-Custody forms will be completed at the time of sample collection and will accompany the sample containers to the analytical laboratories.

## **5.4 Phase I Injections**

Phase I of the Treatability Study is divided into two stages following installation of injection well TAV-INJ1.

1. Push/pull test.
2. Full-scale injection.

### **5.4.1 Push/Pull Test at TAV-INJ1**

The push/pull test will be performed on injection well TAV-INJ1. This is a small-scale proof of concept test designed to deliver substrate solution and the bioaugmentation culture laterally into the formation with a treatment area radius of approximately 5 ft. Performance monitoring will be conducted as outlined in Table 5-4. These analytical results, coupled with field measurements, will be used to assess if the injected bioaugmented substrate solution creates favorable conditions to support larger-scale biodegradation of COCs. Additionally, data will be obtained regarding gravity-injection rates, which will impact planning for subsequent injections. Results of this test will be evaluated under Decision Point #1 to determine whether to implement a full-scale injection at TAV-INJ1 and to refine procedures.

The push/pull test includes the following sequential tasks:

- Extract and store groundwater from TAV-INJ1.
- Prepare substrate solution in aboveground tanks.
- Deoxygenate the injection well water column.
- Reinject substrate solution and bioaugmentation culture.
- Conduct post-injection performance monitoring.

Figure 5-3 shows a conceptual schematic of the gravity-injection system to be used.

#### Groundwater Extraction from TAV-INJ1

The design of the push/pull test includes extracting the volume of groundwater necessary to be used for subsequent delivery of the substrate solution into saturated sediments to a radius of 5 ft from the injection well. It is estimated that approximately 3,700 gallons of groundwater will be sufficient. This volume is based on the design of a well screen set across the upper 25 ft of the saturated zone, and an estimated effective sediment porosity of 25 percent.

The groundwater will be extracted from TAV-INJ1 using an electrical submersible pump. The anticipated pumping rate would be less than 10 gpm. Equal volumes of extracted groundwater will be stored onsite in two tanks, each storing approximately half the groundwater volume (1,850 gallons) and designated as Tank 1 and Tank 2.

#### Preparation of Substrate Solution in Aboveground Tanks

The initial Tank 1 solution will be:

- 1,850 gallons groundwater.
- 5.9 kilograms (13.1 lbs) of KB-1<sup>®</sup> Primer.
- 0.4 lb sodium bromide (tracer).
- 10 lbs of TAV-INJ1 soil core/cutting from the well screen interval.

Tank 2 will hold the other 1,850 gallons of extracted groundwater until the solution in Tank 1 has been deoxygenated and has an ORP of less than negative 75 mV (the minimum required to sustain growth of KB-1<sup>®</sup> Dechlorinator). Tank 1 will then be filled with:

- 1,850 gallons of groundwater from Tank 2.
- 1.9 gallons of ethyl lactate (electron donor).
- 3.5 lbs of diammonium phosphate (nutrient and pH buffer).
- 0.6 lbs of yeast extract (nutrient).
- 0.4 lbs of sodium bromide (tracer).

After mixing the above contents in Tank 1, DO and ORP measurements will be taken of the substrate solution until deoxygenation and lowered ORP have been reestablished indicating it is ready for reinjection along with KB-1<sup>®</sup> Dechlorinator. Deoxygenation may be accelerated by sparging the water with argon gas, if necessary.

Component ratios may be modified if analytical results from baseline sampling of the injection well are significantly different than currently detected in the neighboring monitoring well.



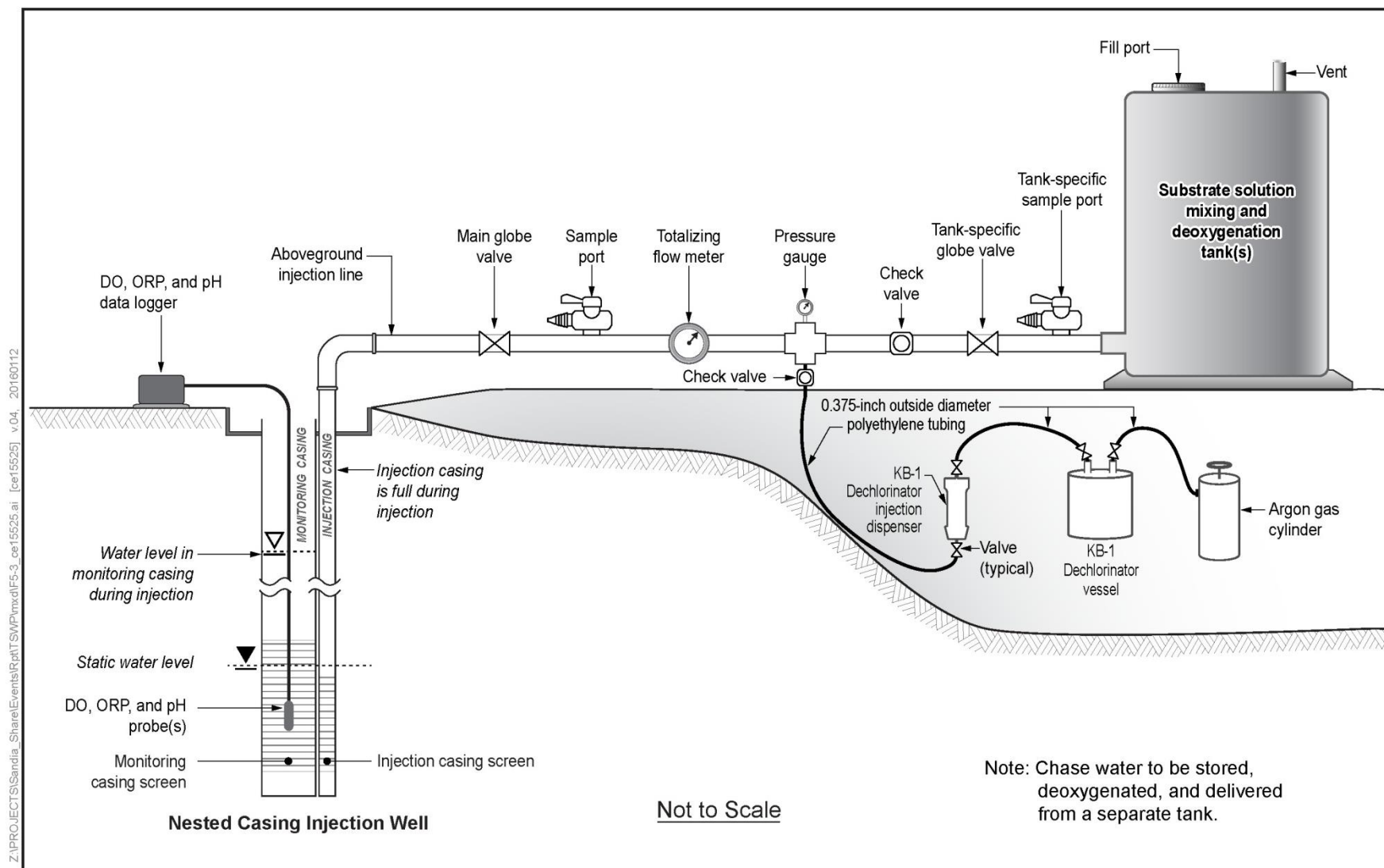


Figure 5-3  
Schematic of Gravity-Injection System

### Water Column Deoxygenation

Prior to reinjection, the aboveground injection line from the substrate solution mixing tanks will be connected to the injection casing at the wellhead (Figure 5-3). The aboveground injection line and the injection casing in well TAV-INJ1 will be primed by draining a sufficient volume of deoxygenated substrate solution from the tank. A pre-injection of a sufficient amount of the substrate solution will be conducted to displace the water column in the monitoring casing in well TAV-INJ1.

### Reinject Substrate Solution and Bioaugmentation Culture into TAV-INJ1

Once the substrate solution has been deoxygenated and reduced to an ORP of less than negative 75 mv, it will be gravity-injected into the injection casing along with KB-1<sup>®</sup> Dechlorinator (Figure 5-3). Injection will start with the substrate solution in the tank, quickly followed by mixing KB-1<sup>®</sup> Dechlorinator. Argon is used to displace the KB-1<sup>®</sup> Dechlorinator from its vessel for mixing during injection. Care will be taken to minimize turbulence during mixing and injection. A total of approximately 1.8 lbs of KB-1<sup>®</sup> Dechlorinator will be needed for the 3,700 gallons of substrate solution.

A sample of the injected substrate solution will be collected as it is being injected and analyzed for parameters listed in Table 5-4 and measured for field parameters specified in section 5.3.

Depth-to-water measurements will be taken in wells TAV-INJ1, TAV-MW6, and TAV-MW7 before, during, and after injection. Injection flow rate into the injection well will be routinely monitored. The injection rate will be reduced, if necessary, to ensure the water level in the monitoring casing in well TAV-INJ1 does not exceed 335 ft above static water level to prevent damage to the well. The injection rate of push/pull test will be used to optimize procedures for the full-scale injection.

### Performance Monitoring of the Push/Pull Test and Decision Point #1

Performance monitoring of the push/pull test will commence after the target volume has been gravity-injected. The performance monitoring well network will consist of injection well TAV-INJ1 and nearby monitoring wells TAV-MW6 (screened across the water table), and TAV-MW7 (screened deeper). Post-injection performance monitoring will consist of weekly water level measurements, groundwater field parameter measurements, and groundwater sampling for analytical parameters for a period of eight weeks followed by monthly measurements and sampling for two months (a total of four months plus one month for final sample analysis and data validation). Section 5.3 lists the analyses and field measurements that will be conducted during each performance monitoring event.

Performance monitoring results up to this point will be evaluated as Decision Point #1 to determine if the push/pull test is successful and that the Treatability Study should proceed to full-scale injection at TAV-INJ1. Decision Point #1 evaluation criteria are listed below. Affirmative answers to these questions will support a decision to proceed to full-scale injection at TAV-INJ1. However, negative answers in of themselves do not preclude further study, but would at least require re-evaluation of implementation procedures or remedial approach before proceeding to full-scale injection.

1. Did the gravity-injection rate indicate that TAV-INJ1 could accommodate the planned rate of 5,000 gpd for full-scale injection without exceeding the 335 ft of maximum pressure head in the monitoring casing?

This will be determined by measuring the injection rate and water levels in the injection well.

2. Did groundwater conditions in well TAV-INJ1 become and remain conducive to denitrifying nitrate and subsequently dechlorinating TCE and its daughter products?

Multiple lines of evidence that the injection is being effective at creating an environment that will stimulate ISB include:

- a. DO concentrations established and maintained well below 1 mg/L.
  - b. ORP measurements established and maintained at or below negative 75 mV.
  - c. Increases in ammonia and orthophosphate concentrations.
  - d. Decreases in nitrate concentration.
  - e. Decreases in sulfate concentration.
  - f. Increases in iron, manganese, or arsenic concentrations.
3. Was a sufficient population of *Dehalococcoides* (with vinyl chloride reductase) established to facilitate complete dechlorination at TAV-INJ1?

Over  $10^7$  gene copies/liter indicates a high potential for complete dechlorination.

4. Did COC concentrations in well TAV-INJ1 demonstrate a decreasing trend that will reach MCLs within the anticipated time frame of the full term performance monitoring?

Concentration decreases indicate either ISB is working or combined with the result of dilution, but support a decision to proceed with full-scale injection at TAV-INJ1.

5. Did bromide concentration initially increase and then attenuate during post-injection monitoring?

An initial increase in bromide concentration at a given location indicates that the substrate solution has been delivered to that point. Subsequent attenuation suggests advection of surrounding groundwater into the push/pull test treatment area.

6. Were TCE dechlorination daughter products produced?

An increase followed by a decrease in TCE daughter products indicates dechlorination is occurring. Because concentrations of TCE are initially very low, it may be difficult to detect some or all daughter products. Inability to quantify dechlorination daughter products does not, in of itself, indicate a lack of complete dechlorination.

7. Did results from deeper well TAV-MW7 support the conclusion that further injections will not adversely affect deeper groundwater?

Increases in nitrate or bromide concentrations and detections of TCE or associated daughter products in well TAV-MW7 would indicate further injection could drive contamination deeper.

Additionally, stability of pH and increases in iron, manganese, and arsenic concentrations will be monitored. This is particularly of interest in deeper well TAV-MW7 where this would suggest vertical communication between the injection horizon and deeper sediments. Increases in dissolved iron, manganese, and arsenic can be expected within the anaerobic treatment area, but should re-precipitate as they migrate with groundwater back into aerobic environments.

Results from the push/pull test will be evaluated against the above criteria to determine if full-scale injection should proceed and if changes in implementation procedures are necessary to optimize full-scale injection and performance monitoring. **Results of the push/pull test and any associated revisions to procedures will be communicated to the NMED-HWB at least 60 days prior to proceeding with full-scale injection at TAV-INJ1.**

#### 5.4.2 Full-Scale Injection at TAV-INJ1

The objective of full-scale injection is to deliver substrate solution and bioaugmentation culture to the treatment area thereby facilitating denitrification of nitrate and dechlorination of TCE and any daughter products in the aquifer to concentrations below MCLs.

##### Full-Scale Injection of Substrate Solution and Bioaugmentation Culture into TAV-INJ1

Full-scale injection will involve mixing substrate solution components at prescribed ratios (Table 4-1) with potable water in two pairs of 5,000-gallon tanks (i.e., four 5,000-gallon tanks), deoxygenating the solution in the tanks and establishing an ORP below negative 75 mV. As in the push/pull test, the initial injection batch will be deoxygenated with KB-1<sup>®</sup> Primer and inoculated with TAV-INJ soil core/cuttings. Once the first pair of tanks are deoxygenated, the aboveground injection line and the injection casing will be primed and the water column in the monitoring casing will be deoxygenated. Then 5,000 gallons (2,500 gallons from each tank) will be injected into TAV-INJ1 along with the bioaugmentation culture. The tanks will be refilled with potable water and commensurate amounts of ethyl lactate, diammonium phosphate, yeast extract, and sodium bromide.

During the anticipated one to two days for the first pair of tanks to reestablish anaerobic conditions and an ORP less than negative 75 mV, 5,000 gallons of deoxygenated and low-ORP substrate solution will be injected from the second pair of 5,000-gallon tank along with the bioaugmentation culture. The second pair of tanks will then be refilled with potable water and the associated substrate solution components like the first pair of tanks. Injection can proceed to the first pair of tanks while the second pair of tanks are being refilled and deoxygenated. This process of alternating two pairs of tanks will continue for the duration of the injection provided it facilitates the most optimal injection schedule. By having two pairs of 5,000-gallon tanks onsite, the planned schedule assumes one 5,000-gallon batch can be injected per 8-hour work day by alternating deoxygenation and ready-to-inject pair of tanks each day.

A total of up to 530,000 gallons of substrate solution will be injected into TAV-INJ1. The estimated timeframe for injection is up to 24 work weeks. If monitoring results at monitoring well TAV-MW6 indicate that the substrate solution has reached that well and created the desired reducing conditions before the full 530,000 gallons has been injected, injection operations will be suspended to confirm that these conditions are stable. Injection will also be suspended if analytical results from deeper monitoring well TAV-MW7 detect an increase in nitrate concentration above 10 mg/L or if TCE or its chlorinated daughter products are detected.

Prior to each daily injection, the DO will be measured in the injection well water column to ensure it is sustaining anaerobic conditions and if not, it will be deoxygenated prior to injection.

During injection, DO, ORP, and pH will be monitored in well TAV-INJ1 using downhole electronic probes and a data logger. Water levels will also be frequently monitored immediately prior and throughout each work day during injections. Additionally, wells TAV-INJ1, TAV-MW6, and TAV-MW7 will be monitored monthly during injection for the analyses (Table 5-4) and the field parameters listed in section 5.3.

Each daily injection batch will be followed with approximately 100 gallons of chase water consisting of unamended potable water deoxygenated by sparging with argon gas. This is intended to push substrate solution away from the well screen and surrounding filter pack pore space and into the formation to mitigate localized biofouling.

#### Performance Monitoring of the Full-Scale Injection and Decision Point #2

Performance monitoring of the full-scale injection will commence after the target volume has been gravity-injected and within one month of the last sampling event during injection. The performance monitoring well network will continue to consist of wells TAV-INJ1, TAV-MW6, and TAV-MW7. Post-injection performance monitoring will be conducted for a total of 24 months at a monthly frequency for three months followed by quarterly monitoring for the remainder of the post-injection monitoring period. Section 5.3 lists the analyses (Table 5-4) and the field measurements that will be conducted during each performance monitoring event.

Within six months after Phase I full-scale injection is completed, sufficient data should be available for evaluation of Decision Point #2 to determine if the full-scale injection at TAV-INJ1 is successful and that the Treatability Study should proceed to Phase II: installation of injection wells TAV-INJ2 and TAV-INJ3 and associated full-scale injections at each location. Decision Point #2 evaluation criteria are listed below. Affirmative answers to these questions will support a decision to proceed to Phase II (i.e., expand the Treatability Study to two more locations). However, negative answers in of themselves do not preclude further study, but would at least require re-evaluation of implementation procedures or remedial approach before proceeding to Phase II.

1. Was the planned full-scale injection volume injected within the anticipated time frame?

Lower than anticipated injection volumes or longer time frames may render Phase II injections impractical or require revision to procedures.

2. Did groundwater conditions in wells TAV-INJ1 and TAV-MW6 become and remain conducive to denitrifying nitrate and subsequently dechlorinating TCE and its daughter products?

Multiple lines of evidence that the injection is being effective at creating an environment that will stimulate ISB include:

- a. DO concentrations established and maintained well below 1 mg/L.
  - b. ORP measurements established and maintained at or below negative 75 mV.
  - c. Increases in ammonia and orthophosphate concentration.
  - d. Decreases in nitrate concentration.
  - e. Decreases in sulfate concentration.
  - f. Increases in iron, manganese, or arsenic concentrations.
3. Was a sufficient population of *Dehalococcoides* (with vinyl chloride reductase) established to facilitate complete dechlorination both at TAV-INJ1 and at TAV-MW6?

Over  $10^7$  gene copies/liter indicates a high potential for complete dechlorination.

4. Did COC concentrations in wells TAV-INJ1 and TAV-MW6 decrease below MCLs?

Concentration decreases indicate either ISB is working or combined with the result of dilution, but support a decision to proceed with full-scale injections at TAV-INJ2 and TAV-INJ3.

5. Did bromide concentration initially increase and then attenuate during post-injection monitoring?

An initial increase in bromide concentration at a given location indicates that the substrate solution has been delivered to that point. Subsequent attenuation suggests advection of surrounding native groundwater into the treatment area.

6. Were TCE dechlorination daughter products produced?

An increase followed by a decrease in TCE daughter products indicates dechlorination is occurring. Because concentrations of TCE are initially very low, it may be difficult to detect some or all daughter products. Inability to quantify dechlorination daughter products does not, in of itself, indicate a lack of complete dechlorination.

7. Did results from deeper well TAV-MW7 support the conclusion that further injections will not adversely affect deeper groundwater?

Increases in nitrate or bromide concentrations and detections of TCE or associated daughter products in well TAV-MW7 would indicate further injection could drive contamination deeper.

The monitoring data collected during the full-scale injection and during the six months after injection is completed will be evaluated against the above criteria to determine if the Treatability Study should proceed to Phase II. **These interim performance results and any associated revisions to procedures will be communicated to NMED-HWB along with the decision whether to proceed to Phase II.**

## **5.5 Impact on Groundwater and Additional Monitoring**

As explained in section 3.0, biodegradation is intended to initially reduce nitrate concentration through denitrification, followed by reductive dechlorination of TCE in the aquifer. Reductive dechlorination occurs under anaerobic and reducing conditions in the aquifer. The process of developing strongly anaerobic redox conditions is likely to result in solubilization and mobilization of some naturally occurring oxidized metals and metalloids, most particularly iron, manganese, and arsenic, as a result of direct reduction and mineral dissolution. Increases in dissolved iron and manganese concentrations are indicators of biodegradation in an anaerobic and reducing environment. However, the solubilization of these metals is generally a transient phenomenon and is limited to the treatment zone. Solubilized metals and metalloids will precipitate into solid form once they leave the anaerobic treatment zone or after the aquifer returns to aerobic conditions in the treatment zone.

Concentrations of dissolved iron, manganese, and arsenic will be monitored within the Treatability Study treatment zone (Table 5-4). In order to monitor the impact of substrate solution discharge on groundwater outside Treatability Study treatment zone, an additional eight wells will be monitored for dissolved iron, manganese, and arsenic, including TAV-MW2, TAV-MW4, TAV-MW8, TAV-MW11, TAV-MW12, TAV-MW14, and two of the three monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW10 inside the treatment zone that are not companion wells for ISB injection. These wells are chosen because they are the nearest existing monitoring wells surrounding the treatment zone as wells as nearest to the ISB injection. Figure 4-1 shows the locations of these monitoring wells. Dissolved iron, manganese, and arsenic will be monitored on a quarterly basis.

## **5.6 Phase II Injections and Performance Monitoring**

Phase II design and implementation procedures will be modified to optimize performance based on lessons learned during Phase I.

Phase II will expand ISB full-scale injection to two additional locations. Injection well TAV-INJ2 will be located near monitoring well TAV-MW10 at SWMU 275 and injection well TAV-INJ3 will be located near monitoring well LWDS-MW1. The approximate locations of wells TAV-INJ2 and TAV-INJ3 are shown in Figure 4-1. The objectives of Phase II mirror that of the full-scale injection at well TAV-INJ1 in Phase I.

The mixing ratios of substrate solution will be adjusted as necessary based on performance indicators from the TAV-INJ1 injection. Water level measurements, field parameter measurements, and groundwater sampling and analysis will be conducted at the injection well and paired groundwater monitoring well similarly to those conducted for the full-scale injection in Phase I.

Monitoring will be conducted monthly during injection. Post-injection performance monitoring will be conducted for a total of 24 months at a monthly frequency for three months followed by quarterly monitoring for the remainder of the post-injection monitoring period. Section 5.3 lists the analyses (Table 5-4) and the field measurements that will be conducted during each performance monitoring event.



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## **6.0 GROUNDWATER MONITORING AT TECHNICAL AREA-V GROUNDWATER AREA OF CONCERN**

### **6.1 Groundwater Monitoring during the Treatability Study**

The Treatability Study focuses on three groundwater monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW10 that have the highest TCE concentrations. Sampling of deeper well TAV-MW7 that is paired with TAV-MW6 is also included in the Treatability Study. During the course of the Treatability Study, each of the four wells will be monitored quarterly unless it becomes a companion well for an injection well and the monitoring parameters and frequency will then be superseded by the Treatability Study design as specified in section 5.0.

The other wells of the TAVG monitoring network that are not part of the Treatability Study are currently being monitored quarterly or semiannually for the parameters listed in Table 5-5 of the Calendar Year 2014 Annual Groundwater Monitoring Report (SNL/NM June 2015). Based on the evaluations detailed in the CCM document (SNL/NM September 2015), the following sampling frequency and parameters will be implemented.

- Reduce the sampling frequency of the perimeter wells that are most distant from the contaminant plumes (AVN-1, LWDS-MW2, TAV-MW3, and TAV-MW5) and the sampling frequency of two of the three deep wells (TAV-MW9 and TAV-MW13).
- Reduce the sampling frequency of wells AVN-1, LWDS-MW2, and TAV-MW13 from quarterly to annually.
- Reduce the sampling frequency of wells TAV-MW3, TAV-MW5, and TAV-MW9 from semiannually to annually.
- The sampling frequency of the third deep monitoring well TAV-MW7 will remain semiannual.
- Reduce the sampling parameters as described in section 7.3 of the CCM document (SNL/NM September 2015). Along with the parameters intended for monitored natural attenuation (dissolved iron, dissolved manganese, calcium, magnesium, potassium, sodium, sulfide, and total organic carbon), quarterly sampling of the general chemistry parameters (alkalinity, chloride, and sulfate) have also become unnecessary. Consequently, the quarterly sampling parameters will include NPN and VOCs. Dissolved metals (arsenic, iron, and manganese) will also be analyzed for the eight wells listed in section 5.5 on a quarterly basis.
- Continue annual sampling of general chemistry, radiological screening parameters, and total metals to supplement waste characterization requirements.

Table 6-1 summarizes the proposed sampling parameters and sampling frequency for the future 18-well monitoring network (current 16 plus TAV-MW15 and TAV-MW16) at the TAVG AOC.

For the two newly installed groundwater monitoring wells (TAV-MW15 and TAV-MW16), four quarters of perchlorate analysis will be performed in accordance with the Consent Order (NMED April 2004) in addition to parameters specified in Table 6-1.

Table 6-1  
Parameters Sampled at TAVG Monitoring Wells for  
each Sampling Event during the Treatability Study

First Quarter of a Calendar Year		Second Quarter of a Calendar Year	
Parameter	Monitoring Wells	Parameter	Monitoring Wells
NPN VOCs Dissolved Metals (arsenic, iron, manganese) <sup>a</sup>	LWDS-MW1 <sup>b</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>b</sup> TAV-MW8 TAV-MW10 <sup>b</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>c</sup> TAV-MW16 <sup>c</sup>	NPN VOCs General Chemistry <sup>d</sup> Radiological Screening Parameters <sup>d</sup> Total Metals <sup>d</sup> Dissolved Metals (arsenic, iron, manganese) <sup>a</sup>	AVN-1 LWDS-MW1 <sup>b</sup> LWDS-MW2 TAV-MW2 TAV-MW3 TAV-MW4 TAV-MW5 TAV-MW6 <sup>b</sup> TAV-MW7 <sup>b</sup> TAV-MW8 TAV-MW9 TAV-MW10 <sup>b</sup> TAV-MW11 TAV-MW12 TAV-MW13 TAV-MW14 TAV-MW15 <sup>c</sup> TAV-MW16 <sup>c</sup>
Third Quarter of a Calendar Year		Fourth Quarter of a Calendar Year	
Parameter	Monitoring Wells	Parameter	Monitoring Wells
NPN VOCs Dissolved Metals (arsenic, iron, manganese) <sup>a</sup>	LWDS-MW1 <sup>b</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>b</sup> TAV-MW8 TAV-MW10 <sup>b</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>c</sup> TAV-MW16 <sup>c</sup>	NPN VOCs Dissolved Metals (arsenic, iron, manganese) <sup>a</sup>	LWDS-MW1 <sup>b</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>b</sup> TAV-MW7 <sup>b</sup> TAV-MW8 TAV-MW10 <sup>b</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>c</sup> TAV-MW16 <sup>c</sup>

<sup>a</sup> Eight wells will be monitored: TAV-MW2, TAV-MW4, TAV-MW8, TAV-MW11, TAV-MW12, TAV-MW14, and two of the three monitoring wells (LWDS-MW1, TAV-MW6, and TAV-MW10 inside the treatment zone that are not companion wells for ISB injection).

<sup>b</sup> Sampling parameters and frequency will be superseded by the Treatability Study design when the well becomes a companion well for ISB injection (see section 5.0).

<sup>c</sup> Four quarters of perchlorate analysis will be performed for newly installed groundwater monitoring wells in accordance with the Consent Order (NMED April 2004).

<sup>d</sup> Waste characterization parameters for compliance with SNL/NM Corporate Procedures and Policies.

AVN = Area V (North).

LWDS = Liquid Waste Disposal System.

MW = Monitoring well.

NPN = Nitrate plus nitrite (reported as nitrogen).

TAV = Technical Area-V (monitoring well designation).

TAVG = Technical Area-V Groundwater.

the Consent Order = The Compliance Order on Consent.

VOC = Volatile organic compound.

## **6.2 Post-Treatability Study Groundwater Monitoring**

The groundwater monitoring program for TAVG AOC will be re-evaluated during the preparation of the Treatability Study report. During report preparation and review, groundwater monitoring will be discontinued at the three injection wells, but continue quarterly at wells LWDS-MW1, TAV-MW6, TAV-MW7, and TAV-MW10.

Factors to be considered in the monitoring program re-evaluation will include but not limited to:

- Groundwater flow direction and gradient.
- Groundwater parameters.
- Remaining COC and associated daughter product concentrations.
- Magnitude of COC concentration rebound or attenuation after treatment.
- Concentrations of other constituents regulated under the NMED GWQB, if applicable.

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## **7.0 WASTE MANAGEMENT**

A project-specific WMP will be prepared upon approval of this Work Plan that will address handling and storage, labeling, profiling, transportation, and disposal of the following categories of waste generated during the Treatability Study.

- Drilling waste.
- Sampling waste (i.e., purge water).
- Excess substrate solution constituents.
- Excess bioaugmentation culture.
- Used personal protective equipment (PPE).
- Trash and used containers or other expendables (e.g., substrate containers/packaging).

Safety procedures related to handling waste generated during decontamination will be incorporated in the Health and Safety Plan.

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## **8.0 HEALTH AND SAFETY**

Level D PPE is required for all personnel performing field activities associated with drilling, well installation and development, and soil sampling.

Level D PPE is also required for all field personnel conducting Treatability Study work involving groundwater extraction, substrate and component handling and injection, and groundwater sampling.

Respiratory protection for dust inhalation is recommended by the manufacturer for field personnel handling the KB-1<sup>®</sup> Primer.

Health and safety records associated with drilling, well installation and development, and the Treatability Study personnel will be maintained on site and will be available from the commencement of respective activities.

All personnel will operate under an SNL/NM HASP and will have SNL/NM-required training including 40-Hour Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) training and subsequent yearly refresher courses. An SNL/NM Subject Matter Expert will perform a safety inspection of the drill rig before drilling commences.



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## **9.0 REPORTING**

The results of this Treatability Study will be documented in accordance with the requirements established by the NMED, NMOSE, and SNL/NM FOPs.

Reporting will consist of the following:

- Well Installation Report and Results of Push/Pull Test– documenting well installation activities and the results of push/pull test.
- Technical Memorandum – documenting activities and performance results from Phase I of the Treatability Study and making recommendations regarding the implementation of Phase II and any necessary procedural revisions.
- Treatability Study Report – documenting activities and performance results from Phase II of the Treatability Study, synthesizing conclusions from both phases, and making recommendations for completing remediation of the TAVG AOC.

Additionally, Environmental Restoration Operations continue to submit Consolidated Quarterly Report to the NMED. Progress of the Treatability Study will be documented in the Consolidated Quarterly Report as part of the status reporting for TAVG AOC.

A summary of activities and results during the prior calendar year will be included in the TAVG section of the Annual Groundwater Monitoring Report.

In addition to reporting, verbal or written communications and meetings will be ongoing with NMED as necessary.

### **9.1 Well Installation Report and Results of Push/Pull Test**

Well Installation Report will be completed to document well installation field activities. One report will be prepared after wells TAV-MW15, TAV-MW16, and TAV-INJ1 have been installed and the push/pull test has been completed. This report will include well installation and the results of push/pull test. A second well installation report will be prepared for wells TAV-INJ2 and TAV-INJ3 provided they are installed.

The well installation report will document site activities and provide final as-built well completion diagrams. Information to be contained in the report includes: (1) the 37 information elements required in section VIII.D of the Consent Order (NMED April 2004), (2) a description of all materials used, (3) final as-built well diagrams, and (4) documentation of notification of Sandia Geographic Information System group and the appropriate regulatory agencies. The following list of documents and records that are generated as part of the well installation process will be provided to the Sandia Well File Coordinator who, in turn, will submit them to the Sandia Customer Funded Record Center:

- Well file contents checklist.
- Well data summary sheet.

- Statement of Work for drilling the well.
- Drilling permit from NMOSE.
- Lithologic log.
- Well construction diagram and completion parameters.
- Well development data and groundwater parameters.
- Copies of field logbook.
- Surveyed elevation and location in New Mexico state plane coordinates (with a degree of accuracy of  $\pm 0.01$  ft) from a New Mexico-licensed surveyor.
- Location map.
- Water level measurements.
- Borehole geophysical logs.
- Geophysical logs for completed wells.
- Aquifer test data.
- Analytical data.
- Waste management documentation.
- Photographs.

## **9.2 Technical Memorandum**

A Technical Memorandum will be prepared upon the completion of the Phase I performance monitoring. This document will include documentation of field activities and results from the short-term push/pull test and the subsequent full-scale injection and associated performance monitoring. It will also present recommendations for either proceeding with Phase II along with any associated revisions to procedures, or to discontinue the Treatability Study based on Phase I results.

## **9.3 Treatability Study Report**

A Treatability Study Report will be prepared upon the completion of the Phase II performance monitoring. It will include documentation of all field activities conducted under the Treatability Study, as well as Treatability Study results and recommendations for completing remediation of the TAVG AOC.

## 10.0 SCHEDULE

Figure 10-1 shows a general flow chart of the Treatability Study with estimated durations. The two primary decision points are shown. Decision Point #1 occurs at the end of the Phase I push/pull test performance monitoring at TAV-INJ1. Data will be evaluated against the performance criteria to determine if the test should proceed to full-scale injection at TAV-INJ1. Decision Point #2 occurs six months into the performance monitoring after the TAV-INJ1 full-scale injection is complete where data to that point will be evaluated to determine if the test should scale up to Phase II (installation of TAV-INJ2 and TAV-INJ3 and successive full-scale injections at those locations). Regardless of the decision whether to proceed with Phase II or not, the planned 24 months of Phase I post-injection performance and rebound monitoring will be completed.

# PHASE I

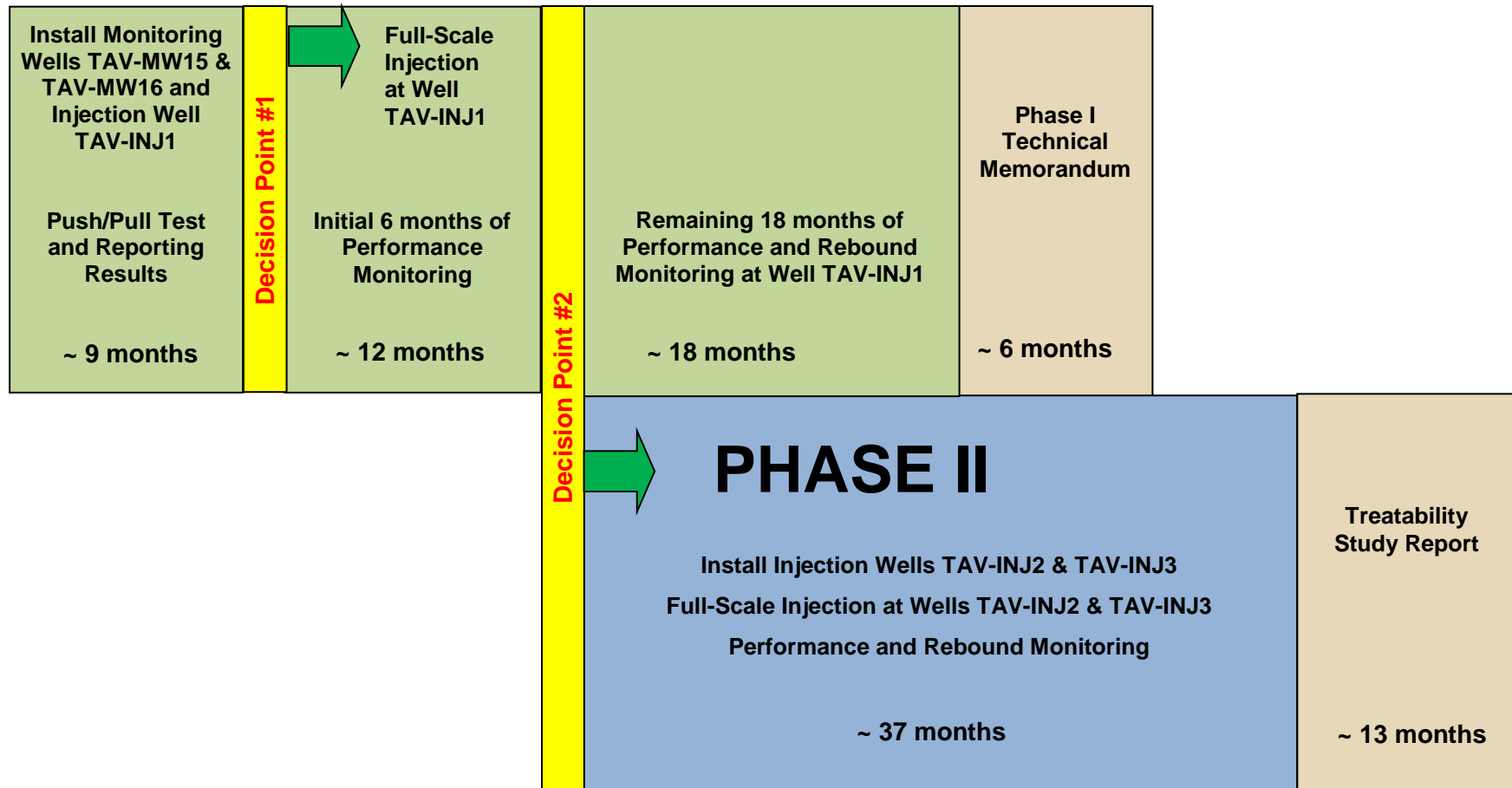


Figure 10-1  
Treatability Study Flow Chart with Estimated Durations (not to Scale)

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**APPENDIX A**  
**Electron Donor Demand Calculation**





## ELECTRON DONOR DEMAND AND MASS CALCULATIONS

The following spreadsheets present the calculations to estimate the mass of ethyl lactate needed to meet electron donor demand in groundwater and soil within the projected treatment area for each full-scale injection to be implemented during Phase I and Phase II of the Treatability Study.

The spreadsheet first presents the dimensions of the treatment area for one injection location. Each of the three injection locations is assumed to have the same treatment zone dimensions and effective porosity. Electron donor demand also used electron acceptor concentrations from monitoring well LWDS-MW1 where concentrations of nitrate and TCE are highest. Electron donor demand calculations will be performed on a location-specific basis based on initial sampling results from injection wells once they are installed and these results will be used to refine substrate solution constituent ratios prior to injection.

Electron donor demand was divided into three categories that calculate demand based on a stoichiometric ratio:

- Electron donor demand for competing terminal electron acceptors (TEAs).
- Electron donor demand for dissolved volatile organic compounds (VOCs).
- Electron donor demand for VOCs sorbed to saturated soil.

Experience from projects at similar sites shows that the theoretical stoichiometric value is often not sufficient to create the desired conditions. Research (Lee et al. March 2004) shows that only 30 percent of the electron donor is utilized for dechlorination (referred to as the 'McCarty' factor). The McCarty factor was applied to calculate electron donor demand based on stoichiometry. A safety factor of 10 was then applied based on full-scale field experience and to account for low permeability of the saturated sediments at the site.<sup>1</sup>

Estimated delivery timeframe per full-scale injection is also presented based on the assumption that 5,000 gallons per day of potable water mixed with the electron donor, amendments, and bioaugmentation culture could be gravity-injected each work day, plus an additional three weeks to allow for system set up and optimization.

Due to the very low concentrations of VOCs, the total electron donor demand is almost completely governed by concentrations of competing terminal electron acceptors in groundwater (dissolved oxygen, nitrate, iron, manganese, and sulfate). The bulk of electron donor will be adjusted in-situ for reductive dechlorination to take place.

---

<sup>1</sup> Brian Timmins (Director, Etec, LLC Environmental Technologies, discussions with Thomas Berry (Senior Geologist, CE2 Corporation, Pleasanton, California contracted to SNL/NM) regarding electron donor selection, demand, and mass calculations (April 2014 through July 2015).

## Electron Donor (Ethyl Lactate) Demand and Mass Calculations

### Dimensions of Treatment Area (one injection well)

Delivery Radius	60	ft	Effective Porosity	0.25	
Area	11,310	ft <sup>2</sup>	Volume of soil matrix	7,854	CY
Thickness	25	ft	Pore Volume (PV)	70,688	ft <sup>3</sup>
Total Target Volume	282,750	ft <sup>3</sup>	Pore Volume (PV)	2,001,661	L
Total Target Volume	10,472	CY	<b>Pore Volume (PV)</b>	<b>528,783</b>	<b>gal</b>

### Electron Donor Demand for Competing Terminal Electron Acceptors (TEAs)

TEA	Concentration (mg/L) <sup>a</sup>	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol TEA)	Electron Donor Demand (mg/L)
Dissolved oxygen	7.28	32	1/6	4.478
Nitrate	12.7	62	5/24	5.040
Iron	20	55.9	1/24	1.761
Manganese	20	54.9	1/12	3.585
Sulfate	41.5	96	1/3	17.018
<b>Electron donor: ethyl lactate</b>		<b>118.1</b>		
Total electron donor demand (mg/L)				31.882
Treatment area pore volume (L)				2,001,661
Total electron donor demand (mg)				63,816,956
<b>Total electron donor demand for competing TEAs (lbs) – rounded to nearest 0.1 lb.</b>				<b>140.7</b>

### Electron Donor Demand for Dissolved Volatile Organic Compounds (VOCs)

VOC	Concentration (µg/L) <sup>a</sup> November 2014	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol VOC)	Electron Donor Demand (µg/L)
PCE	0	165.8	1/3	0.000
TCE	16.9	131.4	1/4	3.797
cis-1,2-DCE	3.45	96.9	1/6	0.701
VC	0	62.5	1/12	0.000
Subtotal electron donor demand (µg/L) (based on ethyl lactate)				4.498
Treatment area pore volume (L)				2,001,823
Total electron donor demand (µg)				9,004,510
<b>Total electron donor demand for dissolved VOCs (lbs)</b>				<b>0.020</b>

### Electron Donor Demand for VOCs Sorbed to Saturated Soil

VOC	Concentration in groundwater (µg/L) <sup>a</sup>	Koc (mL/g) <sub>b</sub>	foc <sup>c</sup>	Concentratio n sorbed to soil (µg/kg)	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol VOC)	Electron Donor Demand (µg/kg)
PCE	0	265	0.000539	0	165.8	1/3	0
TCE	16.9	94.3		0.859	131.4	1/4	0.193
cis-1,2-DCE	3.45	35.5		0.066	96.9	1/6	0.013
VC	0	18		0	62.5	1/12	0
Subtotal electron donor demand (µg/kg) (based on ethyl lactate)							0.206
Treatment area soil volume (CY)							7,854
Soil bulk density (kg/cm <sup>3</sup> )							0.0018
Soil bulk density (kg/CY)							1,376
Treatment area soil mass (kg)							10,808,642
Total electron donor demand (µg)							2,231,123
Total electron donor demand for VOCs sorbed to saturated soil (lbs)							0.008

### Mass of Electron Donor to be Injected

Total electron donor demand for competing TEAs (lbs)	140.7
Total electron donor demand for dissolved VOCs (lbs)	0.020
Total electron donor demand for VOCs sorbed to saturated soil (lbs)	0.005
<b>Total electron donor demand as ethyl lactate</b>	<b>140.7</b>
Adjusted total accounting for the McCarty Factor (30% efficiency) (lbs) <sup>d</sup>	469
Safety factor for Low K Sediment	10
<b>Total electron donor to be Injected in one pore volume (lbs)</b>	<b>4,690</b>
<b>Total electron donor to be Injected per 1,000 gallons of water (lbs)</b>	<b>8.9</b>

### Injection timeframe

Target Volume (gal)	<b>528,783</b>
# Injection Wells	1
Total Injection Volume (gal)	528,783
Batch volume (gal)	5,000
Batches/day	1
<b>Estimated injection rate (gpd)</b>	<b>5,000.00</b>
Total injection batches for one pore volume (rounded up to nearest whole batch)	106
Total injection timeframe (days)	106
<b>Total injection timeframe (weeks) - assume 5 days/week + 3 weeks for system set up, optimization, and demobilization</b>	<b>24</b>

**Acronyms & Abbreviations:**

µg/kg	= Micrograms per kilograms.
µg/L	= Micrograms per liter.
CY	= Cubic yard.
DCE	= Dichloroethene.
foc	= Fraction of organic carbon.
ft	= Feet/foot.
ft <sup>2</sup>	= Square feet.
ft <sup>3</sup>	= Cubic feet.
g/mol	= Grams per mole.
gal	= Gallons.
gpd	= Gallons per day.
K	= Hydraulic conductivity.
kg/cm <sup>3</sup>	= Kilograms per cubic centimeter.
kg/CY	= Kilograms per cubic yard.
Koc	= Soil organic carbon-water partitioning coefficient.
L	= Liter.
lbs	= Pounds.
mg	= Milligrams.
mg/L	= Milligrams per liter.
mL/g	= Milliliters per gram.
mol	= Mole(s).
PCE	= Tetrachloroethylene.
TEA	= Terminal electron acceptor.
TCE	= Trichloroethene.
VC	= Vinyl chloride.
VOCs	= Volatile organic compounds.

**Notes:**

See footnote 1 on page A-1.

<sup>a</sup> Concentrations in LWDS-MW1 from November 2014 groundwater sampling event. Iron and manganese concentrations are estimated values under anaerobic conditions based on field experience.

<sup>b</sup> Koc values taken from 1996 EPA Soil Screening Criteria.

<sup>c</sup> SNL/NM Site-Wide Hydrogeologic Characterization Project (February 1998), Table 3.2.3-1 Mean TOC = 539 mg/kg = 0.000539 foc. Based on samples collected at Chemical Waste Landfill (and a few from Mixed Waste Landfill).

<sup>d</sup> Lee, Il-Su, Joe-Ho Bae, Yanru Yang, Perry L. McCarty, March 2004. "Simulated and Experimental Evaluation of Factors Affecting the Rate and Extent of Reductive Dehalogenation of Chloroethenes with Glucose," Journal of Contaminant Hydrogeology, 74: pp. 313-331.

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**APPENDIX B**  
**Safety Data Sheets**

**Ethyl lactate**  
**Diammonium phosphate**  
**Yeast extract**  
**Sodium bromide**  
**KB-1<sup>®</sup> Primer**  
**KB-1<sup>®</sup> Dechlorinator**





## Ethyl-(S)-Lactate

REVISION DATE 07/05/07  
REF. SD0310/2007-01

### 1. IDENTIFICATION OF THE SUBSTANCE / PREPARATION AND THE COMPANY / UNDERTAKING

<b>Product name</b>	PURASOLV® EL, PURASOLV® ELECT		
<b>Use of the Substance</b>	Solvent, Flavour, Specialty chemical		
<b>Supplier</b>	PURAC biochem Arkelsedijk 46 NL-4206 AC Gorinchem The Netherlands	PURAC bioquímica Gran Vial 19 -25 08160 Montmelo-Barcelona Spain	
<b>Telephone</b>	++31 183 695695	++34 93 568 6300	
<b>Fax</b>	++31 183 695604	++34 93 568 3955	
<b>Emergency telephone</b>	++31 183 695695	++34 93 568 6300 (Ext 222)	

### 2. COMPOSITION / INFORMATION ON INGREDIENTS

<b>Chemical name of the substance</b>	Ethyl (S)-2-Hydroxy Propanoate			
<b>Synonyms</b>	Lactic Acid Ethyl Ester, Ethyl-L-Lactate			
<b>Components</b>	<b>CAS-No.</b> 687-47-8	<b>EC-No.</b> 211-694-1	<b>RTECS-No.</b> OD5075000	<b>Weight, %</b> 100
<b>Hazard classification</b>	R10, R37, R41. For details see chapter 15.			

### 3. HAZARDS IDENTIFICATION

<b>Most important hazards</b>	Risk of serious damage to eyes. Irritating to eyes. Combustible liquid.
<b>Specific hazards</b>	May degrease the skin. Effects of skin contacts may include erythema.

### 4. FIRST AID MEASURES

<b>General advice</b>	Show this safety data sheet to the doctor in attendance.
<b>Inhalation</b>	Move to fresh air.
<b>Skin contact</b>	Wash off immediately with plenty of water.
<b>Eye contact</b>	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes.
<b>Ingestion</b>	Induce vomiting if person is conscious. Consult a physician.
<b>Major effects of exposure</b>	Inhalation of vapors is irritating to the respiratory system, and may cause coughing. Irritating to eyes. May degrease the skin.
<b>Protection of firstaiders</b>	Wear tightly fitting safety goggles.

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## Ethyl-(S)-Lactate

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### 5. FIRE-FIGHTING MEASURES

<b>Suitable extinguishing media</b>	Water spray, carbon dioxide (CO <sub>2</sub> ), dry powder, AFFF, foam.
<b>Extinguishing media which must not be used for safety reasons</b>	None.
<b>Specific hazards</b>	Thermal decomposition can lead to release of irritating gases and vapors.
<b>Special protective equipment for firefighters</b>	None.
<b>Specific methods</b>	Standard procedure for chemical fires. Cool containers / tanks with water spray.

### 6. ACCIDENTAL RELEASE MEASURES

<b>Personal precautions</b>	Remove all sources of ignition. Wear tightly fitting safety goggles.
<b>Environmental precautions</b>	No special environmental precautions required.
<b>Methods for cleaning up</b>	Soak up with inert absorbent material (e.g. sand, silica gel, universal binder, sawdust). Shovel into suitable container for disposal. After cleaning, flush away traces with water.

### 7. HANDLING AND STORAGE

<b>Handling</b>	
<b>Technical measures/Precautions</b>	Remove all sources of ignition. Avoid temperatures above 139°F (59°C).
<b>Safe handling advice</b>	Wear tightly fitting safety goggles. Handle in accordance with good industrial hygiene and safety practice.
<b>Storage</b>	
<b>Technical measures/Storage conditions</b>	Keep container tightly closed. In order to prevent oxidation, the product is supplied under a nitrogen or argon blanket. After opening the packaging, it is recommended to use or store the product under inert conditions (e.g. nitrogen or argon).
<b>Packaging material</b>	High density polyethylene containers.

## Ethyl-(S)-Lactate

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### 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

<b>Engineering measures to reduce exposure</b>	Insure adequate ventilation, especially in confined areas.
<b>Control parameters</b>	None.
<b>Personal protection equipment</b>	
<b>Respiratory protection</b>	In case of insufficient ventilation wear suitable respiratory equipment.
<b>Hand protection</b>	Solvent-resistant gloves (PVA / H4).
<b>Eye protection</b>	Tightly fitting safety goggles.
<b>Skin and body protection</b>	Solvent-resistant apron.
<b>Hygiene measures</b>	When using, do not eat, drink or smoke. Remove and wash contaminated clothing before re-use.

### 9. PHYSICAL AND CHEMICAL PROPERTIES

<b>Form</b>	liquid
<b>Color</b>	colorless
<b>Odor</b>	mild, characteristic
<b>Odor Threshold</b>	0.18 ppm
<b>pH</b>	not applicable
<b>Molecular Weight</b>	118.15
<b>Boiling point/range</b>	307°F (153°C)
<b>Melting point/range</b>	26.6°F (-3 °C)
<b>Decomposition temperature</b>	> 307°F (153°C)
<b>Autoignition temperature</b>	752°F (400°C)
<b>Flash point</b>	139°F (59°C) (Tested according to: ISO 2719, closed cup)
<b>Explosion limits</b>	- lower: 1.5% @ 212°F (100°C) - upper: 11.4% @ 212°F (100°C)
<b>Density</b>	1.033 g/ml @ 68°F (20°C)
<b>Vapor density</b>	4.07 (Air = 1)
<b>Vapor pressure</b>	2.7 mbar @ 68°F (20°C), 172 mbar @ 212°F (100°C)
<b>Solubility</b>	Water solubility: completely miscible, miscible with most organic solvents Partition coefficient (n-octanol/water) log Pow = 0.06
<b>Viscosity</b>	2.8 mPa.S @ 68°F (20°C)
<b>Surface Tension</b>	30.6 mN/m @ 77°F (25°C)

### 10. STABILITY AND REACTIVITY

<b>Stability</b>	Stable at normal conditions. Hydrolyses in presence of water, acids, bases.
<b>Conditions to avoid</b>	Avoid temperatures above 139°F (59°C).
<b>Materials to avoid</b>	None.
<b>Hazardous decomposition products</b>	Carbon oxides.

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REVISION DATE 07/05/07  
REF. SD0310/2007-01

### 11. TOXICOLOGICAL INFORMATION

<b>Acute toxicity</b>	LD50/oral/mouse = 2500 mg/kg LC50/inhalation/8h/rat > 5400 mg/m <sup>3</sup>
<b>Sub acute Toxicity (28 day inhalation)</b>	NOAEL (systemic toxicity) 600mg/m <sup>3</sup> , NOAEL (local toxicity) 200 mg/m <sup>3</sup>
<b>Local effects</b>	Effects of skin contacts may include erythema. Irritating to eyes. Risk of serious damage to eyes. May cause irritation of the mucous membranes. Inhalation of high vapor concentrations can cause CNS-depression and narcosis.
<b>Specific effects</b>	Based on tests with L-lactic acid and its esters, there is no evidence to suggest carcinogenic nor mutagenic properties from lactic acid itself nor from the lactate portion of its esters. Developmental toxicity in rats: No effect at 3.619 g/kg/day.
<b>Long term toxicity</b>	Repeated or prolonged exposure may cause irritation of eyes and skin.
<b>Further information</b>	Lactate esters are readily hydrolyzed in vivo.

### 12. ECOLOGICAL INFORMATION

<b>Mobility</b>	Completely miscible in water.
<b>Persistence / degradability</b>	Readily biodegradable, according to appropriate OECD test. Biochemical oxygen demand (BOD)=1.43 mg O <sub>2</sub> /mg Chemical oxygen demand (COD)=1.66 mg O <sub>2</sub> /mg.
<b>Bioaccumulation</b>	Unlikely, hydrolyses in presence of: water, acids, bases.
<b>Ecotoxicity</b>	EC50/48h/Daphnia = 683mg/l LC50/48h/Fish = 320 mg/l EC50/Algae = 2200 mg/l

### 13. DISPOSAL CONSIDERATIONS

<b>Waste from residues / unused products</b>	Subject to disposal regulations US EPA 40 CFR 2 62.
<b>Contaminated packaging</b>	Clean container with water. Empty containers should be taken for local recycling, recovery or waste disposal.

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For further information:

<http://www.purac.com/>

## Ethyl-(S)-Lactate

REVISION DATE 07/05/07  
REF. SD0310/2007-01

### 14. TRANSPORT INFORMATION

**HI/UN No:** 30/1192  
**ADR/RID** Class 3 Item 31°(c) ADR/RID-Labels 3  
Proper shipping name Ethyl Lactate, 3,31°(c)  
**IMO** Class 3.3 IMDG Page 3343 IMO-Labels Flammable liquid  
Packaging group. III EmS. F-E S-D MFAG. 330  
Proper shipping name Ethyl Lactate, UN 1192  
**ICAO** Class 3 UNID No. 1192 ICAO-Labels Flammable liquid  
Packing group III  
Proper shipping name Ethyl Lactate, UN 1192  
**US DOT (see further information below)**  
UN 1192 Class 3 DOT Labels Flammable liquid  
Packaging group. III  
Maximum quantity (passenger aircraft): 60 liters Maximum quantity (cargo aircraft): 220 liters

#### Further information

In the US, PURASOLV EL is a combustible liquid, and not regulated for non bulk shipments (truck). It is regulated for air and rail shipments.

### 15. REGULATORY INFORMATION

**US Regulations** TSCA Inventory Status: Y  
SARA III: N  
California Proposition 65: N  
Carcinogen status: OSHA: N. NTP: N, IARC: N  
Gras as food flavor, ADI not specified.  
Massachusetts Substances List: Y  
Pennsylvania Right to Know List: Y  
According to National equivalent of EC-Dir. 67/548, as amended, the product is labeled as follows:  
**EU Status**  
**Symbol** Xi - Irritant  
**R-Phrases** R41 - Risk of serious damage to eyes  
R37 - Irritation to respiratory system  
R10 - Flammable  
**S-Phrases** S24 - Avoid contact with skin.  
S26 - In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.  
S39 - Wear eye/face protection.

**Ethyl-(S)-Lactate**REVISION DATE 07/05/07  
REF. SD0310/2007-01**16. OTHER INFORMATION****NFPA Ratings (Scale 0-4):** 2(health)-2(flammability)-0(reactivity)  
**HMIS Rating:** 1(health)-2(flammability)-0(reactivity)-B (protective equipment)

For further information on the safety assessment of lactic acid esters, see the paper titled: Safety Assessment of Lactate Esters, published in Regulatory Toxicology and Pharmacology, 27, 88-97, 1998.

Additional data on the calculated ecotoxicity of lactic acid and its salts and esters can be obtained in a report entitled 'The ecotoxicity and biodegradability of lactic acid, alkyl lactate esters and lactic acid salts' by Bowmer et al.  
(Reference: Chemosphere 37: 1317-1333 (1998)).

This information only concerns the above mentioned product and is not valid if used with other product(s) or in any process. The information is to our best present knowledge correct and complete and is given in good faith but without warranty. It remains the user's own responsibility to make sure that the information is appropriate and complete for his special use of this product.

# Indicates updated section.



## Material Safety Data Sheet

### DIAMMONIUM PHOSPHATE

Date Prepared: 11/01/07

Supersedes Date: 8/13/04

#### 1. PRODUCT AND COMPANY DESCRIPTION

Innophos  
PO Box 8000  
259 Prospect Plains Road  
Cranbury NJ 08512-8000

**Emergency Phone Numbers:**

FOR EMERGENCIES INVOLVING A SPILL, LEAK, FIRE, EXPOSURE OR ACCIDENT CONTACT: CHEMTREC (800-424-9300 within the United States or 703-527-3887 for international collect calls) or INNOPHOS ECT (Emergency Communication Team) at 615-386-7816.

**For Product Information:**

(609) 495-2495

**Chemical Name or Synonym:**

AMMONIUM PHOSPHATE, SECONDARY; DAP; AMMONIUM PHOSPHATE, DIBASIC

**Molecular Formula:**

$(\text{NH}_4)_2\text{HPO}_4$

#### 2. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS Reg Number	OSHA Hazard	Percentage
DIAMMONIUM PHOSPHATE	7783-28-0	Y	100

#### 3. HAZARDS IDENTIFICATION

**A. EMERGENCY OVERVIEW:**

**Physical Appearance and Odor:**

white powder solid, ammonia-like odor.

**Warning Statements:**

CAUTION! MAY CAUSE SKIN AND EYE IRRITATION.

**B. POTENTIAL HEALTH EFFECTS:**



**Acute Eye:**

May cause irritation.

**Acute Skin:**

Skin absorption not likely. May cause irritation.

**Acute Inhalation:**

May cause upper respiratory tract irritation.

**Acute Ingestion:**

Ingestion of large quantities may cause nausea, vomiting, diarrhea, abdominal cramps.

**Chronic Effects:**

This product does not contain any ingredient designated by IARC, NTP, ACGIH or OSHA as probable or suspected human carcinogens.

## 4. FIRST AID MEASURES

**FIRST AID MEASURES FOR ACCIDENTAL:****Eye Exposure:**

Hold eyelids open and flush with a steady, gentle stream of water for at least 15 minutes. Seek medical attention if irritation develops or persists or if visual changes occur.

**Skin Exposure:**

In case of contact, immediately wash with plenty of soap and water for at least 5 minutes. Seek medical attention if irritation develops or persists. Remove contaminated clothing and shoes. Clean contaminated clothing and shoes before re-use.

**Inhalation:**

If respiratory irritation or distress occurs remove victim to fresh air. Seek medical attention if respiratory irritation or distress continues.

**Ingestion:**

Do not induce vomiting, unless directed to do so by a physician. If victim is conscious and alert, give 2-3 glasses of water to drink. Seek immediate medical attention. Do not leave victim unattended. To prevent aspiration of swallowed product, lay victim on side with head lower than waist. Vomiting may occur spontaneously. If vomiting occurs and the victim is conscious, give water to further dilute the chemical. Also see Note To Physician.

**MEDICAL CONDITIONS POSSIBLY AGGRAVATED BY EXPOSURE:**

Inhalation of product may aggravate existing chronic respiratory problems such as asthma, emphysema or bronchitis. Skin contact may aggravate existing skin disease.

**NOTES TO PHYSICIAN:**

All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this product may have occurred.

Ingestion of large quantities of phosphate salts (over 1.0 grams for an adult) may cause an osmotic catharsis resulting in diarrhea and probable abdominal cramps. Larger doses such as 4-8 grams will almost certainly cause these effects in everyone. In healthy individuals most of the ingested salt will be excreted in the feces with the diarrhea and, thus, not cause any systemic toxicity. Doses greater than 10 grams hypothetically may cause systemic toxicity. Treatment should take into consideration both anionic and cation portion of the molecule. The following treatments should be considered for the specific group(s) of phosphate salts found in this product:

--All phosphate salts, except calcium salts, have a hypothetical risk of hypocalcemia, so calcium levels should be

monitored.

--Ammonium salts have a hypothetical risk of ammonia toxicity. In addition to calcium levels, ammonia and phosphate levels should be monitored.

--Potassium salts have a hypothetical risk of hyperkalemia which can cause cardiac arrhythmia. In addition to calcium levels, potassium and phosphate levels should be monitored. Also consider continuous EKG monitoring to detect hyperkalemia.

--Sodium salts have a hypothetical risk of hypernatremia. In addition to calcium levels, sodium and phosphate levels should be monitored.

## 5. FIRE FIGHTING MEASURES

### FIRE HAZARD DATA:

#### Flash Point:

Not Applicable

#### Extinguishing Media:

Not combustible. Use extinguishing method suitable for surrounding fire.

#### Special Fire Fighting Procedures:

Firefighters should wear NIOSH/MSHA approved self-contained breathing apparatus and full protective clothing. Dike area to prevent runoff and contamination of water sources. Dispose of fire control water later.

#### Unusual Fire and Explosion Hazards:

Not combustible.

#### Hazardous Decomposition Materials (Under Fire Conditions):

ammonia  
oxides of nitrogen  
oxides of phosphorus

## 6. ACCIDENTAL RELEASE MEASURES

### Evacuation Procedures and Safety:

Wear appropriate protective gear for the situation. See Personal Protection information in Section 8.

### Containment of Spill:

Dike or retain dilution water or water from firefighting for later disposal. Follow procedure described below under Cleanup and Disposal of Spill.

### Cleanup and Disposal of Spill:

Sweep or vacuum up and place in an appropriate closed container (see Section 7: Handling and Storage). Avoid creation of dusty conditions. Clean up residual material by washing area with water and detergent.

### Environmental and Regulatory Reporting:

Runoff from fire control or dilution water may cause pollution. Prevent material from entering public sewer system or any waterways. Spills may be reportable to the National Response Center (800-424-8802) and to state and/or local agencies.

## 7. HANDLING AND STORAGE

### Minimum/Maximum Storage Temperatures:

Not Available

### Handling:

Keep containers closed when not being used. Avoid breathing dusts or vapors. Avoid direct or prolonged contact with skin and eyes.

### Storage:

Store in an area that is cool, dry, well-ventilated, Store in closed containers. This product is hygroscopic and tends to cake on storage.

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### Introductory Remarks:

These recommendations provide general guidance for handling this product. Because specific work environments and material handling practices vary, safety procedures should be developed for each intended application. While developing safe handling procedures, do not overlook the need to clean equipment and piping systems for maintenance and repairs. Waste resulting from these procedures should be handled in accordance with Section 13: Disposal Considerations.

Assistance with selection, use and maintenance of worker protection equipment is generally available from equipment manufacturers.

### Exposure Guidelines:

Exposure limits represent regulated or recommended worker breathing zone concentrations measured by validated sampling and analytical methods, meeting the regulatory requirements. The following limits apply to this material, where, if indicated, S=skin and C=ceiling limit:

#### PARTICULATES NOT OTHERWISE REGULATED RESPIRABLE FRACTION

	Notes	TWA	STEL
OSHA		5 mg/cu m	

#### PARTICULATES NOT OTHERWISE REGULATED TOTAL DUST

	Notes	TWA	STEL
OSHA		15 mg/cu m	

### Engineering Controls:

Where engineering controls are indicated by use conditions or a potential for excessive exposure exists, the following traditional exposure control techniques may be used to effectively minimize employee exposures: general area dilution/exhaust ventilation.

### Respiratory Protection:

When respirators are required, select NIOSH/MSHA approved equipment based on actual or potential airborne concentrations and in accordance with the appropriate regulatory standards and/or industrial recommendations.

Under normal conditions, in the absence of other airborne contaminants, the following devices should provide protection from this material up to the conditions specified by the appropriate OSHA, WHMIS or ANSI standard(s): dust/mist filtering respirator.

**Eye/Face Protection:**

Eye and face protection requirements will vary dependent upon work environment conditions and material handling practices. Appropriate ANSI Z87 approved equipment should be selected for the particular use intended for this material.

Eye contact should be prevented through use of chemical safety glasses with side shields or splash proof goggles. An emergency eye wash must be readily accessible to the work area.

**Skin Protection:**

Skin contact should be minimized through use of gloves and suitable long-sleeved clothing (i.e., shirts and pants). Consideration must be given both to durability as well as permeation resistance.

**Work Practice Controls:**

Personal hygiene is an important work practice exposure control measure and the following general measures should be taken when working with or handling this material:

- (1) Do not use, and/or consume foods, beverages, tobacco products, or cosmetics in areas where this material is stored.
- (2) Wash hands and face carefully before eating, drinking, using tobacco, applying cosmetics, or using the toilet.
- (3) Wash exposed skin promptly to remove accidental splashes or contact with this material.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical and Chemical properties here represent typical properties of this product. Contact the business area using the Product Information phone number in Section 1 for its exact specifications.

**Physical Appearance:**

white powder solid.

**Odor:**

ammonia-like odor.

**pH:**

8 at 1 wt/wt%.

**Specific Gravity:**

Not Available

**Water Solubility:**

soluble 41 wt/wt% at 20 C (68 F).

**Melting Point Range:**

Not Available

**Boiling Point Range:**

Not Available

**Vapor Pressure:**

Not Available

**Vapor Density:**

Not Available

**Molecular Weight:**

132.06

## 10. STABILITY AND REACTIVITY

### **Chemical Stability:**

This material is stable under normal handling and storage conditions described in Section 7.

### **Conditions To Be Avoided:**

dusting conditions  
extreme heat  
extreme humidity

### **Materials/Chemicals To Be Avoided:**

strong bases  
sodium hypochlorite

### **Decomposition Temperature Range:**

155 C (311 F)

### **The Following Hazardous Decomposition Products Might Be Expected:**

#### **Decomposition Type: thermal**

ammonia  
phosphoric acid  
oxides of nitrogen  
oxides of phosphorus

### **Hazardous Polymerization Will Not Occur.**

### **Avoid The Following To Inhibit Hazardous Polymerization:**

not applicable

## 11. TOXICOLOGICAL INFORMATION

### **Acute Eye Irritation:**

No test data found for product.

### **Acute Skin Irritation:**

#### **Toxicological Information and Interpretation:**

skin - skin irritation, rabbit. Mildly irritating.

### **Acute Dermal Toxicity:**

No test data found for product.

### **Acute Respiratory Irritation:**

No test data found for product.

### **Acute Inhalation Toxicity:**

No test data found for product.

### **Acute Oral Toxicity:**

**Toxicological Information and Interpretation:**

LD50 - lethal dose 50% of test species, > 1000 mg/kg, rat.

**Chronic Toxicity:**

This product does not contain any substances that are considered by OSHA, NTP, IARC or ACGIH to be "probable" or "suspected" human carcinogens.

## 12. ECOLOGICAL INFORMATION

**Ecotoxicological Information:****Ecotoxicological Information and Interpretation:**

LC50 - lethal concentration 50% of test species, 155 mg/l/96 hr, fish: Pimephales promelas.

**Chemical Fate Information:**

No data found for product.

## 13. DISPOSAL CONSIDERATIONS

**Waste Disposal Method:**

Chemical additions, processing or otherwise altering this material may make the waste management information presented in this MSDS incomplete, inaccurate or otherwise inappropriate. Please be advised that state and local requirements for waste disposal may be more restrictive or otherwise different from federal laws and regulations. Consult state and local regulations regarding the proper disposal of this material.

**EPA Hazardous Waste - NO**

## 14. TRANSPORTATION INFORMATION

**Transportation Status: IMPORTANT! Statements below provide additional data on listed DOT classification.**

The listed Transportation Classification does not address regulatory variations due to changes in package size, mode of shipment or other regulatory descriptors.

**US Department of Transportation**

Shipping Name:

NOT REGULATED

## 15. REGULATORY INFORMATION

**Inventory Status**

Inventory	Status
UNITED STATES (TSCA)	Y
CANADA (DSL)	Y
EUROPE (EINECS/ELINCS)	Y

AUSTRALIA (AICS)	Y
JAPAN (MITI)	Y
SOUTH KOREA (KECL)	Y

Y = All ingredients are on the inventory.

E = All ingredients are on the inventory or exempt from listing.

P = One or more ingredients fall under the polymer exemption or are on the no longer polymer list. All other ingredients are on the inventory or exempt from listing.

N = Not determined or one or more ingredients are not on the inventory and are not exempt from listing.

## FEDERAL REGULATIONS

### Inventory Issues:

All functional components of this product are listed on the TSCA Inventory.

### SARA Title III Hazard Classes:

Fire Hazard	- NO
Reactive Hazard	- NO
Release of Pressure	- NO
Acute Health Hazard	- YES
Chronic Health Hazard	- NO

## OTHER FEDERAL REGULATIONS:

### FDA Status:

This product meets the compositional requirements of:  
21 CFR 184.1141B AMMONIUM PHOSPHATE, DIBASIC

### STATE REGULATIONS:

This product does not contain any components that are regulated under California Proposition 65.

## 16. OTHER INFORMATION

### National Fire Protection Association Hazard Ratings--NFPA(R):

1	Health Hazard Rating--Slight
0	Flammability Rating--Minimal
0	Instability Rating--Minimal

### National Paint & Coating Hazardous Materials Identification System--HMIS(R):

1	Health Hazard Rating--Slight
0	Flammability Rating--Minimal
0	Reactivity Rating--Minimal

### Reason for Revisions:

Change and/or addition made to Section 4, Section 12.

### Key Legend Information:

ACGIH - American Conference of Governmental Industrial Hygienists  
OSHA - Occupational Safety and Health Administration  
TLV - Threshold Limit Value  
PEL - Permissible Exposure Limit  
TWA - Time Weighted Average

STEL - Short Term Exposure Limit  
NTP - National Toxicology Program  
IARC - International Agency for Research on Cancer  
ND - Not determined  
RPI - INNOPHOS Established Exposure Limits

**Disclaimer:**

The information herein is given in good faith but no warranty, expressed or implied, is made.

**\*\* End of MSDS Document \*\***



# Material Safety Data Sheet

## Yeast Extract

ACC# 08515

### Section 1 - Chemical Product and Company Identification

**MSDS Name:** Yeast Extract

**Catalog Numbers:** AC611801000, AC611805000, S80245-1, S80245-2, S80245-3, BP1422-100, BP1422-2, BP1422-500

**Synonyms:** None known.

**Company Identification:**

Fisher Scientific

1 Reagent Lane

Fair Lawn, NJ 07410

**For information, call:** 201-796-7100

**Emergency Number:** 201-796-7100

**For CHEMTREC assistance, call:** 800-424-9300

**For International CHEMTREC assistance, call:** 703-527-3887

### Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
8013-01-2	Yeast, extract	100.0	232-387-9

### Section 3 - Hazards Identification

#### EMERGENCY OVERVIEW

Appearance: yellow-white to yellow-orange solid.

**Caution!** May cause eye, skin, and respiratory tract irritation. This is expected to be a low hazard for usual industrial handling.

**Target Organs:** None known.

#### Potential Health Effects

**Eye:** May cause eye irritation.

**Skin:** May cause skin irritation. Low hazard for usual industrial handling.

**Ingestion:** May cause irritation of the digestive tract. Low hazard for usual industrial handling.

**Inhalation:** May cause respiratory tract irritation. Low hazard for usual industrial handling.

**Chronic:** No information found.

## Section 4 - First Aid Measures

**Eyes:** Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation develops, get medical aid.

**Skin:** Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

**Ingestion:** Do not induce vomiting. Get medical aid if irritation or symptoms occur.

**Inhalation:** Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

**Notes to Physician:** Treat symptomatically and supportively.

## Section 5 - Fire Fighting Measures

**General Information:** As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts may be an explosion hazard if mixed with air at critical proportions and in the presence of an ignition source.

**Extinguishing Media:** Use water spray, dry chemical, carbon dioxide, or chemical foam.

**Flash Point:** Not applicable.

**Autoignition Temperature:** Not applicable.

**Explosion Limits, Lower:** Not available.

**Upper:** Not available.

**NFPA Rating:** (estimated) Health: 0; Flammability: 1; Instability: 0

## Section 6 - Accidental Release Measures

**General Information:** Use proper personal protective equipment as indicated in Section 8.

**Spills/Leaks:** Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation. Do not let this chemical enter the environment.

## Section 7 - Handling and Storage

**Handling:** Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Avoid ingestion and inhalation.

**Storage:** Store in a cool, dry place. Store in a tightly closed container.

## Section 8 - Exposure Controls, Personal Protection

**Engineering Controls:** Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

### Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Yeast, extract	none listed	none listed	none listed

**OSHA Vacated PELs:** Yeast, extract: No OSHA Vacated PELs are listed for this chemical.

### Personal Protective Equipment

**Eyes:** Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

**Skin:** Wear appropriate protective gloves to prevent skin exposure.

**Clothing:** Wear appropriate protective clothing to prevent skin exposure.

**Respirators:** Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

## Section 9 - Physical and Chemical Properties

**Physical State:** Solid

**Appearance:** yellow-white to yellow-orange

**Odor:** characteristic odor

**pH:** Not available.

**Vapor Pressure:** Not applicable.

**Vapor Density:** Not applicable.

**Evaporation Rate:**Not available.

**Viscosity:** Not applicable.

**Boiling Point:** Not available.

**Freezing/Melting Point:**Not available.

**Decomposition Temperature:**Not available.

**Solubility:** 20% in water.

**Specific Gravity/Density:**Not available.

**Molecular Formula:**Variable.

**Molecular Weight:**Not available.

## Section 10 - Stability and Reactivity

**Chemical Stability:** Stable under normal temperatures and pressures.

**Conditions to Avoid:** Incompatible materials, dust generation.

**Incompatibilities with Other Materials:** Strong oxidizing agents.

**Hazardous Decomposition Products:** Carbon monoxide, carbon dioxide.

**Hazardous Polymerization:** Has not been reported.

## Section 11 - Toxicological Information

**RTECS#:**

**CAS#** 8013-01-2: ZF6610000

**LD50/LC50:**

Not available.

**Carcinogenicity:**

CAS# 8013-01-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

**Epidemiology:** No information found

**Teratogenicity:** No information found

**Reproductive Effects:** No information found

**Mutagenicity:** No information found

**Neurotoxicity:** No information found

**Other Studies:**

## Section 12 - Ecological Information

**Ecotoxicity:** No data available. No information available.

**Environmental:** No information found.

**Physical:** No information found.

**Other:** Do not empty into drains.

## Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

**RCRA P-Series:** None listed.

**RCRA U-Series:** None listed.

## Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated.	Not regulated.
Hazard Class:		
UN Number:		
Packing Group:		

## Section 15 - Regulatory Information

### US FEDERAL

#### TSCA

CAS# 8013-01-2 is listed on the TSCA inventory.

#### Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

#### Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

#### Section 12b

None of the chemicals are listed under TSCA Section 12b.

#### TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

#### CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

#### SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

**Section 313** No chemicals are reportable under Section 313.

#### Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

#### Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

#### OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

#### STATE

CAS# 8013-01-2 is not present on state lists from CA, PA, MN, MA, FL, or NJ.

### California Prop 65

California No Significant Risk Level: None of the chemicals in this product are listed.

## **European/International Regulations**

### **European Labeling in Accordance with EC Directives**

#### **Hazard Symbols:**

Not available.

#### **Risk Phrases:**

#### **Safety Phrases:**

S 24/25 Avoid contact with skin and eyes.

#### **WGK (Water Danger/Protection)**

CAS# 8013-01-2: 0

#### **Canada - DSL/NDSL**

CAS# 8013-01-2 is listed on Canada's DSL List.

#### **Canada - WHMIS**

This product has a WHMIS classification of Not controlled..

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

#### **Canadian Ingredient Disclosure List**

## **Section 16 - Additional Information**

**MSDS Creation Date:** 7/16/1999

**Revision #6 Date:** 9/25/2007

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.*



## Material Safety Data Sheet

### Sodium bromide

MSDS# 21060

#### Section 1 - Chemical Product and Company Identification

MSDS Name: Sodium bromide

Catalog AC205130000, AC205130010, AC205130050, AC205131000, AC246900000, AC246900025

Numbers: AC246900025, AC246901000, AC246905000, S255-3, S255-500

Synonyms: Bromide salt of sodium.

Company Identification:

Fisher Scientific  
One Reagent Lane  
Fair Lawn, NJ 07410

For information in the US, call:

201-796-7100

Emergency Number US:

201-796-7100

CHEMTREC Phone Number, US:

800-424-9300

#### Section 2 - Composition, Information on Ingredients

-----  
CAS#: 7647-15-6  
Chemical Name: Sodium bromide  
%: >99  
EINECS#: 231-599-9  
-----

Hazard Symbols: None listed

Risk Phrases: None listed

#### Section 3 - Hazards Identification

##### EMERGENCY OVERVIEW

Caution! Hygroscopic (absorbs moisture from the air). Causes mild eye irritation. Target Organs: Central nervous system.

##### Potential Health Effects

Eye: Causes mild eye irritation.

Skin: May cause skin irritation. May be harmful if absorbed through the skin.

Ingestion: May cause irritation of the digestive tract. Symptoms may include: headache, excitement, fatigue, nausea, vomiting, stupor, and coma. May be harmful if swallowed.

Inhalation: Inhalation of high concentrations may cause central nervous system effects characterized by nausea, headache, dizziness, unconsciousness and coma. May cause respiratory tract irritation. May be harmful if inhaled.

Chronic: Chronic ingestion may cause central nervous system failure.

#### Section 4 - First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid immediately.

Skin: Get medical aid. Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.

Ingestion: Get medical aid immediately. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician: Treat symptomatically and supportively.

#### Section 5 - Fire Fighting Measures

As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH

General Information: (approved or equivalent), and full protective gear.

Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.

Autoignition Temperature: Not available

Flash Point: Not applicable.

Explosion Limits: N/A  
Lower:

Explosion Limits: N/A  
Upper:

NFPA Rating: health: 1; flammability: 1; instability: 1;

#### Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation.

#### Section 7 - Handling and Storage

Handling: Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Avoid ingestion and inhalation.

Storage: Store in a cool, dry place. Store in a tightly closed container. Store protected from moisture.

#### Section 8 - Exposure Controls, Personal Protection

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Sodium bromide	none listed	none listed	none listed

OSHA Vacated PELs: Sodium bromide: None listed

Engineering Controls:

Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

#### Section 9 - Physical and Chemical Properties

Physical State: Crystalline powder

Color: white

Odor: Not available

pH: 5-8.8 (5% aq soln)

Vapor Pressure: Not applicable.

Vapor Density: Not available

Evaporation Rate: Not applicable.

Viscosity: Not available

Boiling Point: 1390 deg C @ 760 mmHg ( 2,534.00°F)

Freezing/Melting Point: 755 deg C ( 1,391.00°F)

Decomposition Temperature:



Solubility in water: 95g/100 ml water (25°C)

Specific Gravity/Density: 3.208

Molecular Formula: BrNa

Molecular Weight: 102.89

#### Section 10 - Stability and Reactivity

Chemical Stability:	Hygroscopic: absorbs moisture or water from the air.
Conditions to Avoid:	Incompatible materials, dust generation, heating to decomposition, exposure to moist air or water.
Incompatibilities with Other Materials	Strong oxidizing agents, strong acids.
Hazardous Decomposition Products	Hydrogen bromide, sodium oxide, bromine fumes.
Hazardous Polymerization	Has not been reported.

#### Section 11 - Toxicological Information

RTECS#:	CAS# 7647-15-6: VZ3150000
	RTECS:
LD50/LC50:	<b>CAS# 7647-15-6:</b> Oral, mouse: LD50 = 7 gm/kg; Oral, rat: LD50 = 3500 mg/kg;
	.
Carcinogenicity:	Sodium bromide - Not listed as a carcinogen by ACGIH, IARC, NTP, or CA Prop 65.
Other:	See actual entry in RTECS for complete information.

#### Section 12 - Ecological Information

Ecotoxicity:	Fish: Bluegill/Sunfish: >1000 mg/L; 96 h; LC50 Daphnia: Daphnia: >1000 mg/L; 48 h; LC50
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#### Section 13 - Disposal Considerations

Dispose of in a manner consistent with federal, state, and local regulations.

#### Section 14 - Transport Information

US DOT

Shipping Name: Not regulated

Hazard Class:

UN Number:

Packing Group:

Canada TDG

Shipping Name: Not regulated as a hazardous material

Hazard Class:

UN Number:

Packing Group:

#### Section 15 - Regulatory Information

##### European/International Regulations

##### European Labeling in Accordance with EC Directives

Hazard Symbols: Not available

Risk Phrases:

Safety Phrases:

S 24/25 Avoid contact with skin and eyes.

##### WGK (Water Danger/Protection)

CAS# 7647-15-6: 1

##### Canada

CAS# 7647-15-6 is listed on Canada's DSL List

Canadian WHMIS Classifications: Not available

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

CAS# 7647-15-6 is listed on Canada's Ingredient Disclosure List

US Federal

TSCA

CAS# 7647-15-6 is listed on the TSCA  
Inventory.

Section 16 - Other Information

MSDS Creation Date: 12/12/1997

Revision #9 Date 7/20/2009

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential, or exemplary damages howsoever arising, even if the company has been advised of the possibility of such damages.

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# SAFETY DATA SHEET

## 1. CHEMICAL IDENTIFICATION AND COMPANY INFORMATION

**PRODUCT NAME:** KB-1<sup>®</sup> Primer  
**COMPANY INFO:** SiREM Laboratories  
130 Research Lane, Suite 2, Guelph, Ontario, Canada, N1G 5G3  
Phone: Toll Free, North America: 1-866-251-1747  
Main Line: 519-822-2265  
Fax: 519-822-3151  
[www.siremlab.com](http://www.siremlab.com)

**EMERGENCY PHONE NUMBER:** 519-515-0840 (for 24/7 assistance, contact poison center hotline in your jurisdiction)

**RECOMMENDED USE:** For preparation of anaerobic water for use in groundwater remediation

**RESTRICTIONS ON USE:** KB-1<sup>®</sup> products are intended for laboratory research and field applications for groundwater remediation. Products are not intended to be used as human or animal therapeutics, cosmetics, agricultural or pesticidal products, food additives, or as household chemicals.

## 2. HAZARDS IDENTIFICATION

### GHS Classification:

H302 - Acute toxicity, Oral (Category 4)

H319 - Eye irritant, (Category 2)

### GHS Label elements, including hazard and precautionary statements:



**Pictogram:**

**Signal Word:** Warning

### Hazard Statements:

H302 - Harmful if swallowed.

H315 - Causes skin irritation.

H319 - Causes serious eye irritation.

H335 - May cause respiratory irritation.

H402 - Harmful to aquatic life.

### Precautionary Statements:

P264 - Wash hands thoroughly after handling.

P270 - Do not eat, drink or smoke when using this product.

P273 - Avoid [unintended or indiscriminate] release to the environment.

P280 - Wear protective gloves/protective clothing/eye protection/face protection.

P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell.

P308 + P313 - If exposed or concerned: Get medical advice/attention.

P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses. Continue rinsing.

P337+P313 If eye irritation persists: Get medical advice/attention

P330 – Rinse mouth.

P501 – Dispose of contents/container in accordance with local/regional/national regulations.

HMIS Rating:	Health	Flammability	Physical Hazard	Personal Protection
	1	0	0	E*
NFPA Rating:	Health	Flammability	Reactivity	Special Hazard
	1	0	0	N/A

\* E = Safety Glasses, Gloves, Dust Respirator

### 3. COMPOSITION/INFORMATION ON INGREDIENTS

Amino Acid (proteinogenic):	50-70%, C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub> S
Potassium Bicarbonate:	25-50%, KHCO <sub>3</sub> , CAS No. 298-14-6
Sodium Sulfite:	5-20%, Na <sub>2</sub> O <sub>3</sub> S, CAS No. 7757-83-7

### 4. FIRST AID MEASURES

Route of Entry	Symptoms	First Aid Procedures
Ingestion	Irritation of digestive tract	DO NOT INDUCE VOMITING. Rinse mouth. Give plenty of water to drink, do not give active carbon. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin contact	Skin irritation– reddening, itching or inflammation.	Remove contaminated clothes. Wash skin with plenty of water and soap.
Eye contact	Eye irritation – redness, tearing, blurred vision.	Rinse immediately with plenty of water for 15 – 20 minutes, lifting lower and upper eyelids occasionally (remove contact lenses if easily possible) and seek medical advice.
Inhalation of dust	Respiratory irritation, coughing	Safely remove victim to fresh air. If not breathing, institute cardiopulmonary resuscitation (CPR). If breathing is difficult, ensure clear airway and give oxygen. Get medical attention.

### 5. FIRE FIGHTING MEASURES

Suitable extinguishing media:	Water in copious quantities, carbon dioxide, dry chemical powder, or appropriate foam. Use extinguishing media suitable for surrounding fire.
Special protective equipment and precautions for firefighters:	In the event of a fire, wear full protective clothing and NIOSH approved self-contained breathing apparatus. Evacuate the area and fight fire from a safe distance.
Hazardous combustion products:	May emit toxic fumes under fire conditions.
Toxic gases produced:	Carbon monoxide, carbon dioxide, nitrogen oxides, potassium oxides, sulfur oxides
Shock/impact sensitivity:	Not shock sensitive.

### 6. ACCIDENTAL RELEASE MEASURES

Ventilation:	If released in ventilated fume hood, ensure fume hood is on. If released in general room environment, open windows and provide adequate ventilation.
Eye/skin protection:	Have eye-washing facilities readily available where eye contact can occur. Wear chemical safety goggles. Use appropriate chemical protective gloves when handling. Showering and changing into street clothes after work is recommended.

Protective equipment for airborne dust:

A NIOSH/MSHA approved air purifying respirator is recommended where airborne concentrations are expected to exceed exposure limits. Protection provided by purifying respirators is limited. Wear suitable protective clothing and a self-contained breathing apparatus if available.

Method of containment and cleanup:

Wear suitable protective clothing. Avoid dust formation. Avoid breathing dust. Carefully sweep up and remove. Place material in a dry container and cover. Remove from the area. Flush spill area with water. Do not let products enter drains.

## 7. HANDLING AND STORAGE

Storage and handling precautions:

Store in a tightly sealed container in a cool, dry and well-ventilated place. Store away from direct light. Avoid generation of dust. Do not breathe dust. Wash thoroughly after handling. In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable protective clothing.

Incompatibilities:

Segregate from strong oxidizing agents, acids, bases.

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

OSHA Permissible Exposure Limits (PELs):

Not established

ACHIH Threshold Limit Values (TLVs):

Not established.

Engineering controls:

Generally not required under normal conditions of use. If method of use will result in significant dust generation, use in lab hood or under conditions of adequate ventilation.

Work practices:

Use good hygiene practices, avoid dust generation,

Personal protective equipment (PPE):

Under normal conditions of use, wear safety glasses and protective gloves. For laboratory use, wear lab coat. For higher risk of eye contact, wear safety goggles or face shield, as appropriate.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:

White to off-white powder or granules.

Odor:

Odorless

Solubility:

Soluble in water

pH:

6 – 8

Melting range

No data

Vapor density:

N/A

Vapor pressure:

N/A

Relative density:

2.4 to 2.6 g/cm<sup>3</sup>, depending on formulation

Evaporation rate:

N/A

Initial Boiling point, boiling range

N/A

Flammability

N/A

Partition coefficient	N/A
Auto-ignition temperature	N/A
Decomposition temperature:	No data, decomposes by heating.
Flash point	N/A
Flammable limits	N/A

## 10. STABILITY AND REACTIVITY

Reactivity:	Stable under normal conditions. Hygroscopic – absorbs moisture from air, affecting product quality. Possible decomposition at high temperatures.
Chemical stability	Stable under normal conditions.
Possibility of hazardous reactions:	Stable. Spontaneous hazardous chemical reactions/decomposition will not occur. Hygroscopic – absorbs moisture from air, affecting product quality. Reacts with acids, bases, oxidizing agents, chlorine trifluoride, magnesium, metals, carbon, calcium oxide.
Conditions to avoid:	Incompatibles, may be sensitive to light and moist air
Incompatible materials:	Strong oxidizing agents, bases
Hazardous decomposition products:	Carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, potassium oxides.
Shock sensitivity:	Not shock sensitive; will not decompose and form shock sensitive compounds.

## 10. TOXICOLOGICAL INFORMATION

*The toxicological properties of this product have not been thoroughly investigated.*

<i>The toxicological properties of this product have not been thoroughly investigated.</i>		Amino Acid	Potassium Bicarbonate	Sodium Sulfite
Toxicity:	LD50 (Oral-Rat)(mg/kg):	1890	2064	2610-3560
	LD50 (IV-Rat)(mg/kg):	1140	No data	No data
	LD50 (Oral-Mouse)(mg/kg):	660	No data	No data
	LC50 (Inhalation-Rat)(mg/m <sup>3</sup> )	No data	>4880	>5500
	LD50 (Dermal-Rat)(mg/kg)	No data	No data	>2000
Carcinogenicity:	NTP:	No component of this product is identified as a probable, possible or confirmed human carcinogen.		
	IARC:			
	OSHA Z List:			
	OSHA Reg:			
Teratogenicity:	Not established – the chemical structures of components do not suggest a specific alert for these effects.			
Mutagenicity:				
Reproductive:				
Respiratory or skin sensitization:	Not established			
Specific target organ toxicity:	Respiratory, skin, eye irritant, bladder, kidney			
Effects of overexposure:	Irritation, itching, gastrointestinal upset, respiratory discomfort, blurred vision.			
Medical conditions aggravated by exposure	Chronic lung conditions, dry eye			

Routes of entry:	Ingestion, inhalation of dust, skin and eye contact.
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## 12. ECOLOGICAL INFORMATION

Ecotoxicity:	Components of this product are not considered to exhibit significant ecological risks.
Persistence and degradability:	Amino acid is not persistent in the environment; will readily degrade in the environment via biodegradation. Sodium sulfite and potassium bicarbonate are inorganic products not subject to biodegradation, but will degrade via other chemical processes and are thus not persistent in the environment..
Bioaccumulative potential:	Significant accumulation in organisms is not expected.
Mobility in soil:	Soluble in water, high mobility in soil.

## 13. DISPOSAL CONSIDERATION

**Waste Disposal:** Dispose in accordance with all applicable federal, state, and local environmental regulations.

**Container Disposal:** Dispose in accordance with all applicable federal, state, and local environmental regulations.

## 12. TRANSPORT INFORMATION

Domestic (D.O.T.): Proper Shipping Name: CHEMICALS, N.O.S. (NON-REGULATED)  
Hazard Class: N/A  
UN/NA: N/A  
Labels: N/A

International: Proper Shipping Name: CHEMICALS, N.O.S. (NON-REGULATED)  
IMDG:  
Hazard Class: N/A  
UN/NA: N/A  
Labels: N/A

IATA: Proper Shipping Name: CHEMICALS, N.O.S. (NON-REGULATED)  
Hazard Class: N/A  
UN/NA: N/A  
Labels: N/A

## 15. REGULATORY INFORMATION

TSCA: Yes

SARA TITLE III:

Section 302 (EHS) Ingredients: No

Section 313 Ingredients: No

Section 304 (EHS/CERCLA) Ingredients: No

#### SARA TITLE III NOTIFICATION INFORMATION

Acute Health Hazard: No

Chronic Health Hazard: No

Fire Hazard: No

Sudden Release of Pressure Hazard: No

#### 16. OTHER INFORMATION

SiREM® provides the information contained herein for hazard communication and safety planning purposes, based on existing information on each of the product components available in the literature; no independent testing was conducted on the final product. The above information is intended to be used only as a guide to the appropriate precautionary handling of this material by a properly trained person.

Revision Date: November, 2014





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## **KB-1<sup>®</sup> Dechlorinator Material Safety Data Sheet**

### **Section 1: Material Identification**

**Trade Name:** KB-1<sup>®</sup> Dechlorinator

**Chemical Family:** bacterial mixture

**Chemical name:** No IUC name for mixture is known to exist

**Manufacturer/Supplier:** SiREM  
130 Research Lane, Suite 2,  
Guelph, Ontario,  
Canada N1G 5G3

**For Information call:** 519-822-2265 / 1-866-251-1747

**Emergency Number:** 519-822-2265

**Description:** Microbial inoculum (non-pathogenic, non-hazardous)

**Trade Name:** KB-1<sup>®</sup> Dechlorinator

**Product Use:** Bioremediation of contaminated groundwater.

**Date Prepared:** 2 February 2005

### **Section 2: Composition, Information on Ingredients**

KB-1<sup>®</sup> Dechlorinator is a microbial culture grown in an aqueous dilute mineral salt solution media containing no hazardous ingredients.

The microbial composition of KB-1<sup>®</sup> Dechlorinator (as determined by phylogenetic analysis) is listed in Table 1. Identification of organisms was obtained by matching 16S rRNA gene sequence of organisms in KB-1<sup>®</sup> Dechlorinator to other known organisms. The characteristics of related organisms can be used to identify potential or likely characteristics of organisms in KB-1<sup>®</sup> Dechlorinator.

***Table 1. Genus' identified in KB-1<sup>®</sup> Dechlorinator Microbial Inoculum***

<b>Genus</b>
<i>Dehalococcoides</i> sp.
<i>Geobacter</i> sp.
<i>Methanomethylovorans</i> sp.

### **Section 3: Hazards Identification:**

A review of the available data does not indicate any known health effects related to normal use of this product.

### **Section 4: First Aid Measures:**

Avoid direct contact with skin and eyes. In any case of any exposure which elicits a response, a physician should be consulted immediately.



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**Eye Contact:** Flush eyes with water for at least 15 minutes, occasionally lift upper and lower eyelids, if undue irritation or redness occurs seek medical attention.

**Skin Contact:** Remove contaminated clothing and wash skin thoroughly with water and antibacterial soap. Seek medical attention if irritation develops or open wounds are present.

**Ingestion:** Do not induce vomiting, drink several cups of water, seek medical attention.

**Inhalation:** Remove to fresh air. If not breathing give artificial respiration. In case of labored breathing give oxygen. Call a physician.

### **Section 5 - Fire Fighting Measures:**

Non-flammable

Flash Point: not applicable

Upper flammable limit: not applicable

Lower flammable limit: not applicable

### **Section 6 – Accidental Release Procedures**

Spilled KB-1<sup>®</sup> Dechlorinator should be soaked up with sorbant and saturated with a 10% bleach solution (prepared by making a one in ten dilution of diluted standard bleach [normally sold at a strength of 5.25% sodium hypochlorite] to disinfect affected surfaces. Sorbant should be double bagged and disposed of as indicated in section 12. After removal of sorbant, area should be washed with 10% bleach solution to disinfect. If liquid from the culture vessel is present on the fittings, non-designated tubing or exterior of the stainless steel pressure vessel liquid should be wiped off and the area washed with 10% bleach solution.

### **Section 7 - Handling and Storage**

KB-1<sup>®</sup> Dechlorinator is shipped in stainless steel pressure vessels and connected to injection lines and inert gas is used to pressurize the vessel to displace the contents. KB-1<sup>®</sup> Dechlorinator should be handled with care to avoid any spillage. Vessels are shipped with 1 pound per square inch (psi) pressure; valves should not be opened until connections to appropriate lines for subsurface injection are in place.

**Storage Requirements:** Avoid exposing stainless steel pressure vessels to undue temperature extremes (i.e., temperatures less than 0°C or greater than 30°C may result in harm to the microbial cultures and damage to the vessels). All valves should be in the closed position when the vessel is not pressurized to prevent the escape of gases and to maintain anaerobic conditions in the vessel. Avoid exposure of the culture to air as the presence of oxygen will kill dechlorinating microorganisms.

### **Section 8 - Exposure Controls/Personal Protection**

#### **Personal protective equipment:**

Skin: Protective gloves (latex, vinyl or nitrile) should be worn.

Eye Protection: Wear appropriate protective eyeglasses or goggles when opening pressure vessels valves or when pressurizing vessels to inject contents into the subsurface.

Respiratory: No respiratory protection is required.

Engineering Controls: Good general room ventilation is expected to be adequate.



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### **Section 9: Physical and Chemical Properties:**

Physical State: liquid  
 Odour: skunky odour  
 Appearance: dark grey, slightly turbid liquid under anaerobic conditions, pink if exposed to air (oxygen).  
 Specific gravity: not determined  
 Vapor pressure: not applicable  
 Vapor density: not applicable  
 Evaporation rate: not determined  
 Boiling point: ~100° C  
 Freezing point/melting point: ~ 0°C  
 pH: 6.5-7.5  
 Solubility: fully soluble in water

### **Section 10 – Stability and Reactivity Data**

Stable and non-reactive.  
 Maintain under anaerobic conditions to preserve product integrity.  
 Materials to avoid: none known

### **Section 11 - Toxicological Information**

Potential for Pathogenicity:

KB-1<sup>®</sup> Dechlorinator has tested negative (i.e., the organisms are not present) for a variety of pathogenic organisms listed in Table 2. While there is no evidence that virulent pathogenic organisms are present in KB-1<sup>®</sup> Dechlorinator, there is potential that certain organisms in KB-1<sup>®</sup> Dechlorinator may have the potential to act as opportunistic (mild) pathogens, particularly in individuals with open wounds and/or compromised immune systems. For this reason standard hygienic procedures such as hand washing after use should be observed.

**Table 2, Results of Human Pathogen Screening of KB-1<sup>®</sup> Dechlorinator**

<b>Organism</b>	<b>Disease(s) Caused</b>	<b>Test result</b>
<i>Salmonella</i> sp.	Typhoid fever, gastroenteritis	Not Detected
<i>Listeria monocytogenes</i>	Listeriosis	Not Detected
<i>Vibrio</i> sp.,	Cholera, gastroenteritis	Not Detected
<i>Campylobacter</i> sp.,	Bacterial diarrhea	Not Detected
<i>Clostridia</i> sp.,	Food poisoning, Botulism, tetanus, gas gangrene	Not Detected
<i>Bacillus anthracis</i>	Anthrax	Not Detected
<i>Pseudomonas aeruginosa</i>	Wound infection	Not Detected
<i>Yersinia</i> sp.,	Bubonic Plague, intestinal infection	Not Detected
Yeast and Mold	Candidiasis, Yeast infection etc.	Not Detected
Fecal coliforms	Indicator organisms for many human pathogens diarrhea, urinary tract infections	Not Detected
<i>Enterococci</i>	Various opportunistic infections	Not Detected



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### **Section 12. Disposal Considerations**

Material must be disinfected or sterilized prior to disposal. Consult local regulations prior to disposal.

### **Section 13 – Transport Information**

Non-hazardous, non-pathogenic microbial inoculum – Biosafety Risk Group 1.

Chemicals, Not Otherwise Indexed (NOI), Non-hazardous

Not subject to TDG or DOT guidelines.

### **Disclaimer:**

The information provided on the MSDS sheet is based on current data and represents our opinion based on the current standard of practice as to the proper use and handling of this product under normal, reasonably foreseeable conditions.

Last revised: 24 June 2008



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## Sandia National Laboratories, New Mexico Environmental Restoration Operations

### **Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern**

**September 2015 March 2016**



United States Department of Energy  
Sandia Field Office

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



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## LIST OF APPENDICES

### Appendix

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- B        Safety Data Sheets

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## ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
AOC	Area of Concern
AOPs	Administrative Operating Procedures
ARCH	Air-Rotary Casing-Hammer
bgs	below ground surface
CCM	Current Conceptual Model
cis-1,2-DCE	cis-1,2-dichloroethene
COC	constituent of concern
the Consent Order	the Compliance Order on Consent
CY	cubic yard
Dhc	<i>Dehalococcoides</i>
DO	dissolved oxygen
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FOPs	Field Operating Procedures
Fe(III)	ferric iron
ft	foot or feet
ft/day	feet per day
ft/year	feet per year
g/mL	grams per milliliter
gpd	gallons per day
gpm	gallons per minute
GWQB	Ground Water Quality Bureau
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HWB	Hazardous Waste Bureau
ISB	in-situ bioremediation
KAFB	Kirtland Air Force Base
L	liter
lb(s)	pound(s)
LWDS	Liquid Waste Disposal System
MCL	maximum contaminant level
mg/L	milligrams per liter
mV	millivolts
<u>NAD</u>	<u>North American Datum</u>
<u>NAVD</u>	<u>North American Vertical Datum</u>
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NNSA	National Nuclear Security Administration
NPN	nitrate plus nitrite
NTU	Nephelometric Turbidity Units
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
psi	pounds per square inch
PVC	polyvinyl chloride

## ACRONYMS AND ABBREVIATIONS (Concluded)

RCRA	Resource Conservation and Recovery Act
Sandia	Sandia Corporation
SC	specific conductivity
SDS	Safety Data Sheet
SNL/NM	Sandia National Laboratories, New Mexico
SOP	standard operating procedure
SWMU	Solid Waste Management Unit
TA	Technical Area
TAVG	Technical Area-V Groundwater
TCE	trichloroethene
TOC	total organic carbon
vcrA	vinyl chloride reductase
VOC	volatile organic compound
WMP	Waste Management Plan
yr	year



## EXECUTIVE SUMMARY

This Work Plan presents the approach for conducting a phased Treatability Study to evaluate the effectiveness of in-situ bioremediation (ISB) as a potential technology for remediation of groundwater contamination at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC) at Sandia National Laboratories, New Mexico (SNL/NM). Trichloroethene (TCE) and nitrate have been identified as the two constituents of concern (COCs) for the TAVG AOC.

Historical discharges of industrial wastewater and sanitary waste to drain field (Solid Waste Management Unit [SWMU 5]) and seepage pits (SWMU 275) between approximately 1962 and 1992 are considered the most likely sources of TCE and nitrate contamination at the site. Concentrations in groundwater are above the Maximum Contaminant Levels of 5 micrograms per liter ( $\mu\text{g/L}$ ) for TCE and 10 milligrams per liter ( $\text{mg/L}$ ) for nitrate, with the highest detected TCE and nitrate concentration in October/November 2014 being 16.9  $\mu\text{g/L}$  and 13.1  $\text{mg/L}$ , respectively.

The technical approach for this Treatability Study is to induce biodegradation of TCE and nitrate by gravity injecting a nutrient-amended substrate solution and a microbial bioaugmentation culture into groundwater at three locations of highest COC concentrations. The intent of this action is to reduce nitrate concentrations through denitrification followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids in the aquifer.

Up to three injection wells will be installed in the vicinity of the highest contaminant concentrations to facilitate effective and thorough delivery of substrate solution and bioaugmentation culture. In total, a substrate solution consisting of approximately 530,000 gallons of potable water mixed with approximately 4,700 pounds of ethyl lactate amended with nutrients and pH buffer will be injected into each injection well along with over 200 pounds of a dechlorinating microbial culture including *Dehalococcoides*. Each full-scale injection is estimated to take approximately six months. The estimated delivery area extends to a radius of 60 feet (ft) surrounding the injection well to a depth of approximately 25 ft below the static water level.

ISB performance will be monitored at the injection wells and at nearby groundwater monitoring wells. An inert tracer will be included with the injection stream to help evaluate delivery and the effect of dilution from the injected potable water. Because contaminant concentrations are initially very low, several lines of evidence will be evaluated to assess the effectiveness of ISB, including injection rate and volume, changes in dissolved oxygen and redox potential, evidence of sequential redox reactions, establishment of a dechlorinating microbial population, contaminant and tracer concentrations, and production of degradation daughter products.

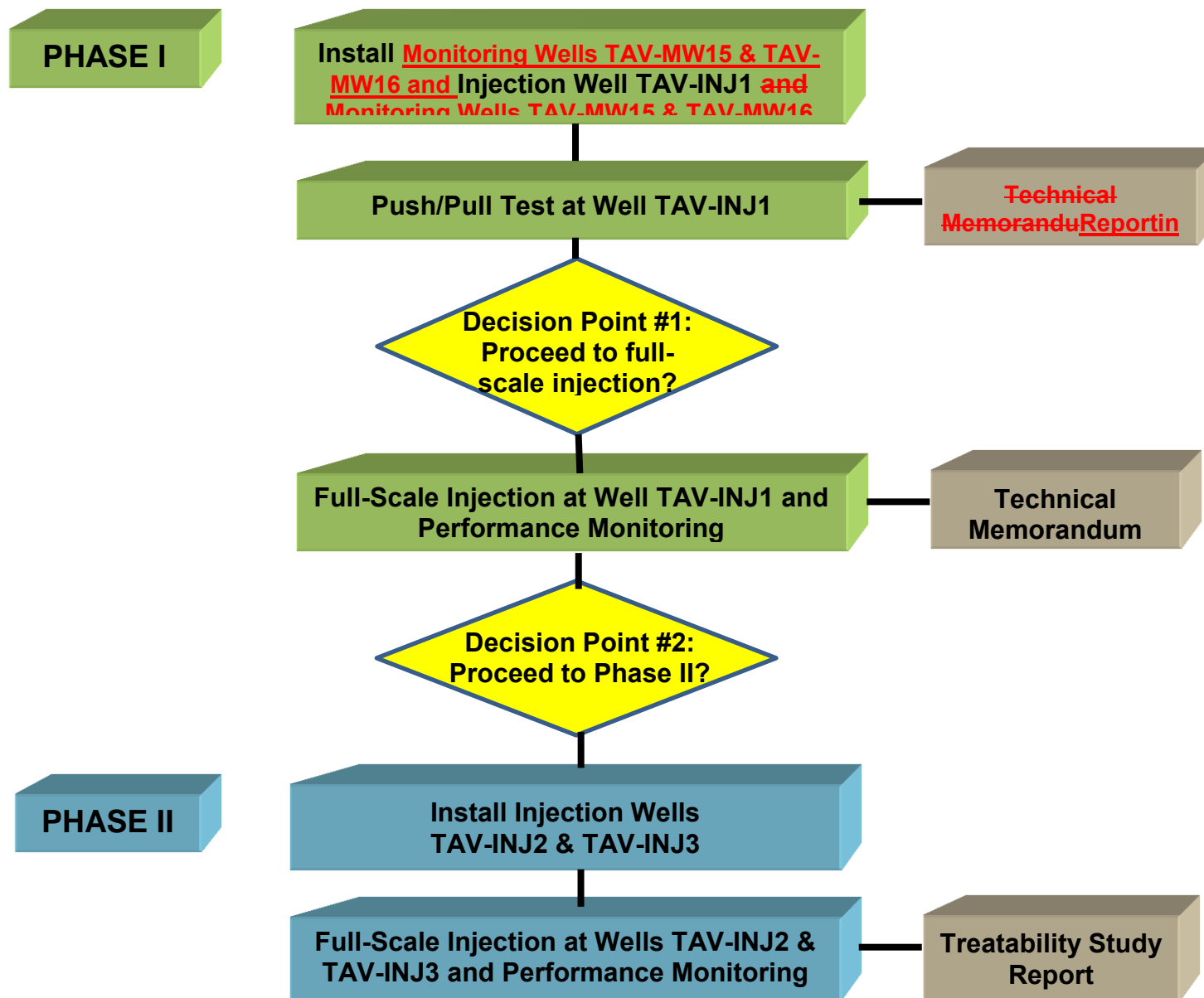
The overall sequence of Treatability Study work is described below, followed by a process flow diagram.

## Phase I

1. Installation of ~~injection well TAV-INJ1 near SWMU 5 and~~ groundwater monitoring wells TAV-MW15 and TAV-MW16 south of Technical Area-V, and injection well TAV-INJ1 near SWMU 5.
2. Proof of concept push/pull test by mixing a substrate solution using extracted groundwater and reinjecting it along with bioaugmentation culture to affect a 5-ft radius treatment area around well TAV-INJ1. Post-injection performance monitoring for four months.
- ~~2.3.~~ Submittal of push/pull test results and well installation report on TAV-MW15 and TAV-MW16 to New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB).
- ~~3.4.~~ Full-scale injection with substrate solution and bioaugmentation culture to affect a 60-ft radius treatment area around well TAV-INJ1. Post-injection performance and rebound monitoring for 24 months.
- ~~4.5.~~ Submittal of a Phase I Technical Memorandum to the ~~NMED HWB~~New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB), summarizing Phase I work.

## Phase II

1. Installation of injection wells TAV-INJ2 and TAV-INJ3 near SWMU 275 and monitoring well LWDS-MW1, respectively. Submittal of well installation report on TAV-INJ2 and TAV-INJ3 to NMED HWB.
2. Full-scale injection with substrate solution and bioaugmentation culture to affect 60-ft radius treatment areas around wells TAV-INJ2 and TAV-INJ3. Post-injection performance and rebound monitoring for 24 months.
3. Submittal of a Treatability Study Report to the NMED HWB, including recommendations for a path forward for TAVG AOC.



Technical Area-V Treatability Study Process Flow Diagram

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## 1.0 INTRODUCTION

Sandia National Laboratories, New Mexico (SNL/NM) is a government-owned, contractor-operated, multi-program facility overseen by the U.S. Department of Energy (DOE), National Nuclear Security Administration (NNSA) through the Sandia Field Office in Albuquerque, New Mexico. Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation, manages and operates SNL/NM under Contract No. DE AC04-94AL85000. SNL/NM is located on Kirtland Air Force Base (KAFB), in Albuquerque, New Mexico (Figure 1-1). Sandia personnel mostly operate in five technical areas (TAs) (TA-I, TA-II, TA-III, TA-IV, and TA-V) on KAFB.

The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) implements and enforces the Resource Conservation and Recovery Act hazardous waste regulatory program. In April 2004, a Compliance Order on Consent (the Consent Order) became effective between the NMED, DOE, and Sandia (NMED April 2004) to govern environmental investigation and corrective action requirements at SNL/NM.

The Consent Order specified TA-V as an area of groundwater contamination, and trichloroethene (TCE) and nitrate were identified as constituents of concern (COCs) requiring corrective measures based on detections above the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) in samples collected from monitoring wells. As specified in section VI.K.1 of the Consent Order, the EPA MCLs for drinking water contaminants, if available, should be used for groundwater cleanup levels. The EPA MCLs for TCE and nitrate are 5 micrograms per liter ( $\mu\text{g/L}$ ) and 10 milligrams per liter ( $\text{mg/L}$ ) (as nitrogen), respectively. Therefore, the HWB will enforce these MCLs for remediation. This is more stringent than the human health standard that the NMED Ground Water Quality Bureau (GWQB) has adopted for TCE in groundwater (0.1  $\text{mg/L}$  or 100  $\mu\text{g/L}$ ). The human health standard for nitrate in groundwater is also 10  $\text{mg/L}$  (as nitrogen).

This document presents a work plan for conducting a phased Treatability Study to evaluate the effectiveness of in-situ bioremediation (ISB) as a potential technology for remediation of the COCs at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC). The Current Conceptual Model (CCM) document (SNL/NM September 2015) provides detailed information on site history, hydrogeology, the nature and extent of contamination, and the fate and transport of contaminants in groundwater at TA-V.

### 1.1 Overview of the Treatability Study

The technical approach for this Treatability Study is to induce biodegradation of TCE and nitrate by gravity injecting a nutrient-amended substrate solution and a microbial bioaugmentation culture into groundwater at up to three locations of highest COC concentrations. The intent of this action is to reduce nitrate concentrations through denitrification followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids in the aquifer. Biodegradation will ultimately convert these contaminants into innocuous breakdown products.

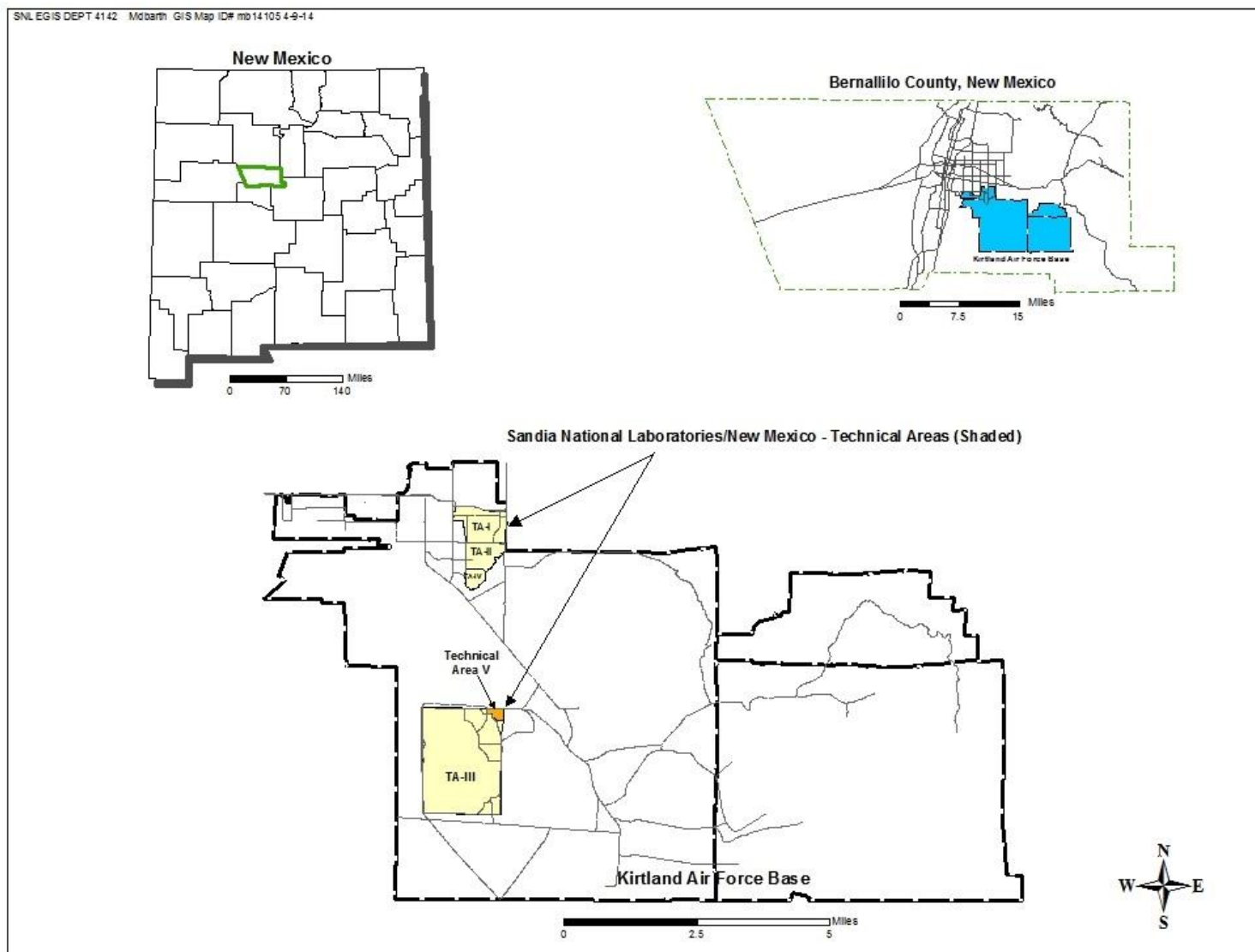


Figure 1-1  
Location of Sandia National Laboratories, New Mexico Technical Area-V

Treatability Study implementation will be conducted in two phases:

1. Phase I will be conducted at one injection location starting with a short-term push/pull test to evaluate proof of concept. Groundwater will be extracted from the injection well and mixed with a nutrient-amended substrate solution that will facilitate biostimulation and creation of an anaerobic and reducing environment in groundwater. An inert tracer will be added and this substrate solution will be reinjected into the well in parallel with a bioaugmentation culture. Subsequent sampling of the injection well and nearest groundwater monitoring wells will be conducted over a 4-month period to establish proof of concept. If the results of the push/pull test are favorable, a full-scale injection will be implemented ~~and monitored~~ over a 6-month period. After full-scale injection is completed, performance and rebound monitoring will be conducted for a 24-month period consisting of three monthly sampling events followed by quarterly sampling.
2. Phase II consists of implementing a full-scale injection at each of the two remaining locations of highest COC concentrations. Implementation design and procedures for each injection will incorporate lessons learned from previous activities. Performance and rebound monitoring will be conducted for 24 months following each of the two full-scale injections as described above for Phase I.

In addition to the Treatability Study performed in the center of TA-V, two additional groundwater monitoring wells will be installed to define the lateral extent of TCE to the south of TA-V.

## 1.2 Objectives of the Treatability Study

The specific objectives of the Treatability Study are to determine the following:

- Effectiveness of gravity injection as a delivery mechanism for substrate solution and bioaugmentation culture.
- Ability of the substrate solution to establish and maintain anaerobic groundwater conditions conducive to nitrate denitrification and reductive dechlorination (biostimulation).
- Magnitude and timeframe of COC concentrations reduction and rebound after ISB treatment.
- Effectiveness of the injected bioaugmentation culture (*Dehalococcoides* bacteria) to fully dechlorinate TCE and its daughter products.
- If measures are needed to mitigate the effect of metal (iron and manganese) and metalloid (arsenic) solubilization potentially caused by changes in oxidation reduction (redox) conditions.

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## **2.0 SUMMARY OF CONCEPTUAL SITE MODEL**

This section presents a summary of the conceptual site model for TA-V, focusing on the Treatability Study area. A schematic conceptual site model cross-section is presented in Figure 2-1. Detailed information on the regional geology and hydrogeology as well as the geology and hydrogeology of TA-V may be found in the CCM document (SNL/NM September 2015).

### **2.1 Site Conditions**

TA-V is located at the northeast corner of TA-III in the west-central portion of KAFB and occupies approximately 35 acres (Figure 1-1). Research operations at TA-V began in the 1960s. TA-V facilities are used to test radiation effects on various weapon and reactor components. Historical operations involved use of the Sandia Engineering Reactor Facility, the Sandia Pulsed Reactor, the High Energy Radiation Megavolt Electron Source, and the PROTO I Facility. Active facilities include the Annular Core Research Reactor, the Gamma Irradiation Facility, and the Auxiliary Hot Cell Facility.

The majority of the fenced area of TA-V is paved. There is no significant vegetation within the fenced area and no wetlands are present.

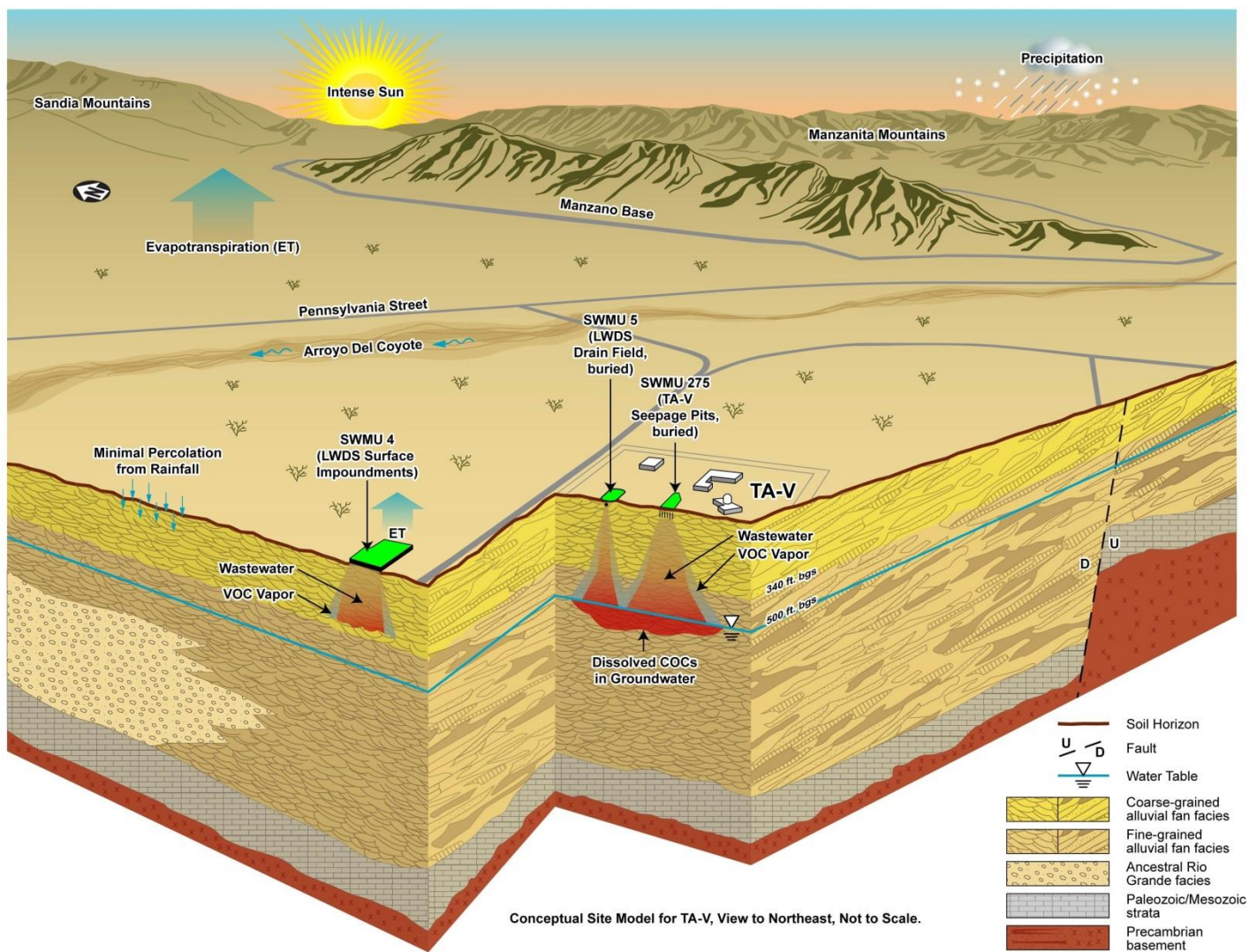
Currently, the land use at TA-V is industrial, with potential future construction and demolition activities. It is anticipated the area will remain industrial through continued use by SNL/NM and land use will not change in the foreseeable future.

### **2.2 Sources of Contamination**

The Liquid Waste Disposal System (LWDS) drain field (Solid Waste Management Unit [SWMU] 5) and the TA-V seepage pits (SWMU 275) are considered the most probable sources of TCE and nitrate contamination in the groundwater at TA-V based on the location of the historical releases with respect to contaminated groundwater. Discharges of wastewater and sanitary waste disposal began in approximately 1962 and were discontinued in 1992. The locations of these SWMUs are shown in Figures 2-1 and 2-2.

### **2.3 Vadose Zone**

The vadose zone at TA-V consists of a thin veneer of soil overlying approximately 500 feet (ft) of interbedded, heterogeneous alluvial-fan sediments that are mostly clay-rich sands deposited in anastomosing stream channels with predominantly east-west trends. Relatively coarse-grained sands extend from the ground surface to a depth of approximately 340 ft below ground surface (bgs). The underlying fine-grained sands extend to a depth exceeding 650 ft bgs (see Figure 2-1). Occasional discontinuous layers of gravel and clay are present in both sand units. No laterally continuous perching horizons have been identified in the vadose zone or saturated sediments.



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Figure 2-1  
Conceptual Site Model for Technical Area-V

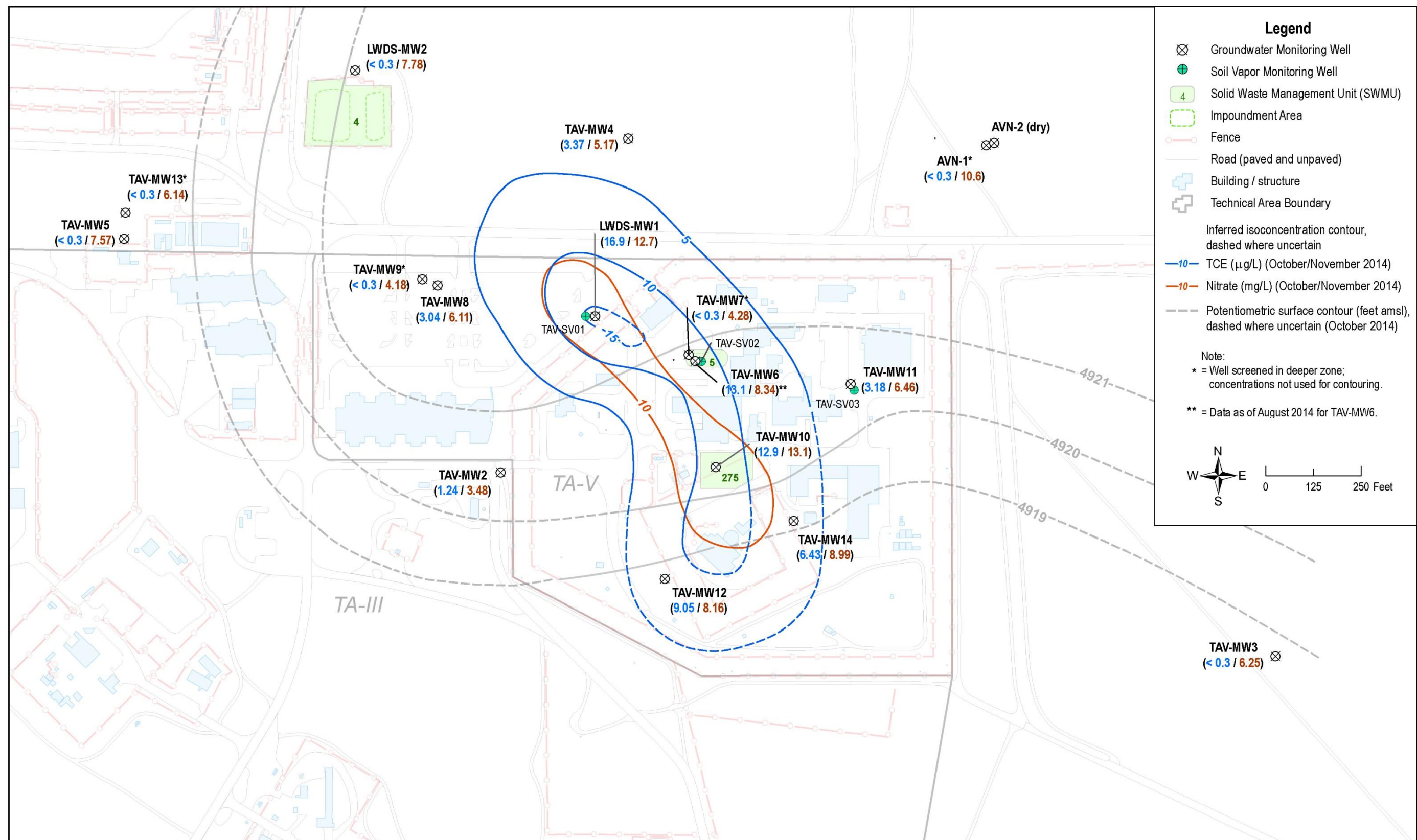


Figure 2-2  
Trichloroethene and Nitrate Distribution in Groundwater, October/November 2014





## 2.4 Groundwater Flow

Water levels measured in October 2014 in the current 16 monitoring wells were used to construct a map of the groundwater potentiometric surface at TA-V (Figure 2-2). The aquifer is under unconfined conditions. Groundwater flow beneath TA-V is generally to the west, with localized flow to the south and southwest. The horizontal [hydraulic](#) gradient at TA-V ranged from approximately 0.002 to 0.008.

The horizontal groundwater flow velocity at TA-V can be calculated from the range of horizontal hydraulic conductivities (0.04 to 30.8 feet per day [ft/day]), the average horizontal hydraulic gradient of 0.005, and an assumed effective porosity of 0.25. The estimates for groundwater flow velocity at TA-V range from 0.29 to 225 feet per year (ft/yr), although the local flow velocity in the Treatability Study area is estimated to be less than 30 ft/yr. The wide range of hydraulic conductivity estimates at TA-V are derived from monitoring well slug tests and attributed to the textural heterogeneities associated with the alluvial-fan lithofacies. Vertical hydraulic conductivity is typically estimated to be one to two orders of magnitude lower than the horizontal hydraulic conductivity.

Groundwater levels have steadily declined at all TA-V monitoring wells due to the pumping of the regional aquifer by the KAFB and the Albuquerque Bernalillo County Water Utility Authority. The rates of decline at TA-V range from 0.55 to 0.88 ft/yr with an average declining rate of 0.77 ft/yr. The decreases in water level elevations are expected to persist as long as pumping of water supply wells in the regional aquifer continues.

## 2.5 Nature and Extent of Contamination in Vadose Zone

No significant concentrations of TCE were found in soil vapor or soil samples collected during subsurface drilling investigations of the SWMUs at TA-V (SNL/NM January 2000 and October 2001).

Three soil-vapor monitoring wells (TAV-SV01, TAV-SV02, and TAV-SV03) were installed adjacent to groundwater monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW11, respectively (Figure 2-2), to a total depth of 500 ft bgs (close to the groundwater table). Volatile organic compound (VOC) concentrations in soil vapor were measured for eight quarters from April 2011 to March 2013. At each well, soil-vapor samples were collected from ten 1-foot long stainless steel screens set at intervals from 50 to 500 ft bgs and analyzed for VOCs. All eight quarters' analytical results were reported in Attachment 5D of the Calendar Year 2013 Annual Groundwater Monitoring Report (SNL/NM June 2014). TCE is the most prevalent VOC in the vadose zone. The soil-vapor results show that the TCE vapor concentrations have stabilized in the vadose zone at TA-V and the TCE in soil vapor is not considered a significant source to groundwater.

Nitrate occurs primarily in the dissolved phase. It typically does not exchange onto sediment surfaces and is not sorbed to sediments in the subsurface. Therefore, nitrate in excess of background concentrations was most likely transported through the vadose zone with the wastewater discharges.

## 2.6 Nature and Extent of Contamination in Groundwater

TCE has been consistently detected above the MCL of 5 µg/L in samples from a number of wells in the area. Figure 2-2 shows TCE isoconcentration contours in groundwater for the fourth quarter of calendar year 2014, except that the TCE concentration from the August sampling event is shown for TAV-MW6 (TCE was anomalously not detected in the fourth quarter).

While TCE has been detected in wells screened across the groundwater table, it has not been detected in wells screened approximately 90 ft deeper.

Figure 2-2 shows the 10 mg/L nitrate isoconcentration contour for the fourth quarter of calendar year 2014. The 10 mg/L nitrate contour is located within the 5 µg/L TCE contour. The general configuration of the 10 mg/L contour has not changed significantly over the past several years.

Nitrate has also been detected in groundwater monitoring wells upgradient of TA-V at concentrations exceeding the MCL, indicating a contribution of nitrate from other unidentified KAFB sources and/or locally elevated background conditions.

## 2.7 Contaminant Transport Mechanisms in Groundwater

Contaminant transport mechanisms in groundwater include advection, dispersion, diffusion, sorption, and biodegradation. Groundwater monitoring results over the past two decades indicate that advection is not the main force driving contamination migration at TA-V, likely due to the low groundwater flow velocities especially in the center of TA-V (i.e., the Treatability Study area). Dispersion and diffusion are the more important transport mechanisms at TA-V.

While nitrate does not tend to sorb to sediment surfaces, TCE is a hydrophobic organic compound and sorbs to the organic matter in the aquifer matrix. Sorption is a reversible process. As the dissolved contaminant concentration in groundwater decreases due to advection, dilution, or biodegradation, the sorbed TCE portion will tend to desorb and reenter the aqueous phase. The relatively stable TCE concentration in TA-V groundwater can be attributed to the relatively slow processes of dispersion, diffusion, and reversible sorption.

Biodegradation of TCE was evaluated during preparation of the 2005 CME Report (SNL/NM July 2005). The assessment indicated that anaerobic reductive dechlorination is not occurring in groundwater at TA-V, nor is biologically mediated transformation of nitrate. This is likely due to the relatively high concentration of dissolved oxygen (DO) and low concentration of dissolved organic carbon as carbon and energy sources. A study of denitrification parameters and isotopic signatures conducted in 2013 also indicated that natural denitrification was insignificant at TA-V (Madrid et al. June 2013).

### 3.0 TECHNICAL APPROACH OF IN-SITU BIOREMEDIATION

The Treatability Study uses a phased approach to increase the scale of ISB injections based on key data-driven decision points starting with a proof of concept push/pull test, followed by a full-scale injection at one location and if successful, full-scale injections at two other locations near the highest COC concentrations in groundwater. These decision points provide the opportunity to incrementally evaluate the degree of success and to optimize procedures and the use of resources.

An overview of the technical approach is described below.

An electron donor (ethyl lactate), nutrients, pH buffer, and an inert tracer (sodium bromide) will be mixed in aboveground tanks with extracted groundwater for the push/pull test and with potable water for the full-scale injections. KB-1<sup>®</sup> Primer (produced by SiREM, Guelph, Ontario, Canada) will be used in the first batch of solution to accelerate deoxygenation within the mixing tanks prior to parallel injection with the bioaugmentation culture. Subsequent batches will replace the KB-1<sup>®</sup> Primer with a mixture of ethyl lactate as the electron donor and diammonium phosphate and yeast extract as nutrients and pH buffer. This deoxygenated substrate solution and bioaugmentation culture will be delivered to the groundwater via injection wells.

To mitigate potential biofouling of the injection well during the full-scale injection periods, each daily injection of the substrate solution and bioaugmentation culture will be followed by injection of unamended potable water of sufficient volume to displace water in the static water column and surrounding filter pack. This unamended water will be deoxygenated with argon gas prior to injection.

Once the injection is completed, the effect of biostimulation and bioaugmentation within the treatment area is expected to be relatively rapid, on the order of months, thereby reducing overall contaminant mass and concentrations in groundwater. Performance monitoring will be conducted at nearby groundwater monitoring wells and compared to results from the injection well. Analyzing groundwater for concentrations of the inert tracer over time at both the injection well and monitoring wells will support evaluation of the size of the treatment area and the degree of dilution caused by the injected water.

Biodegradation is intended to initially reduce nitrate concentration through denitrification eventually followed by reductive dechlorination of TCE dissolved in groundwater and sorbed to solids within the aquifer.

Reductive dechlorination occurs through microbially mediated reactions whereby microorganisms obtain energy through redox reactions. Electron donors, such as ethyl lactate, are used by microbes to reduce various electron acceptors such as oxygen, nitrate, manganese (IV), ferric iron (Fe[III]), sulfate, and carbon dioxide to obtain energy. Bacteria obtain the greatest energy yield by using oxygen as the electron acceptor because it is highly oxidized and can therefore be easily reduced. During the first stages of the Treatability Study, biodegradation of the injected electron donor will deplete the aquifer of DO and other terminal electron acceptors and will lower the oxidation-reduction potential (ORP) of the groundwater. This produces conditions conducive to anaerobic degradation. When DO is depleted in an uncontaminated aquifer, bacteria sequentially use the less oxidized electron acceptors in the following order (ITRC June 2008):

- |                           |  |
|---------------------------|--|
| 1. Nitrate:               | Denitrification to molecular nitrogen.       |
| 2. Manganese (IV):        | Reduction to $\text{MnO}_2/\text{Mn}^{+2}$ . |
| 3. Ferric iron (Fe[III]): | Reduction to ferrous iron (Fe[II]).          |
| 4. Sulfate:               | Reduction to sulfide.                        |
| 5. Carbon dioxide:        | Methanogenic respiration.                    |

Chlorinated VOCs, such as TCE, can also be used as electron acceptors by specific microorganisms such as *Dehalococcoides* and thereby be degraded to innocuous end products. As less oxidized electron acceptors are utilized, the ORP is lowered to a point favorable for reductive dechlorination. Injection of the electron donor to groundwater overcomes terminal electron acceptor sinks (such as DO, nitrate, and sulfate) and creates sulfate-reducing and/or methanogenic conditions throughout the saturated zone. Either of these conditions will promote the transfer of electrons first to nitrate and then to chlorinated solvents, which will reduce their concentrations.

During reductive dechlorination, chlorine ions are successively replaced with hydrogen, degrading TCE to *cis*-1,2-dichloroethene (*cis*-1,2-DCE), followed by vinyl chloride, and finally to innocuous ethene and ethane. TCE can be reduced under ferric iron-reducing conditions (Chapelle, September 1996), *cis*-1,2-DCE under sulfate-reducing or methanogenic conditions (Chapelle, September 1996; Vogel et al., August 1987) and the degradation of vinyl chloride occurs under highly reducing methanogenic conditions (Ballapragada et al., 1997, Freedman and Gosset, 1989; Maymó-Gatell et al., July 1999; Vogel and McCarthy, May 1985). TCE dechlorination can begin to occur at an ORP of approximately 50 millivolts (mV), but a value closer to negative 100 mV is significantly more favorable as iron would be competing for electrons above this ORP value.

A primary objective of the Treatability Study is to create these reducing and methanogenic subsurface conditions to sustain a population of introduced and possible naturally occurring *Dehalococcoides* that will induce complete dechlorination of TCE to ethene. Aerobic conditions found at TA-V, are not favorable for establishing a population of *Dehalococcoides*. Additionally, concentrations of TCE are very low, and therefore may not facilitate rapid *Dehalococcoides* population growth after anaerobic reducing conditions are established. Fully dechlorinating TCE (while preventing a degradation stall at either *cis*-1,2-DCE or at vinyl chloride) at the site based solely on developing a potential native microbe population, would either take a very long time, or may not even occur. Therefore, the Treatability Study includes injecting a bioaugmentation culture (KB-1<sup>®</sup> Dechlorinator, produced by SIREM) along with the substrate solution to establish a robust *Dehalococcoides* population and thereby increase the rate and extent of anaerobic reductive dechlorination. KB-1<sup>®</sup> Dechlorinator includes specific strains of *Dehalococcoides* that possess the vinyl chloride reductase gene needed to fully dechlorinate TCE through vinyl chloride to ethene.

The process of developing strongly anaerobic redox conditions is likely to result in solubilization and mobilization of some naturally occurring oxidized metals and metalloids as a result of direct reduction and mineral dissolution, most particularly iron, manganese, and arsenic. However, the solubilization of these metals is generally a transient phenomenon and is limited to the treatment area. Solubilized metals and metalloids will precipitate into solid form once they leave the anaerobic treatment zone or after the aquifer returns to aerobic conditions in the treatment zone. Active management can be employed, such as direct injection of oxygen or other electron acceptors, but most sites do not require such actions (ITRC June 2008). This Treatability Study includes monitoring changes in iron, manganese, and arsenic concentrations before, during, and after injections are conducted to ascertain if active management of these



constituents will be necessary to return them to background concentrations after groundwater treatment is completed.

Quantifying the effects of denitrification and dechlorination relative to the effect of dilution caused by the substrate solution is complicated by the low initial concentrations of both COCs. Their respective daughter products (nitrite and nitrogen gas for nitrate and *cis*-1,2-DCE, vinyl chloride, and ethene for TCE) may not be produced at readily detectable concentrations. Conclusions about nitrate are further complicated by the fact that background concentrations will rebound with advection over time due to upgradient nitrate sources or possibly elevated background concentration. Therefore, several lines of evidence will be used to make conclusions about the degree of dilution versus denitrification and dechlorination including:

- Attenuation of inert tracer concentrations and any correlation to COC concentration trends,
- Temporary increases in iron, manganese, and arsenic concentrations, and
- Measurement of redox parameters, indicating a reducing environment.

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## 4.0 TREATABILITY STUDY DESIGN

The Treatability Study will be performed in two phases:

### Phase I: Installation of Injection Well TAV-INJ1 Followed by a Push/Pull Test and Full-Scale Injection

Injection well TAV-INJ1 will be installed near SWMU 5 with a screen extending approximately 25 ft below the water table. A small-scale proof of concept push/pull test will then be conducted by preparing a substrate solution using groundwater extracted from well TAV-INJ1 and reinjecting it along with the bioaugmentation culture to deliver a 5-ft radius treatment area. Post-injection performance monitoring will be conducted for 4 months.

Contingent on successful results from the push/pull test, Phase I will continue with full-scale injection using potable water for mixing and delivery of the substrate solution and bioaugmentation culture throughout a 60-ft radius treatment area. Post-injection performance monitoring will be conducted for 24 months.

### Phase II: Installation of Injection Wells TAV-INJ2 and TAV-INJ3 Followed by Successive Full-Scale Injections

Phase II expands the Treatability Study to two additional locations. The objectives of Phase II are the same as the full-scale injection conducted in Phase I with the added objectives of determining performance at locations with different hydraulic conductivities and whether injection(s) at these locations would be sufficient to meet cleanup standards site-wide within a reasonable timeframe. Post-injection performance monitoring will be conducted for 24 months.

The primary components of the Treatability Study design are:

- ISB treatment areas and injection volume.
- Substrate solution and bioaugmentation culture.
- Injection wells for substrate solution delivery.
- Additional groundwater monitoring wells.

## 4.1 ISB Treatment Area and Volume of Injection

Three areas with the highest COC concentrations are targeted for ISB treatment under this Treatability Study:

- Vicinity of SWMU 5.
- Vicinity of SWMU 275.
- Vicinity of monitoring well LWDS-MW1.

Due to the depth of groundwater (over 500 ft), direct-push drilling and injection technology used for shallow plumes is not feasible. Therefore, injections must be performed through injection wells screened within contaminated groundwater. ~~Injection well screens will extend~~

~~approximately 25 ft below the static water table to provide sufficient vertical distribution of the electron donor through the upper portion of the saturated zone. Well screens will extend no more than 10 ft above the static water table to allow for some distribution to the capillary fringe while promoting lateral distribution in the saturated zone.~~

The scope of this Treatability Study includes installing up to three injection wells (TAV-INJ1, TAV-INJ2, and TAV-INJ3) as shown in Figure 4-1. These well locations correspond to the three areas of highest COC concentrations.

Figure 4-2 shows the conceptual treatment area at each injection location. To eliminate a variable in the Treatability Study, the targeted delivery area was kept consistent for each injection location. A 60-ft delivery radius was selected because it covers an area approximately equal to the footprint of the largest release source, SWMU 275. This is a large enough area to provide evaluation of injection performance and, if successful, will eliminate the highest concentrations of COCs without being so large as to take an unreasonable length of time to perform and evaluate the injections.

The volume of substrate solution to be injected for the full-scale test at each of the three locations is based on replacing one pore volume of the aquifer within a radius of approximately 60 ft and a thickness of 25 ft below static water level centered around each injection well. Assuming an effective porosity of 25 percent, the total target volume of substrate solution to be injected per injection well is approximately 530,000 gallons, as shown in the calculation below. The actual areal extent of delivery is difficult to estimate due to preferential flowpaths and lithologic heterogeneities. Actual injected volume may be less if achievable injection rates preclude full injection within a reasonable time frame. Actual injected volume and measurements at monitoring wells near the injection wells will be incorporated into the assessment of radius of influence and delivery area.

#### Substrate Solution Volume Calculation (per injection well)

Delivery radius	60 ft
Area	11,310 square feet (ft <sup>2</sup> )
Thickness	25 ft
Total Volume	282,743 cubic feet (ft <sup>3</sup> )
Effective porosity	25 percent
Effective pore volume	
(target injection volume)	70,688 ft <sup>3</sup>
Effective pore volume	
(target injection volume)	<b>528,783 gallons (rounded to 530,000 gallons)</b>

The volume of the substrate solution components (see section 4.2.1) relative to the potable water is negligible and therefore not included in the total injected volume calculation.

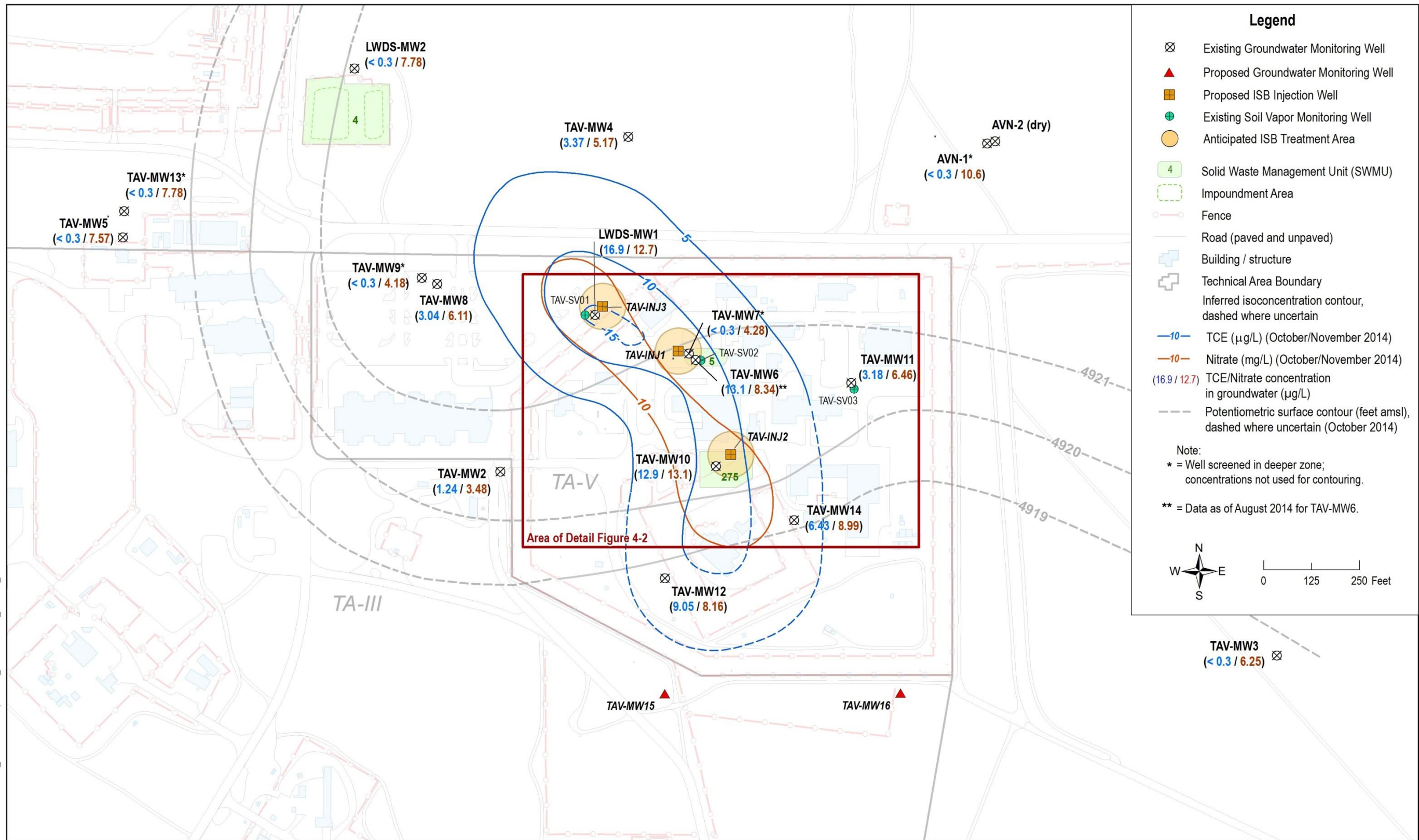


Figure 4-1  
 Proposed Injection Wells and Additional Groundwater Monitoring Wells





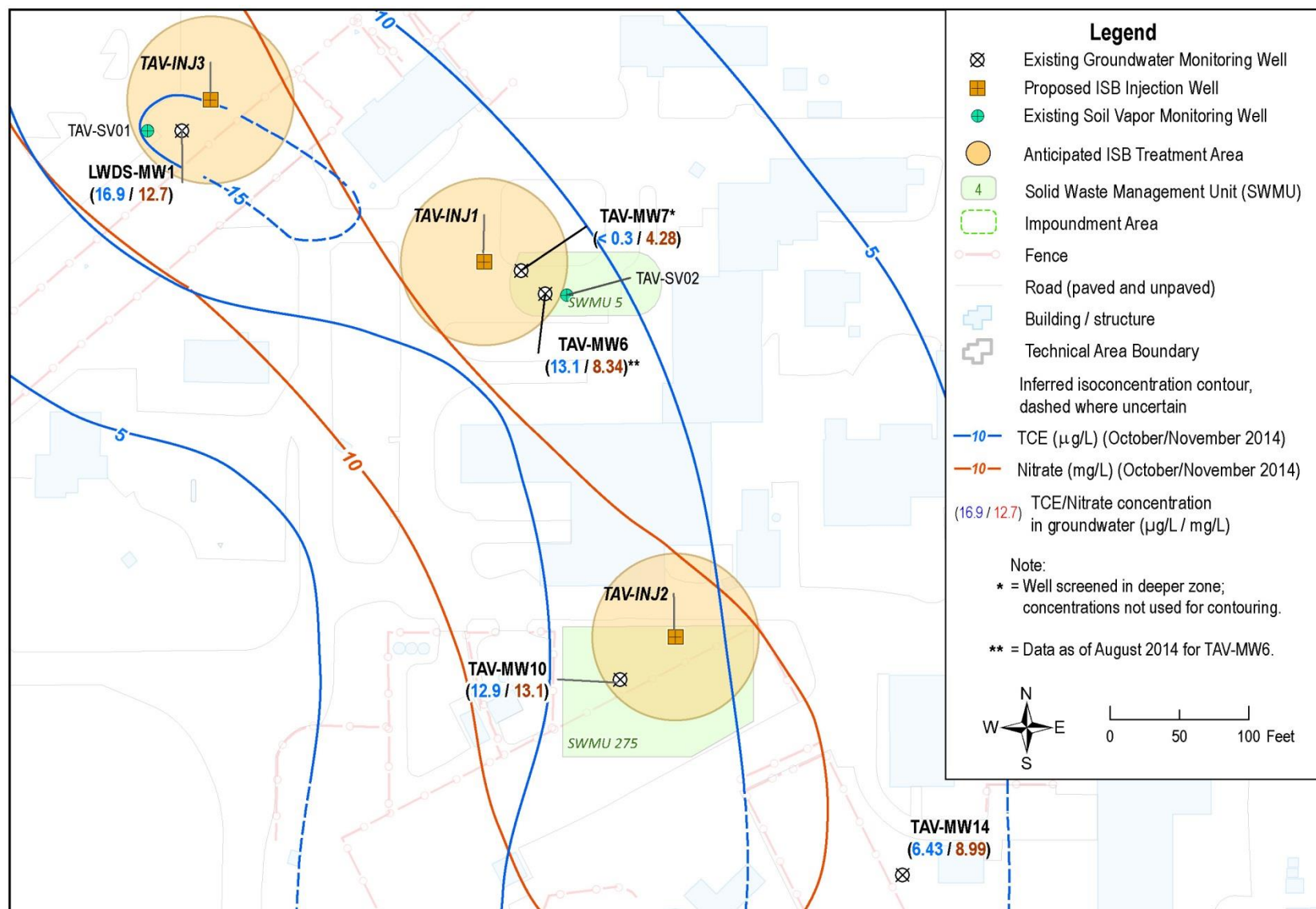


Figure 4-2  
Treatability Study In-Situ Bioremediation Treatment Areas

## 4.2 Substrate Solution and Bioaugmentation Culture

The injected substrate solution and bioaugmentation culture will include several components, each serving a specific purpose. The following section discusses each of these components and the dosage and mixing ratio.

### 4.2.1 Components of Substrate Solution

#### Electron Donor

Ethyl lactate has been selected as the electron donor or substrate for this Treatability Study. Ethyl lactate has high water solubility, a low retardation factor, low viscosity, and lacks particulates, all of which ensure a high degree of transportability within the treatment area. These physical and chemical properties are appropriate for conditions at TA-V.

Ethyl lactate has been shown to be very effective at stimulating microbial growth that produces conditions conducive to anaerobic degradation of contaminants. It also has other favorable properties compared to other electron donors (Jayaraj et al. 2004). It is fully utilizable by microbes, unlike substrates such as sodium lactate where the sodium is not utilized. Ethyl lactate yields the same hydrogen equivalent as dextrose (12:1) and is comprised of ester-linked carbons that break apart to form lactate and ethanol. The ethanol produced during dissolution acts as a co-solvent aiding in desorption of chlorinated solvents, such as TCE, from the aquifer matrix. The ethanol is also highly transportable, as is the lactate that is generated upon dissolution. Both of these components are then utilized by the bacteria, creating the desired anaerobic conditions.

Ethyl lactate is also very effective at reducing nitrate. During a recent pilot study at Lawrence Livermore National Laboratory (LLNL March 2014), ethyl lactate injection reduced nitrate concentrations to below reporting limits within 1-2 months.

From a practical standpoint, ethyl lactate is supplied in a liquid concentrate that will not spoil or freeze, providing a longer shelf life when compared with simple sugars such as glucose or dextrose. Because it is provided as a liquid, ethyl lactate can also be easily blended with other components in the tank prior to injection. To prevent oxidation, the ethyl lactate is supplied under a nitrogen or argon blanket. After opening the container, the product will be stored under inert conditions by purging the container head space with inert gas.

The Treatability Study is designed to deliver one pore volume (based on estimated effective porosity) of potable water mixed with a sufficient mass of electron donor to treat the contaminant mass within that treatment area. Appendix A shows the calculations for the total electron donor demand based on treatment area dimensions (radius and thickness), effective porosity, and concentration of terminal electron acceptors. These calculations use stoichiometric ratios of ethyl lactate (the electron donor) to electron acceptors including chlorinated VOCs to estimate the total electron donor demand.

The desired mass of electron donor to be delivered is determined by:

1. Estimating electron donor demand from the competing terminal electron acceptors.
2. Estimating electron donor demand from chlorinated VOC mass in groundwater.



3. Estimating electron donor demand from chlorinated VOC mass sorbed to the solid matrix within the aquifer.
4. Totalling the above three subsets.
5. Applying utilization and safety factors (described below).

Observations from numerous site implementations across the United States show that the theoretical stoichiometric value is often not sufficient to create the desired conditions at a site. Research (Lee et al. March 2004) shows that only 30 percent of the electron donor is utilized for dechlorination (referred to as the 'McCarty' factor). The McCarty factor was applied to calculate the electron donor demand based on stoichiometry. A safety factor of 10 was then applied based on full-scale field experience and to account for low hydraulic conductivity of the saturated sediments at TA-V.

The final calculated total mass of ethyl lactate to be injected during each full-scale test is 4,690 pounds (lbs) per injection well. Ethyl lactate is supplied as a liquid and has an approximate density of 1.03 grams per milliliter (g/mL) (8.60 lbs/gallon). Therefore, approximately a total of 545 gallons of ethyl lactate will be used to mix with the 530,000 gallons of potable water to be injected at each well. This is approximately equivalent to a 0.10 percent ethyl lactate solution.

### Nutrients

Diammonium phosphate and yeast extract will be added as nutrients to support microbial growth. They will be blended ~~at a ratio~~ with the ethyl lactate at a weight ratio of approximately 80 percent ethyl lactate, 17 percent diammonium phosphate, and 3 percent yeast extract. This will provide a solution that is very similar to that used at wastewater treatment plants where for every 100 parts of carbon, 10 parts of nitrogen and 1 part of phosphorus are required for bacterial growth (Metcalf and Eddy 1991). Without the addition of these nutrients, bacteria will enter nutrient-limited kinetic rates that are much more ineffective at reducing contaminant concentrations. The nitrogen and phosphorus will be mixed with the ethyl lactate before being injected into the subsurface to facilitate utilization by bacteria.

Ammonia and phosphate concentrations will rise as the solution is injected to the saturated zone. However, once the bacteria begin to grow on the substrate, they will rapidly utilize the nitrogen and phosphorus, reducing the ammonia and phosphate concentration to background concentrations. The nitrogen and phosphorus are converted to microorganism biomass, and will not be a concern for downgradient migration.

### pH Buffer

It is important to maintain a relatively neutral pH in the aquifer to support a robust microbial community that can fully dechlorinate TCE to ethene. Therefore, addition of a pH buffer is included to offset pH reduction that can occur as a result of volatile fatty acid production during fermentation of the electron donor. The diammonium phosphate added as a nutrient will also serve as the pH buffer; thereby eliminating the need for an additional component specific to buffering. *Dehalococcoides* optimally dechlorinates in a pH range between 6.9 and 7.5 (Löffler et al. April 2012), although keeping the pH between 6.0 and 8.5 is common practice for

bioremediation. Maintaining a neutral pH also mitigates the degree of metals and metalloid solubilization.

### Tracer

Sodium bromide will be used as an inert tracer added to the substrate solution during the initial push/pull test and in subsequent full-scale injections. In the push/pull test where native groundwater will be extracted, amended, and re-injected, the bromide tracer concentration will be monitored over time after injection to normalize sampling data to account for surrounding groundwater flowing into the re-injected area. Under full-scale injections, where potable water is used to deliver the substrate solution and bioaugmentation culture, bromide concentration data will be used to evaluate the degree of initial dilution caused at the injection location, the rate at which this dilution effect attenuates as a result of mixing with the surrounding groundwater, and delivery of the injected solution to the nearby monitoring well(s).

Background bromide concentrations in groundwater at TA-V are less than 1 mg/L. Assuming that the hydraulic conductivity at each injection well is comparable to that measured in nearby monitoring wells, a bromide concentration of approximately 20 mg/L would be a suitable tracer concentration. This translates to approximately 0.2 lbs of sodium bromide per 1,000 gallons of injected potable water. If significantly higher hydraulic conductivity is encountered at the injection well, the bromide concentration can be increased to as much as 200 mg/L to counter dilution effects from local groundwater advection.

### Component Mixing

The substrate and other components will be mixed in aboveground tanks with water (extracted groundwater for the push/pull test and potable water for the full-scale injections). Table 4-1 ~~below~~ lists the components of the substrate solution, their respective roles, and mixing ratio. The estimated amount of sodium bromide tracer is also shown. The final mixing ratios may vary based on data acquired from injection well sampling. The Safety Data Sheet (SDS) for each component is included in Appendix B.

Each batch of mixed solution will be deoxygenated in the tank prior to gravity injection into the well to protect the anaerobic bioaugmentation culture that will be co-injected with the substrate solution. KB-1<sup>®</sup> Primer (slurry) will initially be used to accelerate the conversion from aerobic to anaerobic in the tank, typically within a few hours. Subsequent batches will rely on the ethyl lactate substrate to develop anaerobic conditions.

#### 4.2.2 KB-1<sup>®</sup> Primer

KB-1<sup>®</sup> Primer is a proprietary mixture of amino acids, potassium bicarbonate, and sodium sulfite that is used to accelerate deoxygenation of water inorganically (sodium sulfite) while still providing an electron donor (amino acids) and buffer (potassium bicarbonate). It can therefore be used as a substitute for ethyl lactate, diammonium phosphate, and yeast extract, although it is significantly more costly and therefore, not suitable for the large volumes planned under full-scale injection.

Table 4-1  
Substrate Solution Components

Substrate Solution Component	Function	Mixing Ratio (by weight)	Weight per 1,000 gal Water
<b>Primary Components</b>			
Ethyl lactate	Electron donor (substrate)	80%	8.9 lbs (1.0 gal)
Diammonium phosphate	Nutrient and pH buffer	17%	1.9 lbs
Yeast extract	Nutrient	3%	0.3 lbs
<b>Primary components per 1,000 gal potable water</b>		<b>100%</b>	<b>11.1 lbs</b>
<b>Additional Component Mixed with Substrate Solution</b>			
Sodium bromide	Inert tracer (as bromide)	Not applicable; adjusted per field condition	0.2 lbs
<b>Initial batch of Substrate Solution (to accelerate deoxygenation)</b>			
KB-1 <sup>®</sup> Primer <sup>a</sup>	Substitute for ethyl lactate, diammonium phosphate, and yeast extract to accelerate deoxygenation in push/pull test and initial full-scale injection batches	100%	7.1 lbs

<sup>a</sup> KB-1<sup>®</sup> Primer is a product manufactured and supplied by SiREM, Guelph, Ontario, Canada.

% = Percent.

gal = Gallon(s).

lbs = Pounds.

The groundwater extracted for ~~the~~ push/pull test will be stored in approximately equal proportions in two tanks. One tank will be inoculated with a small amount of soil core/cuttings from the injection well screened interval and have KB-1<sup>®</sup> Primer added. The purposes of adding soil core/cuttings to the substrate solution are to (1) inoculate the solution with native microorganisms, (2) create a diverse microbial community that will more likely work synergistically with the bioaugmentation culture, and (3) reduce the lag time for initiating biostimulation associated with utilization of the substrate in the subsurface. If sufficient core/cuttings are not recovered during drilling, a commercial lyophilized bacterial septic tank amendment (e.g., Rid-X<sup>®</sup> Septic System Treatment or equivalent) may be substituted at a mass/volume based on manufacturer recommendations.

As water in the first tank turns anaerobic, water from the second tank will be transferred into the first tank and mixed with proportional amounts of the substrate solution components, as outlined in ~~s~~Section 4.2.1. Although addition of groundwater from the second tank is likely to increase the DO and ORP initially, the combined water volume is expected to return to sufficiently decreased DO and ORP within one to two days and ready for gravity injection back into the well as one batch.

A similar process will be applied to the full-scale injections. Two pairs of tanks will be used for full-scale injection (see section 4.3.2). ~~The first~~Both pairs of tanks will be filled halfway with potable water, inoculated, and have KB-1<sup>®</sup> Primer added. After turning anaerobic, the tanks ~~s~~ will be filled with potable water and mixed with proportional amounts of the substrate solution components. As with the push/pull test, deoxygenation of the entire tank volume is expected within one to two days. Once anaerobic conditions are restored, half of the tank contents (from each pair) will be injected. ~~The~~This pair of tanks will then be refilled with potable water and mixed with proportional amounts of the substrate solution components. Provided that

approximately half a tank of the deoxygenated solution remains in ~~the each~~ tank, this accelerated deoxygenation schedule is expected to continue without further use of KB-1<sup>®</sup> Primer during the remainder of the injection period. ~~A second deoxygenating tank will be prepared concurrently.~~ By alternating two pair of tanks, injection would not be interrupted while waiting for the substrate solution to turn anaerobic.

Approximately 7.1 lbs of KB-1<sup>®</sup> Primer is needed per 1,000 gallons of water based on manufacturer recommendations.

#### 4.2.3 KB-1<sup>®</sup> Dechlorinator

To expedite growth of a microbial population capable of fully dechlorinating TCE to ethene, a bioaugmentation culture, KB-1<sup>®</sup> Dechlorinator, will be injected in conjunction with the substrate solution. KB-1<sup>®</sup> Dechlorinator is a naturally occurring, non-hazardous, non-pathogenic, microbial culture that contains a consortium of anaerobic microorganisms that promote dechlorination of chlorinated solvents. It includes *Dehalococcoides* that has a strain possessing the gene capable of producing enzymes that reduce vinyl chloride to non-toxic ethene (vinyl chloride reductase).

*Dehalococcoides* can be found naturally in the environment. However, ~~these~~ bacteria ~~are~~ not ubiquitous, and an aerobic environment, such as that present at TA-V, is not favorable for establishing a population. With concentrations of TCE being very low at the site, development of a robust *Dehalococcoides* population without bioaugmentation either may not be possible or would require a very long time if relying solely on an indigenous population.

Typical dosing of KB-1<sup>®</sup> Dechlorinator for sites with TCE concentrations one or more orders of magnitude higher than that present at TA-V is approximately 0.24 lbs KB-1<sup>®</sup> Dechlorinator per 1,000 gallons of water. The low concentrations of TCE at TA-V would result in a slower microbial population growth rate. Therefore, the KB-1<sup>®</sup> Dechlorinator dosing will be doubled to 0.5 lbs KB-1<sup>®</sup> Dechlorinator per 1,000 gallons of water to facilitate population development within a reasonable timeframe.

To effectively deliver the KB-1<sup>®</sup> Dechlorinator to the treatment area, it will be injected simultaneously with the substrate solution. Waiting to deliver the bioaugmentation culture until after the initial injection of substrate solution alone would require additional injection volumes to reach the same treatment area and would have to be delayed long enough to ensure the groundwater had been deoxygenated.

KB-1<sup>®</sup> Dechlorinator is a liquid and is shipped by the supplier to the site in stainless steel containers. KB-1<sup>®</sup> Dechlorinator has a shelf life of approximately two weeks, so shipments will be sized and delivered as needed to match the pace of injections without compromising the product shelf life.

KB-1<sup>®</sup> Dechlorinator injection will be performed in accordance with the supplier's ~~standard operating~~ procedure and be mixed in-line with the substrate solution via a connection placed between the substrate solution mixing tank and the wellhead. The KB-1<sup>®</sup> Dechlorinator is purged from its vessel into the aboveground injection line with inert gas (argon) under sufficient pressure to ensure proper mixing with the substrate solution injection stream.

Concentrations of solubilized metals and metalloids and the pH in groundwater will also be evaluated prior to adding *Dehalococcoides* to determine if adjustments in buffering amendment are required over the course of the full-scale injection period.

## 4.3 Injection Locations and Injection Rate

### 4.3.1 Location of Injection Wells

Injection well locations are shown in Figure 4-2. Each injection well will be paired with an existing groundwater monitoring well and installed at a distance so that evidence of substrate delivery can be observed within the 24-week active injection period. The detailed derivation of the 24-week active injection period is presented in Appendix A. Placing the injection wells in slightly closer proximity to the monitoring wells accelerates the data collection timeframe and helps offset uncertainties regarding subsurface heterogeneity. However, ~~the~~ the injection well cannot be placed too close to the existing monitoring well because well construction might damage the existing monitoring well due to gradual deviation of the drill stem during drilling or due to inaccurate/undesirable placement of grout in the borehole annulus during well construction. Well pairings are as follows:

- TAV-INJ1 is paired with monitoring well TAV-MW6 and deeper monitoring well TAV-MW7.
- TAV-INJ2 is paired with monitoring well TAV-MW10.
- TAV-INJ3 is paired with monitoring well LWDS-MW1.

~~Each injection well screened interval will be designed based on encountered lithology, but in general, will be screened from 5-10 ft above the water table to approximately 25 ft below the water table.~~

Modeling of substrate solution injection using MODFLOW 2000 was used to guide the location of injection wells with respect to existing monitoring well locations. Each injection well is located at a distance from its paired monitoring well that modeling indicates the substrate solution will travel during the 24-week active injection period. Delivery will continue for several weeks after active injection ceases as the residual mound dissipates, returning water levels to pre-injection elevations. ~~Therefore, injection wells will be placed inside the final estimated delivery radius of 60 ft. Placing the injection wells in slightly closer proximity to the monitoring wells accelerates the data collection timeframe and helps offset uncertainties regarding subsurface heterogeneity.~~

Modeling, using the anticipated injection rate and hydraulic conductivity, indicates that substrate solution injected into TAV-INJ1 and TAV-INJ2 would travel approximately 50 ft during the 24-week active injection period and approximately 10 ft farther as the residual mound dissipates. Therefore, these two wells will be installed at approximately 50 ft from the paired monitoring wells (TAV-MW6 and TAV-MW10, respectively). Modeling of injection at TAV-INJ3, where hydraulic conductivity is expected to be much lower, results in placing the well approximately 30 ft away from monitoring well LWDS-MW1. Delivery to the remaining 30 ft of the treatment area radius would be achieved as the residual mound dissipates.

Injection wells will be installed upgradient of their respective monitoring wells to the degree logistically possible. Prior to drilling, available engineering drawings will be reviewed, a utility location survey will be performed, and facility and security operations management will be involved throughout project planning activities. Figure 4-2 takes into account known access limitations, but final well locations will be determined in the field and modified as needed due to proximity to buildings, fencing, secured nuclear facility buffer zones, underground utilities, and other obstructions. If an appropriate upgradient location is not accessible, an alternative

location proximal to the paired monitoring well(s) will be selected. The groundwater gradient is relatively low (averaging approximately 0.005) throughout TA-V and will be overwhelmed by the temporary mounding effect induced during injection. Therefore, the relative lateral proximity to the neighboring monitoring well is more important than orientation with respect to the hydraulic gradient.

#### 4.3.2 Injection Rate

The target injection rate is approximately 5,000 gallons per 8-hour work day (i.e., approximately 10.4 gallons per minute [gpm]). The achievable injection rate is controlled by two factors: (1) the time required to deoxygenate each batch of substrate solution prior to injection, and (2) controlling the pressure exerted by the height of the substrate solution column within the well during injection to prevent damage to the well casing and well screen.

##### Deoxygenation of Substrate Solution

~~An accelerated schedule of one to two days will be needed per injection batch to deoxygenate the substrate solution before injection. Therefore, two 10,000-gallon tanks will be used, alternating injection of 5,000-gallon batches from each tank. Two pairs of 5,000-gallon tanks will be used for substrate solution mixing and deoxygenation.~~ After the initial total of 10,000 gallons of substrate solution ~~in a tank (in two tanks)~~ are mixed and deoxygenated, 5,000 gallons ~~(2,500 gallons from each tank)~~ will be gravity-injected along with ~~the~~ bioaugmentation culture ~~(KB-1® Dechlorinator)~~ into the injection well, leaving ~~5,000~~2,500 gallons of deoxygenated solution in ~~the~~ each tank. This remaining volume will facilitate the accelerated deoxygenation of ~~the~~ refilled water ~~(5,000~~2,500 gallons ~~for each tank)~~ after mixing with commensurate substrate solution components. ~~It is anticipated that the entire tank volume will turn anaerobic in one to two days. Two pairs of 5,000-gallon tanks will be used, alternating injection of 5,000-gallon batch while waiting for the other 5,000-gallon batch to be deoxygenated.~~ At this rate, and allowing time to optimize injection procedures, it will take approximately 24 weeks at each injection well to inject the total target volume of 530,000 gallons substrate solution.

If deoxygenation takes longer than anticipated, procedures may be modified based on site conditions and implementation feasibility. Modifications may include, but are not limited to adding inorganic constituents in the tanks to help scavenge oxygen and accelerate the process, sparging the solution with argon gas, modifying injection schedules, and modifying total injection volumes.

##### Controlling Internal Pressure in the Injection Wells

~~The planned injection well design detailed in section 5.2.5 consists of two equally deep, nested polyvinyl chloride (PVC) well casings installed in a single borehole. A 1.5-inch nominal diameter injection casing will be connected to the mixing tanks and used to convey the substrate solution and bioaugmentation culture to the subsurface. A 5-inch nominal diameter monitoring casing will be used for groundwater sample collection and field parameter measurements.~~ During the injection process the height of the fluid column in the monitoring casing well will rise. Controlling the height of the substrate solution column in the well casing during injection is necessary to prevent bursting of the well casing or well screen. The manufacturer's specification for bursting strength of the ~~type of well construction materials to be used~~5-inch diameter casing is



145 pounds per square inch (psi). This pressure would be generated by a water column of approximately 335 ft above the static water level. The elevation of the substrate solution in the injection wells monitoring casing will be monitored during injection to ensure the internal pressure does not exceed this height.

The bursting strength of the 1.5-inch diameter casing is 235 psi, which corresponds to a water column of approximately 545 ft. This is above the ground surface and the height of the connected mixing tanks. Therefore, there is no concern with respect to casing integrity of the injection casing during gravity injection.

Additionally, ~~the numerical modeling package~~ MODFLOW 2000 was used to estimate the injection rate (and resulting water column height) that could be maintained without the internal ~~well~~ pressure exceeding the bursting pressure of the ~~well~~ casing. Of the three injection well locations, the hydraulic conductivity is lowest in the vicinity of well TAV-INJ3, ~~and therefore,~~ for a given injection rate the height of the column in this well ~~would~~ should be greater than at the other two locations where hydraulic conductivities are higher. The modeling estimates a maximum safe constant injection rate of approximately 15 gpm in well TAV-INJ3, which would result in approximately 7,200 gallons of substrate solution being delivered per 8-hour working day. This is over 40% ~~percent~~ greater than the target delivery rate of 5,000 gallons per day (gpd). Additionally, the manufacturer's specification for casing bursting strength incorporates a 50% ~~percent~~ safety factor. Therefore, damage due to excessive pressure in injection well TAV-INJ3 should not be of concern.

The estimated hydraulic conductivity at the proposed locations of TAV-INJ1 and TAV-INJ2 is much higher than in the TAV-INJ3 area. Thus, the expected height of the water column in these wells would be much lower, and internal well pressure would not be of concern at these locations either. Therefore, higher injection rates at these two wells may be accommodated. Water levels will be monitored during injections to ensure the height of the water column does not exceed 335 ft above the static water level.

The magnitude of rise of injected substrate solution into the vadose zone adjacent to the injection wells is uncertain, but would likely be significantly less than the modeled pressure head because hydraulic conductivity in anisotropic sedimentary deposits is typically an order of magnitude higher horizontally than vertically.

#### 4.4 Additional Groundwater Monitoring Wells

Two additional groundwater monitoring wells (TAV-MW15 and TAV-MW16) will be installed south of the TA-V boundary, as shown in Figure 4-1. These wells will help define the extent of TCE concentrations and the potentiometric surface ~~to the south~~ along the southern boundary of TA-V. Long-term sampling from these locations, along with other TAVG monitoring wells, will provide data to evaluate the long-term effectiveness of remedial actions.

Well screens for these two monitoring wells will extend from approximately ~~5-2~~ ft above the water table to 20-23 ft below the water table to be consistent with other monitoring wells at the site. Actual screen placement will be based on the observed lithology of the aquifer material.

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## 5.0 TREATABILITY STUDY IMPLEMENTATION AND PERFORMANCE MONITORING

Treatability Study implementation will occur in the following order.

1. Pre-field activities.
2. Two groundwater monitoring well installations.
3. Phase I injection well installation and background sampling.
4. Phase I push/pull test and performance monitoring.
5. Phase I full-scale injection and performance monitoring.
6. Two groundwater monitoring well installations.
7. Phase II injection well installations and background sampling.
8. Phase II full-scale injection and performance monitoring.

Applicable Sandia Field Operating Procedures (FOPs) and Administrative Operating Procedures (AOPs) are listed in Table 5-1. Most current versions will be used. Specific procedures for activities that are not currently described under existing FOPs or AOPs are either incorporated into this work plan or will be prepared prior to Treatability Study implementation.

Table 5-1  
Applicable Sandia National Laboratories, New Mexico Operating Procedures.

Procedure Number	Procedure Title
FOP 03-02	Groundwater Level Data Acquisition and Management
FOP 05-01	Groundwater Monitoring Well Sampling and Field Analytical Measurements
FOP 05-02	Groundwater Monitoring Equipment Field Check for Water Quality Measurements
FOP 05-03	General Sampling Equipment Decontamination
FOP 05-04	Groundwater Monitoring Waste Management
FOP 09-05	Conducting Slug Test Using Pressure Transducer & Data Logger
FOP 10-01	Borehole and Downhole Well Video Inspection
FOP 12-11	Drilling Methods, Designing, and Installing Groundwater Monitoring Wells
FOP 94-01	Safety Meetings, Inspections, and Pre-Entry Briefings
FOP 94-05	Borehole Lithologic Logging
FOP 94-25	Documentation of Field Activities
FOP 94-28	Health and Safety Monitoring of Organic Vapors (FID and PID)
FOP 94-41	Well Development
FOP 94-43	Decommissioning of Wells
FOP 94-44	Monitoring Well Inspection, Assessment, and Rehabilitation
FOP 94-57	Decontaminating Drilling and Associated Field Equipment
FOP 94-68	Field Change Control
FOP 94-69	Personnel Decontamination (Level D, C, and B Protection)
AOP 00-03	Data Validation Procedure for Chemical and Radiochemical Data
AOP 08-05	Monitoring Well Installation, Decommissioning, and Planning
AOP 95-16	Sample Management and Custody
AOP 97-01	Well Registry and Tracking System

FID = Flame ionization detector.

PID = Photoionization detector.

## 5.1 Pre-Field Activities

Activities that must be completed prior to implementing the Treatability Study include:

- Approval of this Work Plan by NMED ~~Hazardous Waste Bureau~~HWB.
- Submittal to and review and approval from the DOE-Sandia Field Office of the National Environmental Policy Act checklist.
- Submittal to and approval from the New Mexico Office of the State Engineer (NMOSE) of the well installation permit application.
- Submittal of the Notice of Intent and Discharge Permit Application if required by~~and approval from the NMED GWQB of the Groundwater Discharge Permit application.~~
- Completion of the SNL Institutional Biosafety Committee Project Registration.
- Request and approval of the SNL/NM excavation permit.
- Preparation and approval of the SNL/NM site-specific Health and Safety Plan (HASP).
- Preparation of the SNL/NM Engineered Safety Review.
- Preparation of the ~~SNL/NM Safety Plans for~~Contract-Specific Safety Plans by contractors.
- Preparation of the SNL/NM Primary Hazard Screening document.
- Preparation of the SNL/NM Technical Work Document.
- Preparation of the SNL/NM Waste Management Plan (WMP).
- Preparation of the SNL/NM Statement of Work for drilling and well installation.
- Preparation of the SNL/NM Statement of Work for substrate preparation and injection contractor.
- Coordinate sampling with the SNL/NM Sample Management Office.
- Completion, review, and approval of the SNL/NM field work punch list.
- Conduct the SNL/NM readiness review meeting.

## 5.2 Well Installation

Phase I will include installation of three wells: ~~one injection well (TAV-INJ1) and two~~ groundwater monitoring wells (TAV-MW15 and TAV-MW16) and one injection well (TAV-INJ1). If implemented, Phase II will include installation of two additional injection wells (TAV-INJ2 and

TAV-INJ3). The following procedures are applicable to both monitoring and injection ~~and groundwater monitoring~~ wells, except where noted.

### 5.2.1 Mobilization and Site Setup

Work areas will be set up in accordance with the HASP and coordinated with facility management personnel, including but not limited to, exclusion zone delineation and signage, applicable alternative routes for traffic and pedestrians, eye wash, and sanitation facilities.

SNL/NM personnel will ensure that waste containers for cuttings, development water, and trash have been obtained and are ready for drilling operations.

### 5.2.2 Well Survey

The new monitoring and injection wells will be surveyed relative to North American Datum of 1983 (NAD 83) and elevations surveyed relative to North American Vertical Datum of 1988 (NAVD 88). Survey data will include northings, eastings, and elevations to the nearest hundredth of a foot. Survey elevations will be established at top-of-casing and ground surface, with a permanent marker indicating the point of survey. Well survey will be completed and certified by a licensed New Mexico professional surveyor.

### ~~5.2.25.2.3~~ Borehole Drilling

Based on local topography, recent groundwater level measurements at TA-V, and the lithology recorded during installation of the nearest groundwater monitoring wells, boreholes for the two new groundwater monitoring wells and the three injection wells are anticipated to be drilled to approximately 540-535 to 560 ft bgs.

Boreholes for the new monitoring and injection ~~Injection wells and groundwater monitoring wells boreholes~~ will be drilled using Air-Rotary Casing-Hammer (ARCH) drilling methods. It is anticipated that a telescoped borehole will be drilled and temporarily cased to reduce friction between the steel drive casing and borehole during drilling. The borehole will be advanced with approximately 11.75-inches in nominal diameter drive casing from ground surface to approximately 200 ft bgs and cased. The remaining borehole from 200 ft bgs to total depth will be advanced with a 9.625-inches in nominal diameter drive casing and cased. The ARCH drilling method will use environmentally friendly lubricants and will be able to penetrate highly variable lithologies such as cobbles, boulders, gravel, sand, clay, and caliche. The borehole lithology will be logged by the Sandia field geologist during drilling. SNL staff will retain cutting samples in chip boxes for three years after each well is installed. The depth of the first encounter with regional groundwater and any perched groundwater will be noted and recorded during drilling. Standby time will be used as needed for determining the accurate water level.

Minimal water (but no other foams/liquids) in the form of mist may be introduced into the drive casing to aid in the removal of cuttings. Borehole cuttings and core will be stored within an area adjacent to the well. Water produced from the well during drilling or development will be contained in 55-gallon polypropylene drums and placed on spill control pallets. Management and final disposition of cuttings, core, and water will be performed according to applicable state

and federal regulations, as specified in the project-specific WMP to be prepared as part of the pre-field activities.

### Core Sampling at Injection Well Locations

To optimize the injection well construction design, continuous core will be collected from approximately 20 ft above the anticipated static water table to approximately 40 ft below the observed water table to allow detailed lithologic logging of the saturated zone and the overlying capillary fringe. Core will be obtained by advancing an acetate-lined, 4-inch inner diameter core barrel (or functional equivalent) ahead of the ARCH drill bit. The total depth of each borehole will be determined by the Sandia field geologist based on observed lithology and injection well design objectives. Lithology from coring will be used to refine the final well screen and filter pack placement to ensure ~~the injection wells~~ s are is completed at the proper depth to optimize substrate delivery. The field crew will take photographs of the entire core before segments are removed for laboratory analysis, inoculation, or sieve analysis. The rest of the core material will be stored onsite in core boxes for at least six months.

Unsaturated and saturated soil samples will be collected from the most permeable observed sediment layers within the core at a minimum of one per 10-ft interval. Soil samples will be analyzed for VOCs on overnight turnaround. Samples will also be analyzed for total organic carbon (TOC) to compare against values used in calculating substrate demand for TCE sorbed to soil. Sieve analysis may also be conducted on the core samples for lithological composition.

The injection well screen will be set at least deep enough to intersect any significant detection of VOCs in soil below the water table. If VOCs are not detected in any of the soil samples, the injection well screen completion interval will default to the injection well design detailed in section 5.2.5 ~~5 ft above static water level to 25 ft below static water level~~. Because detected VOC concentrations have been historically very low at TA-V, lack of VOC detection in the soil samples does not preclude their presence at low concentrations in groundwater. The purposes of VOC analysis of soil samples are to confirm historical results of negligible contaminants in soil samples and to determine if significant concentrations are present in a deeper horizon than is monitored by the current groundwater monitoring network.

### 5.2.35.2.4 Geophysical Logging

Geophysical logging of the new monitoring and injection wells will be performed after well construction. ~~Neutron and gamma logging~~ Wire-line geophysical logging will be performed through the steel drive casing, before well construction using neutron and gamma logging techniques to supply lithologic data to support final well completion design for injection wells, for optimum placement of the injection casing screens. Neutron logging will be contingent upon receiving access permission from TA-V radiological control administration. Drill rig standby time up to two calendar days will be used to allow for completion of neutron and gamma logging ~~geophysical logging~~. However, waiting longer risks getting the drive casing lodged in the borehole due to swelling clays. Removal of drive casing would be costly and risk compromising the borehole for proper completion of the well. If neutron and gamma logging geophysical logging cannot be performed within two calendar days after the borehole total depth has been reached, and the drilling supervisor determines that getting the drive casing stuck is likely if standby is continued, the well screen length and vertical placement will be based on field

geologist observations of lithologic and hydrologic characteristics and analytical data.  
~~Geophysical logging of the monitoring wells will be performed after well construction.~~

#### 5.2.45.2.5 Well Construction

~~The new monitoring and injection wells~~ ~~Injection wells and groundwater monitoring wells~~ will be installed through the temporary steel drive casing ~~(nominal 10-inch diameter)~~, and completed ~~with using 5-inch nominal diameter~~, flush-threaded, ~~polyvinyl chloride (PVC)~~ Schedule-80 water well casing. No petroleum-based solvents, cleaners, or lubricants will be used for well construction. The casing and screen will be delivered pre-cleaned and bagged, or steam-cleaned on site prior to installation. To preserve the structural integrity of well materials, the ~~casing and~~ screen ~~and riser pipe~~ will be suspended in the drive casing while the primary filter pack, bentonite ~~pellet chips~~ seal, and annular ~~laral~~ seal are installed. PVC centralizers ~~will~~ ~~might~~ be placed at the bottom and top of the well screen, and at intervals not to exceed 100 ft along the well casing up to the ground surface.

#### Groundwater Monitoring Well Design

The locations of groundwater monitoring wells TAV-MW15 and TAV-MW16 are shown in Figure 4-1. The well screen and filter pack will either be 0.010-inch slot with #20/40 sand or 0.020-inch slot with #10/20 silica sand as the primary filter pack material depending on the degree of fines in the surrounding sediments. The well screen will be 25-ft long and extend 23 ft below and 2 ft above the static water level. Table 5-2 shows the anticipated design specifications. The configuration and construction of the monitoring well casing and screen will follow the same process as for the injection well described below.

Table 5-2  
Anticipated Groundwater Monitoring Well Design Specifications

<u>Well Name</u>	<u>Estimated Depth to Water 2016-2017 (ft bgs)</u>	<u>Screen Interval (ft bgs)</u>	<u>Filter Pack Interval (ft bgs)</u>	<u>Total Casing Depth (ft bgs)</u>
<u>TAV-MW15</u>	<u>519</u>	<u>517 – 542</u>	<u>507 – 547</u>	<u>547</u>
<u>TAV-MW16</u>	<u>535<sup>a</sup></u>	<u>533 – 558</u>	<u>523 – 563</u>	<u>563</u>

<sup>a</sup> Assumes TAV-MW16 ground surface elevation is approximately 12 ft higher and water table is 2 ft lower than at TAV-MW15.

bgs = Below ground surface.

ft = Feet.

Previously installed groundwater monitoring wells at TA-V currently extend approximately 15 ft below the water table. Water levels have been declining at a rate of approximately 0.8 ft/year at TA-V. The additional 8 ft of screen for these new wells is intended to allow a longer useful lifespan. The final monitoring well construction design will be determined based on lithology and geophysics.

The planned locations for groundwater monitoring wells TAV-MW15 and TAV-MW16 are not in areas requiring at-grade completion. The well casing will extend approximately 30 inches above ground surface with a water-tight cap. The borehole will be grouted to within 5 ft of the ground surface, allowed to cure, followed by placing another 2-foot lift of bentonite chips to serve as a firm base for the stovepipe. The wellhead will be protected with a steel stovepipe with locking hinged lid, set in a reinforced concrete pad and surrounded by three concrete-filled guard posts. Each concrete pad will be affixed with a brass well identification plate.

## Injection Well Design

A nested casing design will be used for injection wells, which consists of two separate casings in one borehole: a 5-inch nominal diameter monitoring casing and screen with an adjacent 1.5-inch nominal diameter injection casing and screen, as shown in Figure 5-1. This nested casing design allows the separation of downhole substrate injection from the deployment and retrieval of a sampling pump and downhole measurement tools, which are operated in the monitoring casing. This design streamlines substrate injection and avoids equipment restrictions and tangling in a single casing design.

The two separate, equally deep casings will be installed simultaneously in the borehole and affixed to each other with straps placed at appropriate intervals determined by driller's. The injection casing screen will be 20 ft long with its top placed approximately 5 ft below the water table to facilitate submerged placement of the injected solution. The monitoring casing screen will be 30 ft long extending from approximately 5 ft above to 25 ft below the water table. This is longer than existing groundwater monitoring wells at TA-V, but is intended to help facilitate vertical distribution of the injected substrate in the subsurface. The monitoring casing screen will extend 5 ft above the static water table to allow for distribution to the capillary fringe above the water table. Each casing will have a 5-ft long blank sump casing at the bottom to mitigate long term silting up of the wells. The monitoring casing screen will have a 0.020-inch slot and the injection casing screen will have a 0.040-inch slot size to enhance injection rates.

To enhance injection rate and lessen chance of biofouling, a relatively coarse-grained filter pack material, #8/12 sand or equivalent, will be used as the primary filter pack material extending from the bottom of the sumps to at least 5 ft above the top of the monitoring casing screen. An additional 5 ft of #60 silica sand will be placed on top of the primary filter pack. Each filter pack interval will be tagged to verify the depth setting. Swabbing using a surge block will be performed to help settle the filter pack and reduce possible bridging of the sand.

An approximately 30-ft thick lift of 3/8-inch grade bentonite chips will be placed above the filter pack in 5-ft lifts. Each lift will be hydrated with 5 gallons of potable water and tagged prior to emplacement of the next lift. The first lift of bentonite chips will be allowed to hydrate for at least one hour to facilitate sufficient hydration.

Well screen design will be slightly different for injection wells than for groundwater monitoring wells, reflecting their respective purposes. Screen lengths for injection wells will be longer than in the nearby groundwater monitoring wells to facilitate substrate delivery through a larger vertical profile. Injection well screen slot sizes and filter pack materials may also be larger to minimize potential restriction on the injection rate.

Two well-screen configuration options may be used for injection wells depending on lithology encountered in the upper 25-30 ft of the saturated zone as described below and as shown in Table 5-2 and Figures 5-1 and 5-2.

Table 5-2  
Injection Well Screen Design Options

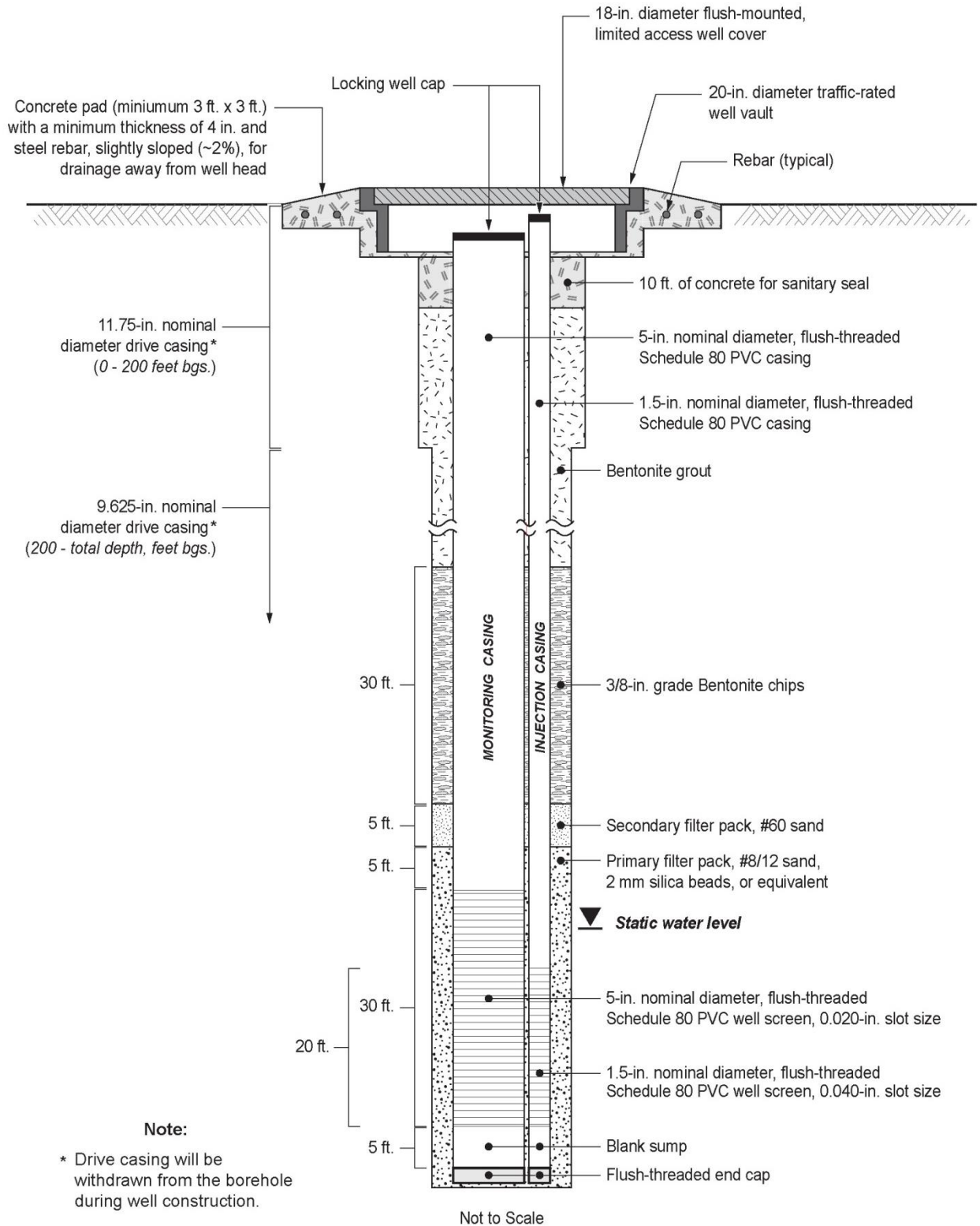
Lithology	Well screen configuration / design objective
Sediments with relatively consistent permeability through the targeted injection interval.	<p><u>Single Screen</u></p> <p>Single-screen design with one continuous screen extending from approximately 5 ft above the water table to 25 ft below the water table. Filter pack will be continuous from below bottom sump to approximately 5 ft above the top of the screen. Final screen lengths to be based on lithology, geophysics, and analytical results.</p> <p><u>Objective</u></p> <p>Maximize substrate delivery throughout vertical saturated interval of relatively uniform permeability or thinly interbedded heterogeneous layers.</p>
Distinct change in strata permeability within the targeted injection interval.	<p><u>Dual Screen</u></p> <p>Two shorter screen lengths separated by a short (approximately 5 ft) section of blank casing with filter pack replaced with hydrated bentonite pellets alongside the blank casing to provide isolation between the two screened sections. Final screen lengths to be based on lithology, geophysics, and analytical results.</p> <p><u>Objective</u></p> <p>Provide option to customize targeted delivery to distinct horizons of differing permeability using a packer system to isolate upper screened zone from the lower screened zone. Not intended to bridge two high permeability zones across a low permeability zone.</p>

ft — = Feet.

A primary filter pack material will extend from the bottom of the sump to at least 5 ft above the top of the well screen (except for the lower screen of the dual-screen option). The size of this material will be matched to the screen slot size. If the screened interval consists predominantly of fine-grained sediments, a 0.020-inch screen slot and primary filter pack of clean #10/20 silica sand will be placed in the annulus. Larger sand materials may be used for injection wells if the screened interval has very few fines and is predominantly coarser-grained materials. An additional 5 ft of clean #60 silica sand will be placed on top of the primary filter pack (except for the lower screen of the dual-screen option). Each filter pack section will be tagged to verify the depth interval. Swabbing using a surge block will be performed to help settle the filter pack and reduce possible bridging prior to installing the bentonite layer described below.

The remaining annular space to ground surface will then be filled with bentonite grout. To prevent overloading, the first lift of bentonite grout will be approximately 100-ft thick and will be allowed to set for a minimum of 24 hours. Subsequently, the annulus will be filled continuously with grout to within 10 ft below ground surface. To prevent bridging inside the annular space, during well construction the field crew will (1) tally the amount of emplaced materials to verify that the theoretical (planned) volume of each material corresponds to the actual volume installed, (2) pour the materials by hand at a slow rate into the annulus at the top of the drive casing, and (3) use a measuring tape at approximately 3-foot intervals to verify that the materials have fallen to the proper depths. Concrete will be used to complete the well installation.





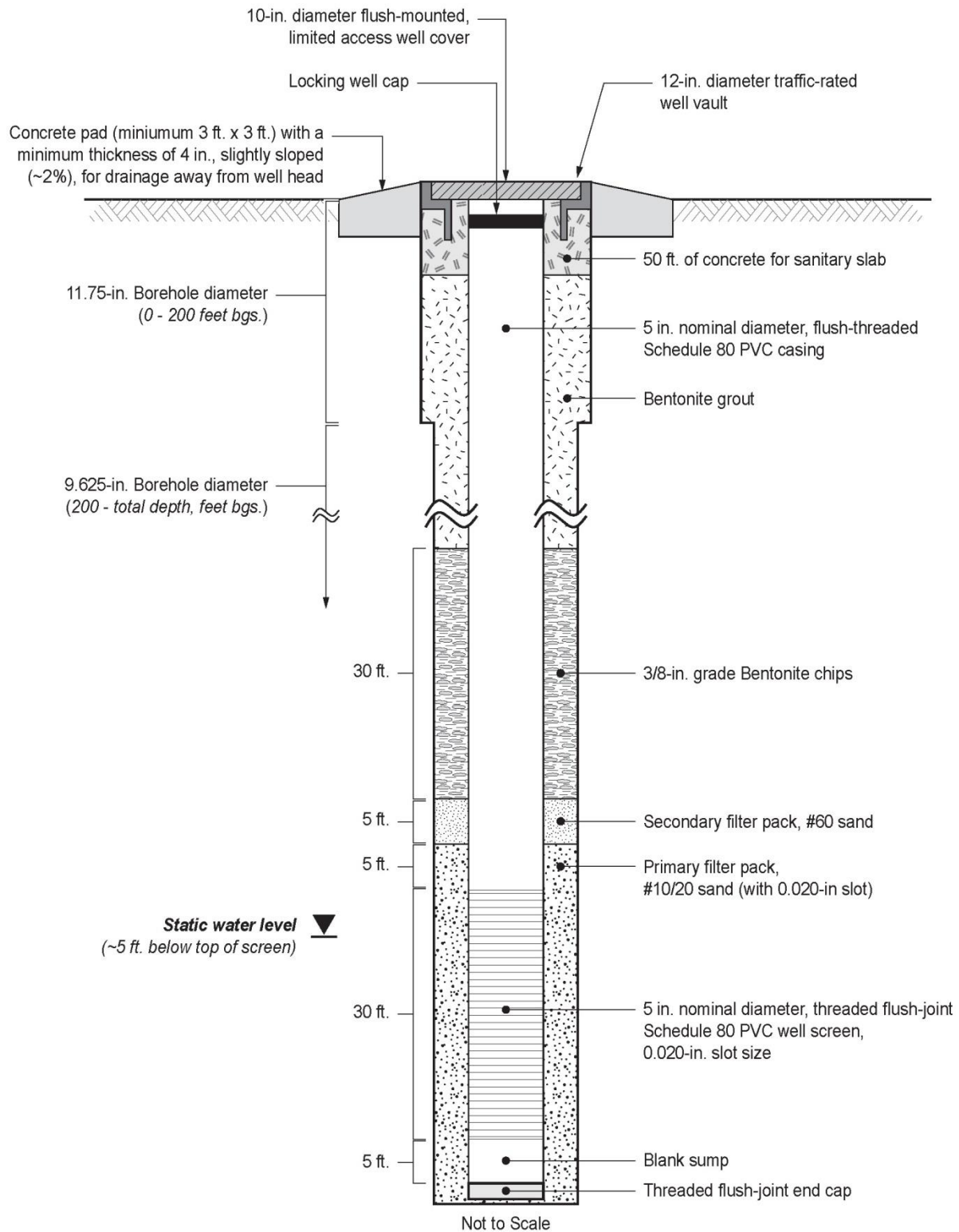
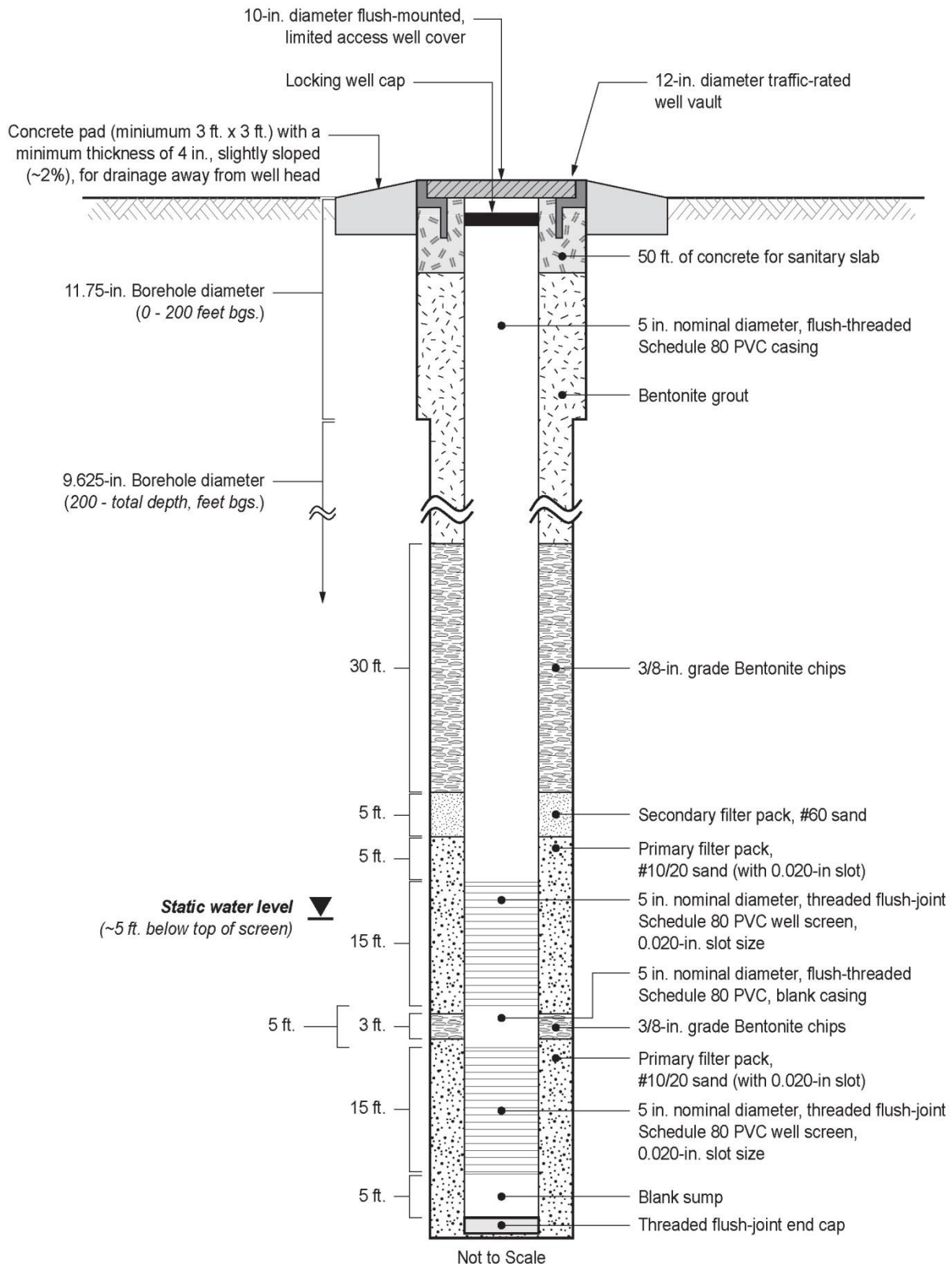


Figure 5-1  
Injection Well Design: ~~Single-Screen~~ Nested Casing



**Figure 5-2**  
**Injection Well Design: Dual Screen**

~~An approximately 30-ft thick layer of 3/8-inch grade bentonite chips will be placed above the filter pack in 5-ft lifts. Each lift will be hydrated with 5 gallons of potable water and tagged prior to emplacement of the next lift. The bentonite pellets/chips will be allowed to hydrate for at least one hour to facilitate sufficient hydration.~~

~~The remaining annular space to ground surface will then be filled with bentonite grout to within 50 ft of ground surface. To prevent overloading, the bentonite grout will be installed in multiple lifts. The first lift will be approximately 100-ft thick and will be allowed to set a minimum of 24 hours before placement of the next lift. Subsequent lifts will each be approximately 200-ft thick and brought to within 50 ft below grade. The annular space will be filled with concrete from 50 ft below grade to approximately 18 inches below grade.~~

The planned locations for injection wells TAV-INJ1, TAV-INJ2, and TAV-INJ3 will require at-grade completions. The PVC well casing for these wells will be cut off below grade, and fitted with a water-tight cap and a lock. The well casing and well cap will be protected by installing an 1218-inch diameter by approximately 18-inch deep traffic-rated steel vault centered over the PVC casing. The vault will be set in concrete, rebar-reinforced, constructed to surround the upper portion of each vault that slopes evenly away from the vault, to meet the surrounding ground surface to direct water away from the top of the vaults. A brass well identification marker will be fastened to each vault ~~skirt~~.

Table 5-3 shows the planned design for the three injection wells based on their paired groundwater monitoring wells and the anticipated static depth to water in 2016-2017 (the anticipated timeframe for well construction). ~~This assumes single-screen well construction.~~

Table 5-3  
Anticipated Injection Well Design Specifications

Treatment Area and Well Description	Well Name	Estimated Depth to Water 2016-2017 (ft bgs)	<u>Monitoring Casing Screen Interval</u> <sup>a</sup> (ft bgs)	Filter Pack Interval (ft bgs)	Total Casing Depth (ft bgs)
<b>SWMU 5 Area</b>					
Planned Injection Well	TAV-INJ1	513	508 - 538	498 - 543	543
Existing Monitoring Well	TAV-MW6	513	507 - 527	498 - 534	532
<b>SWMU 275 Area</b>					
Planned Injection Well	TAV-INJ2	519	514 - 544	504 - 549 <sup>a</sup>	549
Existing Monitoring Well	TAV-MW10	519	508 - 528	494 - 539	533
<b>LWDS-MW1 Area</b>					
Planned Injection Well	TAV-INJ3	505	500 - 530	490 - 535	535
Existing Monitoring Well	LWDS-MW1	505	495 - 515	495 - 525 <sup>b</sup>	520.3

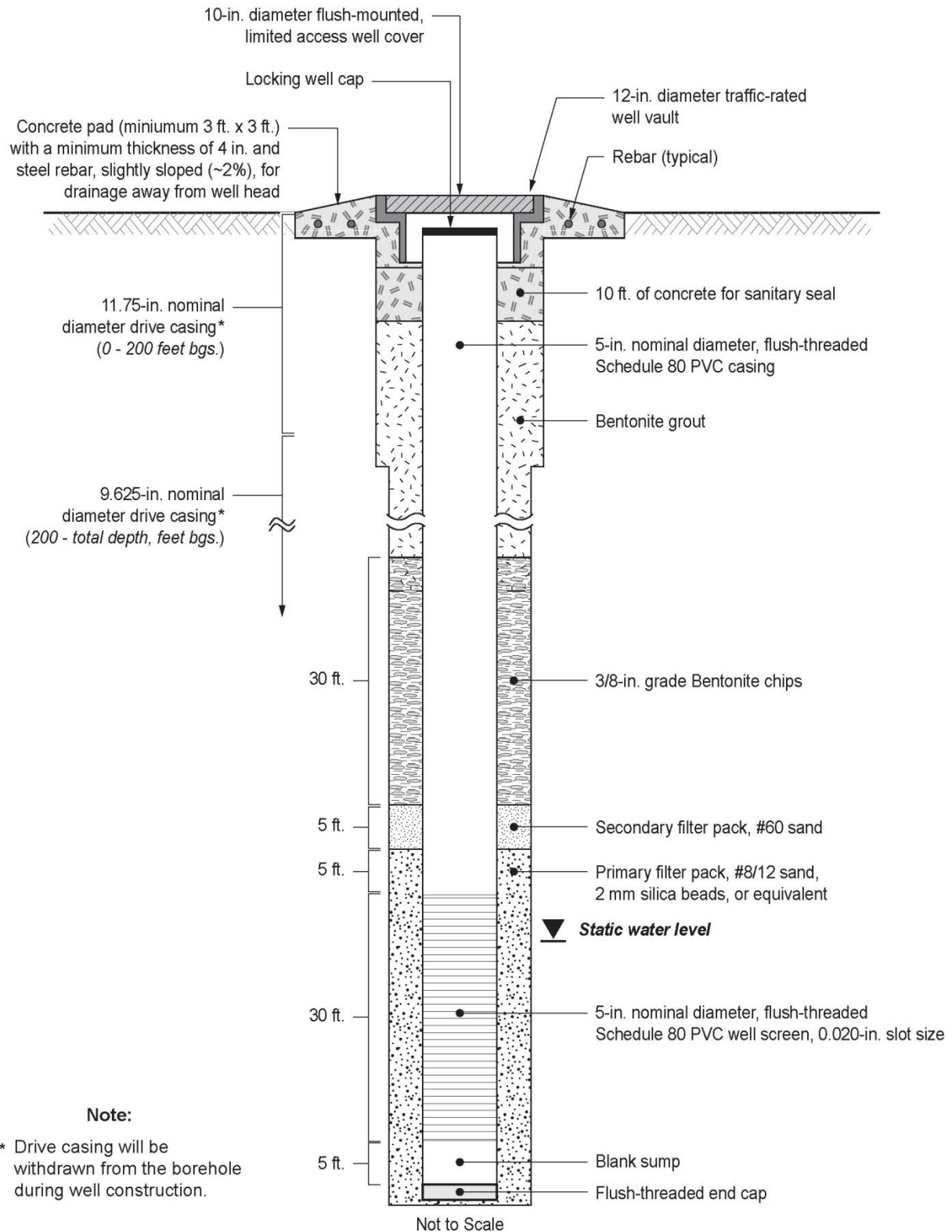
<sup>a</sup> ~~TAV-MW10 well log indicates coarse-grained material encountered from approximately 512-531 ft bgs underlain by silty material. Screen interval shown is for the monitoring casing screen. Top of adjacent injection casing screen is 10 ft lower with same bottom depth as the monitoring casing.~~

<sup>b</sup> LWDS-MW1 well log indicates "plug back" beneath well casing from 520.3-525 ft bgs, but does not specify material. Material is Assumed to be a combination of filter pack sand and slough.

bgs = Below ground surface.

ft = Feet.

A single casing injection well design will be retained as the contingent injection well design if the nested casing design is not successful, as shown in Figure 5-2. A larger diameter well casing and screen may be used to facilitate operations of all necessary downhole equipment including substrate injection hose, sampling pump, and downhole parameter measurement device. The configuration and construction of the well casing and screen will follow the same process as the monitoring casing of the nested casing injection well.



**Figure 5-2**  
Injection Well Design: ~~Dual Screen~~ Single Screen



## Groundwater Monitoring Well Design

Groundwater monitoring wells TAV-MW15 and TAV-MW16 will be constructed similarly to the single-screen injection well design. However, the screen and filter pack will either be 0.010-inch slot with #20/40 sand or 0.020-inch slot with #10/20 silica sand as the primary filter pack material depending on the degree of fines in the surrounding sediments. The well screen will be 25-ft long and extend 20 ft below and 5 ft above the static water level. Table 5-4 shows anticipated well design specifications.

Table 5-4  
Anticipated Groundwater Monitoring Well Design Specifications

Well Name	Estimated Depth to Water 2016-2017 (ft bgs)	Screen Interval (ft bgs)	Filter Pack Interval (ft bgs)	Total Casing Depth (ft bgs)
TAV-MW15	519	514–539	499–544	544
TAV-MW16	535 <sup>a</sup>	530–555	520–560	560

<sup>a</sup> Assumes TAV-MW16 ground surface elevation is approximately 12 ft higher and water table is 2 ft lower than at TAV-MW15.

bgs — = Below ground surface.

ft — = Feet.

Previously installed groundwater monitoring wells at TA-V currently extend approximately 15 ft below the water table. Water levels have been declining at a rate of approximately 0.8 ft/year at TA-V. The additional 5 ft of screen for these new wells is intended to allow a longer useful lifespan. As with injection wells, final well construction design will be determined based on lithology and geophysics.

The planned locations for groundwater monitoring wells TAV-MW15 and TAV-MW16 are not in areas requiring at-grade completion. The well casings will extend approximately 30 inches above ground surface with a water-tight cap. The borehole will be grouted to within 5 ft of the ground surface, allowed to cure, followed by placing another 2-foot lift of bentonite chips to serve as a firm base for the stovepipe. The wellheads will be protected with a steel stovepipe with locking hinged lid, set in a reinforced concrete pad and surrounded by three concrete-filled guard posts. Each concrete pad will be affixed with a brass well identification plate.

### 5.2.55.2.6 Well Development

Well development will begin after at least 48 hours following final grout placement. ~~The well will be developed for approximately 8 hours, and~~ Development of groundwater monitoring wells will consist of bailing, surging, swabbing, and/or pumping techniques. Development of the nested casing injection wells will consist of pumping the 5-inch casing only to limit the amount of fine-grained material being forced into the well screen slots. Small amounts of potable water may be poured into the 1.5-inch casing during pumping to facilitate development. During development, groundwater field parameters (pH, specific conductivity [SC], temperature, and turbidity) will be continuously monitored, and development will continue until these parameters have stabilized. ~~All d~~ Development water will be contained in polyethylene drums and not allowed to discharge to the ground surface. The development water will either be re-purposed or disposed of as waste.

All waste will be disposed of according to applicable state and federal regulations, and in accordance with the site-specific WMP. The method of development, the volume of water added or removed, the parameters measured, the results of the measurements, and the time these activities take place will be documented on field forms. If addition of water is necessary during development of a low-yielding well, only potable water will be used.

During well development, a minimum of five well bore volumes of groundwater will be removed. One bore volume is calculated as the interior casing volume from static water level to ~~total well depth~~the bottom of screen, plus the estimated porosity of the saturated filter pack. After the minimum volume has been removed, development will continue until representative groundwater is obtained. Representative water is assumed to be obtained when pH, SC, and temperature readings stabilize (less than 10 percent variability over three consecutive well bore volumes) and the water is visually clear of suspended solids with a target turbidity of less than 5 Nephelometric Turbidity Units (NTU).

#### ~~5.2.6~~5.2.7 Hydraulic Testing

Slug tests will be performed on each newly installed well in accordance with FOP 09-05 “Conducting Slug Test Using Pressure Transducer & Data Logger.” Water-level changes induced in the wells will be measured using a Solinst electronic pressure transducer (or equivalent) and data logger software. The “slug out” (removal of the slug from the water column) portion of the test for each well will be recorded and analyzed. The slug test data will be analyzed by the AquiferTest™ Software developed by Waterloo Hydrogeologic, Inc. (Waterloo Hydrogeologic 2001). The hydraulic conductivities calculated from the slug tests performed on each well will be presented in the Treatability Study Report.

#### ~~5.2.7~~5.2.8 Equipment Decontamination

The drill rig and related equipment, including development and slug test equipment, will be decontaminated at the decontamination pad in TA-III prior to beginning of drilling operations. Decontamination of equipment will also be required after completing each well. Decontamination waste will be kept to a minimum and contained in drums placed on spill control pallets at the decontamination pad, consistent with the WMP.

### 5.3 Groundwater Sampling

Groundwater samples will be collected from each new injection well and analyzed for the constituents listed in Table 5-~~45~~ to establish baseline conditions prior to substrate injection. These analyses will also be performed on the paired groundwater monitoring wells. Analytical results from groundwater monitoring wells obtained during the most recent quarterly ~~TA-V~~ groundwater monitoring event ~~will could~~ be used to reduce redundancy for baseline sampling. Table 5-~~45~~ also shows analyses to be conducted during performance and rebound monitoring.



Table 5-~~45~~  
Analytical Parameters for Groundwater Samples

Analytical Group/Analyte	Analytical Method	Reference
Alkalinity (total, bicarbonate, and carbonate)	SM2320B	Standard Methods Online <sup>a</sup>
Ammonia (as Nitrogen)	EPA 350.1	EPA 1983
Anions ( <del>including nitrite, sulfate, and bromide, chloride, fluoride, nitrite, and sulfate</del> )	SW846-9056	EPA 1986 (and updates)
<i>Dehalococcoides</i> (Dhc) and, if Dhc is present, vinyl chloride reductase (vcrA).	Gene-Trac-Dhc Gene-Trac-VC	Proprietary methods of SiREM, Guelph, Ontario, Canada.
Dissolved metals ( <del>arsenic, calcium, iron, magnesium, and manganese, potassium, and sodium</del> ) <del>and arsenic</del>	SW846-3005/6020	EPA 1986 (and updates)
Methane/ethane/ethene	RSK-175 SOP	Laboratory dependent <sup>ba</sup>
Nitrate plus nitrite (NPN)	EPA 353.2	EPA 1983
Orthophosphate (as P)	EPA 300.0	EPA 1983
Total organic carbon	SW846-9060	EPA 1986 (and updates)
Sulfide	SW846-9034	EPA 1986 (and updates)
Volatile organic compounds	SW846-8260	EPA 1986 (and updates)

<sup>a</sup> Standard Methods for the Examination of Water and Wastewater. <http://standardmethods.org/>

<sup>b</sup> RSK-175 is not an analytical method, it is a standard operating procedure (SOP). Each laboratory adopts a procedure that is consistent with the quality controls of the SOP, but may have different specific processes.

EPA = U.S. Environmental Protection Agency.

SOP = Standard Operating Procedure.

The following field parameter measurements will also be collected:

- pH, ~~temperature~~, SC, ~~temperature~~, and turbidity to comply with pre-sampling purging protocols. Monitoring the pH is also necessary for maintaining optimal ISB conditions.
- DO and ORP to evaluate how effectively biodegradation is affecting groundwater conditions in the treatment area.

Groundwater sampling will be conducted in accordance with the requirements specified in section IX.A of the Consent Order (NMED April 2004).

A portable Bennett sampling system will be used to collect the groundwater samples. The sampling pump and tubing bundle will be decontaminated prior to installation into each well according to procedures described in FOP 05-03 "General Sampling Equipment Decontamination." After decontamination, the pump intake will be set near the bottom of the screened interval.

In accordance with procedures described in FOP 05-01 "Groundwater Monitoring Well Sampling and Field Analytical Measurements," all wells will be purged a minimum of one saturated casing volume (the volume of one length of the saturated screen plus the porosity of borehole annulus~~the saturated filter pack~~ around the saturated screen interval). The saturated casing volume of a nested casing injection well will be the volume of one length of the saturated screens of monitoring casing and injection casing, plus the porosity of the saturated filter pack

around the two casings. After the minimum volume is removed, purging will continue until four consecutive measurements of water quality parameters (pH, ~~temperature~~, SC, ~~temperature~~, and turbidity) exhibit stabilized conditions. Groundwater stability is considered acceptable for sample collection when consecutive measurements are within 1.0 degrees Celsius, 0.1 pH units, ~~—~~within 5 percent for SC, and turbidity is less than 5 NTUs or within 10 percent for turbidity higher than 5 NTUs. If these parameters do not stabilize within removal of three saturated casing volumes, purging will cease and samples will be collected. Additional field parameters to be collected for all wells will include DO, ORP, and water level measurements.

Samples will be analyzed by off-site analytical laboratories accredited by the National Environmental Laboratory Accreditation Program. Quality ~~C~~ontrol samples will include duplicate samples, equipment blanks, field blanks, and trip blanks.

Groundwater samples will be collected directly from the sample discharge tubing into laboratory-prepared sample containers. If chemical preservatives are required, the analytical laboratories will add the preservatives to the sample containers prior to shipping. Immediately after collection, all sample containers will be custody-taped, sealed in plastic bags, and placed on blue ice in shipping containers. Analytical Request/Chain-of-Custody forms will be completed at the time of sample collection and will accompany the sample containers to the analytical laboratories.

## 5.4 Phase I Injections

Phase I of the Treatability Study is divided into two stages following installation of injection well TAV-INJ1.

1. Push/pull test.
2. Full-scale injection.

### 5.4.1 Push/Pull Test at TAV-INJ1

The push/pull test will be performed on injection well TAV-INJ1. This is a small-scale proof of concept test designed to deliver substrate solution and the bioaugmentation culture laterally into the formation with a treatment area radius of approximately 5 ft.

Performance monitoring will be conducted as outlined in Table 5-~~45~~. These analytical results, coupled with field measurements, will be used to assess if the injected bioaugmented substrate solution creates favorable conditions to support larger-scale biodegradation of COCs. Additionally, data will be obtained regarding gravity-injection rates, which will impact planning for subsequent injections. Results of this test will be evaluated under Decision Point #1 to determine whether to implement a full-scale injection at TAV-INJ1 and to refine procedures.

The push/pull test includes the following sequential tasks:

- Extract and store groundwater from TAV-INJ1.
- Prepare substrate solution in aboveground tanks.
- Deoxygenate the injection well water column.
- Reinject substrate solution and bioaugmentation culture.
- Conduct post-injection performance monitoring.

Figure 5-3 shows a conceptual schematic of the gravity-injection system to be used.

#### Groundwater Extraction from TAV-INJ1

The design of the push/pull test includes extracting the volume of groundwater necessary to be used for subsequent delivery of the substrate solution into saturated sediments to a radius of 5 ft from the injection well. It is estimated that approximately 3,700 gallons of groundwater will be sufficient. This volume is based on the design of a well screen set across the upper 25 ft of the saturated zone, and an estimated effective sediment porosity of 25 percent.

The groundwater will be extracted from TAV-INJ1 using an electrical low-flow submersible pump to minimize volatilization of VOCs. The anticipated pumping rate is approximately 1 would be less than 10 gpm. Equal volumes of extracted groundwater (1,850 gallons) will be stored onsite in two tanks, each storing approximately half the groundwater volume (1,850 gallons) and designated as Tank 1 and Tank 2.

#### Preparation of Substrate Solution in Aboveground Tanks

The initial Tank 1 solution will be:

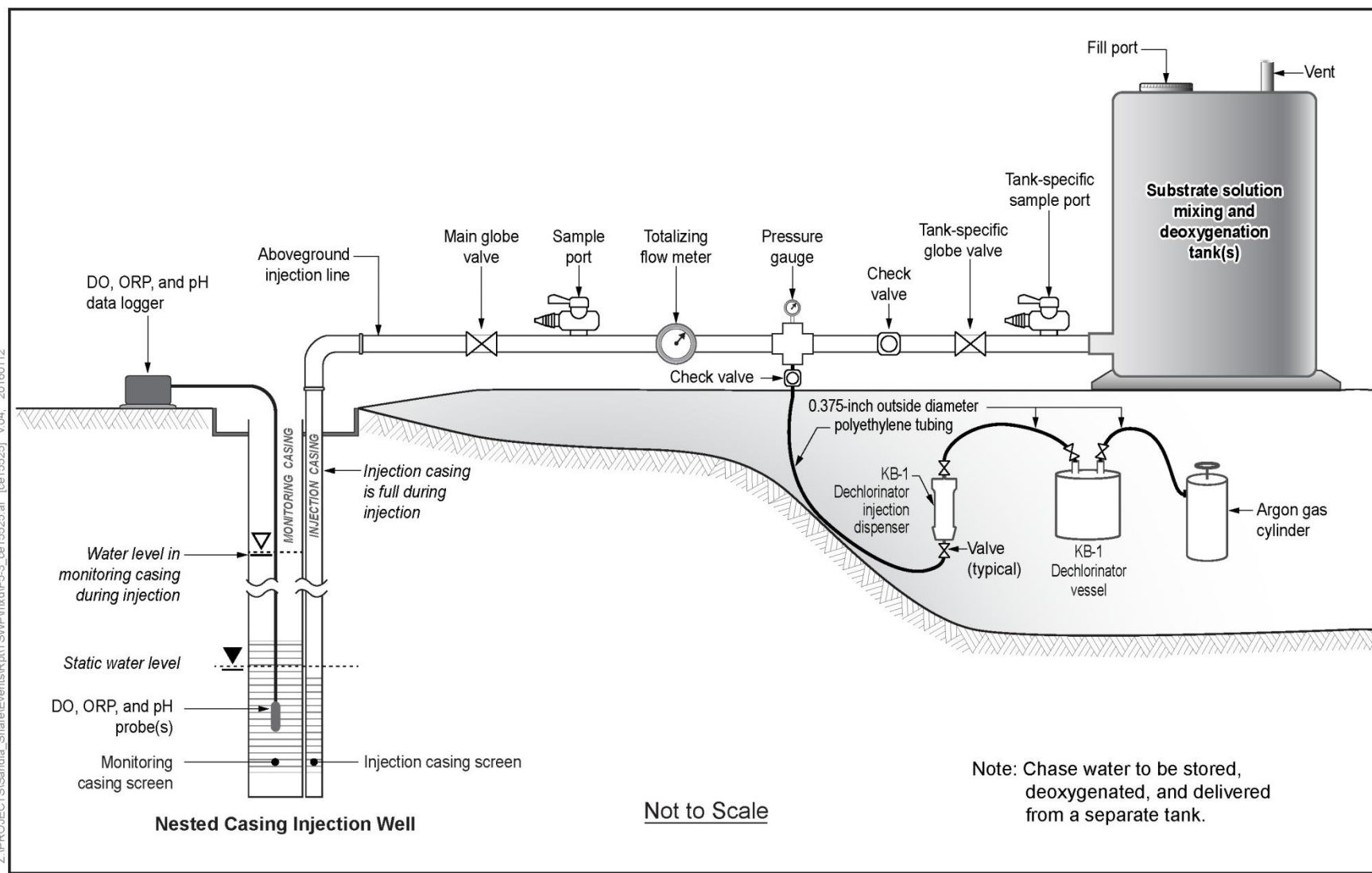
- 1,850 gallons groundwater.
- 4.55.9 kilograms (3.313.1 lbs) of KB-1® Primer.
- 0.4 lb sodium bromide (tracer).
- 10 lbs of TAV-INJ1 soil core/cutting from the well screen interval.

Tank 2 will hold the other 1,850 gallons of extracted groundwater until the solution in Tank 1 has been deoxygenated and has an ORP of less than negative 75 mV (the minimum required to sustain growth of KB-1® Dechlorinator). Tank 1 will then be filled with:

- 1,850 gallons of groundwater from Tank 2.
- 1.9 gallons of ethyl lactate (electron donor).
- 3.5 lbs of diammonium phosphate (nutrient and pH buffer).
- 0.6 lbs of yeast extract (nutrient).
- 0.4 lbs of sodium bromide (tracer).

After mixing the above contents in Tank 1, DO and ORP measurements will be taken of the substrate solution until deoxygenation and lowered ORP have been reestablished indicating it is ready for reinjection along with KB-1® Dechlorinator. Deoxygenation may be accelerated by sparging the water with argon gas, if necessary.

Component ratios may be modified if analytical results from baseline sampling of the injection well are significantly different than currently detected in the neighboring monitoring well.



**Figure 5-3**  
**Schematic of Gravity-Injection System**

## Water Column Deoxygenation

~~Immediately prior to reinjection, the aboveground injection line from the substrate solution mixing tanks will be connected to the injection casing at the wellhead (Figure 5-3). The aboveground injection line and the injection casing in well TAV-INJ1 will be primed by draining a sufficient volume of deoxygenated substrate solution from the tank. A pre-injection of a sufficient amount of the substrate solution will be conducted to displace the water column in the monitoring casing in well TAV-INJ1. the water column in well TAV-INJ1 will be deoxygenated by sparging the water with argon gas. Argon is the same inert gas used to displace the KB-1<sup>®</sup> Dechlorinator from its vessel for mixing during injection.~~

~~Polyethylene tubing will be lowered into the well casing to place its discharge end below the screened interval, near the bottom of the 5-ft sump to ensure the argon gas rises throughout the water column. A sufficient volume of gas will be injected to displace air in the tubing and will then continue to be injected for at least 15 minutes to deoxygenate the water. Purging the air within the well casing above the water table is not necessary because argon gas is heavier than air. As it escapes the water column, it will accumulate between the air and water column interface, thereby forming a barrier that prevents air from contacting the water column. After the water column is deoxygenated, the tubing discharge end will be raised to middle of the water column before substrate solution injection.~~

## Reinject Substrate Solution and Bioaugmentation Culture into TAV-INJ1

Once the substrate solution has been deoxygenated and reduced to an ORP of less than negative 75 mv, it will be gravity-injected into the ~~well injection casing via the polyethylene tubing~~ along with KB-1<sup>®</sup> Dechlorinator ~~(Figure 5-3). Figure 5-3 shows a conceptual schematic of the gravity injection system to be used.~~ Injection will start with the substrate solution in the tank, quickly followed by mixing KB-1<sup>®</sup> Dechlorinator. ~~Argon is used to displace the KB-1<sup>®</sup> Dechlorinator from its vessel for mixing during injection.~~ Care will be taken to minimize turbulence during mixing and injection. A total of approximately 1.8 lbs of KB-1<sup>®</sup> Dechlorinator will be needed for the 3,700 gallons of substrate solution.

A sample of the injected substrate solution will be collected ~~of the injected substrate solution~~ as it is being injected and analyzed for parameters listed in Table 5-45 ~~except for Dehalococcoides~~ and measured for field parameters specified in section 5.3 ~~plus any other parameters that could be required by the NMED GWQB Discharge Permit.~~

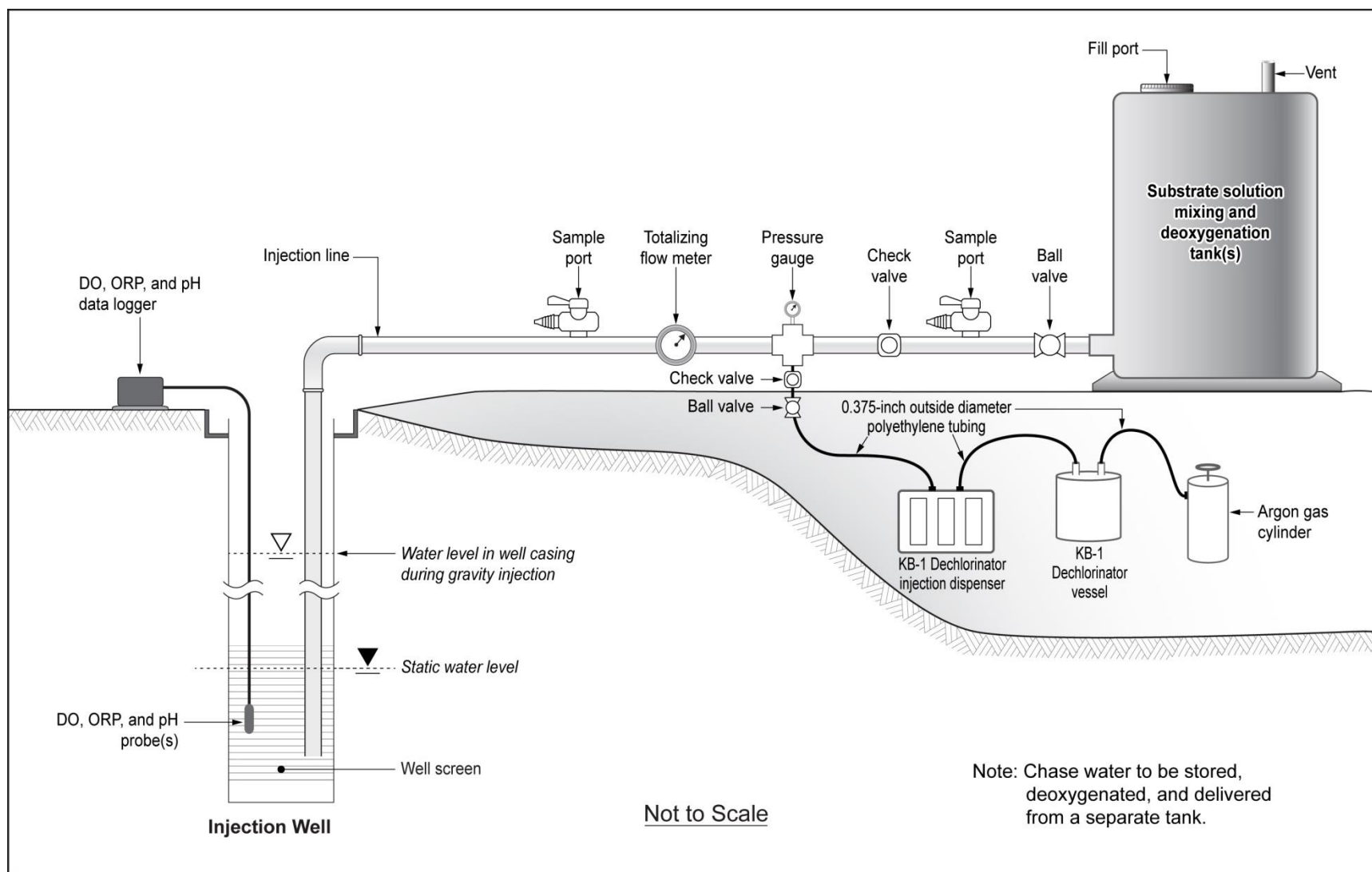
Depth-to-water measurements will be taken in wells TAV-INJ1, TAV-MW6, and TAV-MW7 before, during, and after injection. Injection flow rate into the injection well will be routinely monitored. The injection rate will be reduced, if necessary, to ensure the water level in the monitoring casing in well TAV-INJ1 remains below does not exceed 335 ft above static water level to prevent damage to the well. The injection rate of push/pull test will be used to optimize procedures for the full-scale injection.

~~A total of approximately 1.8 lbs of KB-1<sup>®</sup> Dechlorinator will be needed for the 3,700 gallons of substrate solution.~~

### Performance Monitoring of the Push/Pull Test and Decision Point #1

Performance monitoring of the push/pull test will commence after the target volume has been gravity-injected. The performance monitoring well network will consist of injection well TAV-INJ1 and nearby monitoring wells TAV-MW6 (screened across the water table), and TAV-MW7 (screened deeper). Post-injection performance monitoring will consist of weekly water level measurements, groundwater field parameter measurements, and groundwater sampling for analytical parameters for a period of eight weeks followed by monthly measurements and sampling for two months (a total of four months plus one month for final sample analysis and data validation). Section 5.3 lists the analyses and field measurements that will be conducted during each performance monitoring event.

Performance monitoring results up to this point will be evaluated as Decision Point #1 to determine if the push/pull test is successful and that the Treatability Study should proceed to full-scale injection at TAV-INJ1. Decision Point #1 evaluation criteria are listed below. Affirmative answers to these questions will support a decision to proceed to full-scale injection at TAV-INJ1. However, negative answers in of themselves do not preclude further study, but would at least require re-evaluation of implementation procedures or remedial approach before proceeding to full-scale injection.



**Figure 5-3**  
**Schematic of Gravity Injection System**



1. Did the gravity-injection rate indicate that TAV-INJ1 could accommodate the planned rate of 5,000 gpd for full-scale injection without exceeding the 335 ft of maximum pressure head in the well-monitoring casing?

This will be determined by measuring the injection rate and water levels in the injection well.

2. Did groundwater conditions in well TAV-INJ1 become and remain conducive to denitrifying nitrate and subsequently dechlorinating TCE and its daughter products?

Multiple lines of evidence that the injection is being effective at creating an environment that will stimulate ISB include:

- a. DO concentrations established and maintained well below 1 mg/L.
  - b. ORP measurements established and maintained at or below negative 75 mV.
  - c. Increases in ammonia and orthophosphate concentrations.
  - d. Decreases in nitrate concentration.
  - e. Decreases in sulfate concentration.
  - f. Increases in iron, manganese, or arsenic concentrations.
3. Was a sufficient population of *Dehalococcoides* (with vinyl chloride reductase) established to facilitate complete dechlorination at TAV-INJ1?

Over  $10^7$  gene copies/liter indicates a high potential for complete dechlorination.

4. Did COC concentrations in well TAV-INJ1 demonstrate a decreasing trend that will reach MCLs within the anticipated time frame of the full term performance monitoring?

Concentration decreases indicate either ISB is working or may-be-a-combined with the result of dilution, but support a decision to proceed with full-scale injection at TAV-INJ1.

5. Did bromide concentration ~~trend~~ initially increase and then attenuate during post-injection monitoring?

An initial increase in bromide concentration at a given location indicates that the substrate solution has been delivered to that point. Subsequent attenuation suggests advection of surrounding groundwater into the push/pull test treatment area. ~~Bromide concentration should decrease with successive sampling indicating that surrounding native groundwater is mixing with the re-injected groundwater.~~

6. Were TCE dechlorination daughter products produced?

An increase followed by a decrease in TCE daughter products indicates dechlorination is occurring. Because concentrations of TCE are initially very low, it may be difficult to detect some or all daughter products. Inability to quantify



dechlorination daughter products does not, in of itself, indicate a lack of complete dechlorination.

7. Did results from deeper well TAV-MW7 support the conclusion that further injections will not adversely affect deeper groundwater?

Increases in nitrate or bromide concentrations and detections of TCE or associated daughter products in well TAV-MW7 would indicate further injection could drive contamination deeper.

Additionally, stability of pH and increases in iron, manganese, and arsenic concentrations will be monitored. This is particularly of interest in deeper well TAV-MW7 where this would suggest vertical communication between the injection horizon and deeper sediments. Increases in dissolved iron, manganese, and arsenic can be expected within the anaerobic treatment area, but should re-precipitate as they migrate with groundwater back into aerobic environments.

Results from the push/pull test will be evaluated against the above criteria to determine if full-scale injection should proceed and if changes in implementation procedures are necessary to optimize full-scale injection and performance monitoring. **Results of the push/pull test and any associated revisions to procedures will be communicated to the NMED-HWB at least 60 days prior to proceeding with full-scale injection at TAV-INJ1.**

#### 5.4.2 Full-Scale Injection at TAV-INJ1

The objective of full-scale injection is to deliver substrate solution and bioaugmentation culture to the treatment area thereby facilitating denitrification of nitrate and dechlorination of TCE and any daughter products in the aquifer to concentrations below MCLs.

##### Full-Scale Injection of Substrate Solution and Bioaugmentation Culture into TAV-INJ1

Full-scale injection will involve mixing substrate solution components at prescribed ratios (Table 4-1) with potable water into ~~two 10,000~~two pairs of 5,000-gallon tanks (i.e., four 5,000-gallon tanks), deoxygenating the solution in the tanks and establishing an ORPPR below negative 75 mV, ~~then gravity draining half of each batch into TAV-INJ1~~. As in the push/pull test, the initial injection batch will be deoxygenated with KB-1<sup>®</sup> Primer and inoculated with TAV-INJ soil core/cuttings. Once the first pair of tanks are deoxygenated, the aboveground injection line and the injection casing will be primed and the water column in the well monitoring casing will be deoxygenated ~~by sparging with argon gas, and then~~ half of the tank contents (5,000 gallons) (2,500 gallons from each tank) will be injected into TAV-INJ1 along with the bioaugmentation culture. The tanks will be refilled with potable water and commensurate amounts of ethyl lactate, diammonium phosphate, yeast extract, and sodium bromide.

During the anticipated one to two days for the first pair of tanks to reestablish anaerobic conditions and an ORP less than negative 75 mV, 5,000 gallons of deoxygenated and low-ORP substrate solution will be injected from the ~~other second pair of 10~~5,000-gallon tank along with the bioaugmentation culture. The second pair of tanks will then be refilled with potable water and the associated substrate solution components like the first pair of tanks. Injection can proceed to the first pair of tanks while the second pair of tanks is-are being refilled and deoxygenated.

This process of alternating two pairs of tanks will continue for the duration of the injection provided it facilitates the most optimal injection schedule. By having ~~two 10,000~~two pairs of 5,000-gallon tanks onsite, the planned schedule assumes one 5,000-gallon batch can be injected per 8-hour work day by alternating deoxygenation and ready-to-inject pair of tanks each day.

A total of up to 530,000 gallons of substrate solution will be injected into TAV-INJ1. The estimated timeframe for injection is up to 24 work weeks. If monitoring results at monitoring well TAV-MW6 indicate that the substrate solution has reached that well and created the desired reducing conditions before the full 530,000 gallons has been injected, injection operations will be suspended to confirm that these conditions are stable. ~~The~~ injection will also be suspended if analytical results from deeper monitoring well TAV-MW7 detect an increase in nitrate concentration above 10 mg/L or if TCE or its chlorinated daughter products are detected.

Prior to each daily injection, the DO will be measured in the injection well water column to ensure it is sustaining anaerobic conditions and if not, it will be ~~sparged with argon~~ gasdeoxygenated prior to injection.

During injection, DO, ORP, and pH will be monitored in well TAV-INJ1 using downhole electronic probes and a data logger. Water levels will also be frequently monitored immediately prior and throughout each work day during injections. Additionally, wells TAV-INJ1, TAV-MW6, and TAV-MW7 will be monitored monthly during injection for the analyses (Table 5-4) and the field parameters listed in section 5.3.

Each daily injection batch will be followed with approximately 90-100 gallons of chase water consisting of unamended potable water deoxygenated by sparging with argon gas. This is intended to push substrate solution away from the well screen and surrounding filter pack pore space and into the formation to mitigate localized biofouling.

~~Additionally, wells TAV-INJ1, TAV-MW6, and TAV-MW7 will be monitored monthly during injection for the analyses (Table 5-5) and the field parameters listed in Section 5.3.~~

## Performance Monitoring of the Full-Scale Injection and Decision Point #2

Performance monitoring of the full-scale injection will commence after the target volume has been gravity-injected and within one month of the last sampling event during injection. The performance monitoring well network will continue to consist of wells TAV-INJ1, TAV-MW6, and TAV-MW7. Post-injection performance monitoring will be conducted for a total of 24 months at a monthly frequency for three months followed by quarterly monitoring for the remainder of the post-injection monitoring period. Section 5.3 lists the analyses (Table 5-~~45~~) and the field measurements that will be conducted during each performance monitoring event.

Within six months after Phase I full-scale injection is completed, sufficient data should be available for evaluation of Decision Point #2 to determine if the full-scale injection at TAV-INJ1 is successful and that the Treatability Study should proceed to Phase II: installation of injection wells TAV-INJ2 and TAV-INJ3 and associated full-scale injections at each location. Decision Point #2 evaluation criteria are listed below. Affirmative answers to these questions will support a decision to proceed to Phase II (i.e., expand the Treatability Study to two more locations). However, negative answers in of themselves do not preclude further study, but would at least

require re-evaluation of implementation procedures or remedial approach before proceeding to Phase II.

1. Was the planned full-scale injection volume injected within the anticipated time frame?

Lower than anticipated injection volumes or longer time frames may render Phase II injections impractical or require revision to procedures.

2. Did groundwater conditions in wells TAV-INJ1 and TAV-MW6 become and remain conducive to denitrifying nitrate and subsequently dechlorinating TCE and its daughter products?

Multiple lines of evidence that the injection is being effective at creating an environment that will stimulate ISB include:

- a. DO concentrations established and maintained well below 1 mg/L.
- b. ORP measurements established and maintained at or below negative 75 mV.
- c. Increases in ammonia and orthophosphate concentration.
- d. Decreases in nitrate concentration.
- e. Decreases in sulfate concentration.
- f. Increases in iron, manganese, or arsenic concentrations.

3. Was a sufficient population of *Dehalococcoides* (with vinyl chloride reductase) established to facilitate complete dechlorination both at TAV-INJ1 and at TAV-MW6?

Over  $10^7$  gene copies/liter indicates a high potential for complete dechlorination.

4. Did COC concentrations in wells TAV-INJ1 and TAV-MW6 decrease below MCLs?

Concentration decreases indicate either ISB is working or ~~may be a combined~~ with the result of dilution, but support a decision to proceed with full-scale injections at TAV-INJ2 and TAV-INJ3.

5. Did bromide concentrations ~~s-trends~~ initially increase and then attenuate during post-injection monitoring?

An initial increase in bromide concentration at a given location indicates that the substrate solution has been delivered to that point. Subsequent attenuation suggests advection of surrounding native groundwater into the treatment area.

6. Were TCE dechlorination daughter products produced?

An increase followed by a decrease in TCE daughter products indicates dechlorination is occurring. Because concentrations of TCE are initially very low, it may be difficult to detect some or all daughter products. Inability to quantify dechlorination daughter products does not, in of itself, indicate a lack of complete dechlorination.

7. Did results from deeper well TAV-MW7 support the conclusion that further injections will not adversely affect deeper groundwater?

Increases in nitrate or bromide concentrations and detections of TCE or associated daughter products in well TAV-MW7 would indicate further injection could drive contamination deeper.

The monitoring data collected during the full-scale injection and during the six months after injection is completed will be evaluated against the above criteria to determine if the Treatability Study should proceed to Phase II. **These interim performance results and any associated revisions to procedures will be communicated to NMED-HWB along with the decision whether to proceed to Phase II.**

## 5.5 ~~New Groundwater Monitoring Wells~~ Impact on Groundwater and Additional Monitoring

~~After injection well TAV-INJ1 has been installed and Phase I of the ISB Treatability Study is in progress, two additional groundwater monitoring wells (TAV-MW15 and TAV-MW16) will be installed immediately south of the TA-V boundary to better define the southern extent of the TCE plume. The locations for these two wells are shown in Figure 4-1. Construction of these wells is discussed in section 5.2.4. As explained in section 3.0, biodegradation is intended to initially reduce nitrate concentration through denitrification, followed by reductive dechlorination of TCE in the aquifer. Reductive dechlorination occurs under anaerobic and reducing conditions in the aquifer. The process of developing strongly anaerobic redox conditions is likely to result in solubilization and mobilization of some naturally occurring oxidized metals and metalloids, most particularly iron, manganese, and arsenic, as a result of direct reduction and mineral dissolution. Increases in dissolved iron and manganese concentrations are indicators of biodegradation in an anaerobic and reducing environment. However, the solubilization of these metals is generally a transient phenomenon and is limited to the treatment zone. Solubilized metals and metalloids will precipitate into solid form once they leave the anaerobic treatment zone or after the aquifer returns to aerobic conditions in the treatment zone.~~

~~Concentrations of dissolved iron, manganese, and arsenic will be monitored within the Treatability Study treatment zone (Table 5-4). In order to monitor the impact of substrate solution discharge on groundwater outside Treatability Study treatment zone, an additional eight wells will be monitored for dissolved iron, manganese, and arsenic, including TAV-MW2, TAV-MW4, TAV-MW8, TAV-MW11, TAV-MW12, TAV-MW14, and two of the three monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW10 inside the treatment zone that are not companion wells for ISB injection. These wells are chosen because they are the nearest existing monitoring wells surrounding the treatment zone as wells as nearest to the ISB injection. Figure 4-1 shows the locations of these monitoring wells. Dissolved iron, manganese, and arsenic will be monitored on a quarterly basis.~~

## 5.6 Phase II Injections and Performance Monitoring

Phase II design and implementation procedures will be modified to optimize performance based on lessons learned during Phase I.

Phase II will expand ISB full-scale injection to two additional locations. Injection well TAV-INJ2 will be located near ~~groundwater~~ monitoring well TAV-MW10 at SWMU 275 and injection well TAV-INJ3 will be located near monitoring well LWDS-MW1. The approximate locations of wells TAV-INJ2 and TAV-INJ3 are shown in Figure 4-1. The objectives of Phase II mirror that of the full-scale injection at well TAV-INJ1 in Phase I.

The mixing ratios of substrate solution will be adjusted as necessary based on performance indicators from the TAV-INJ1 injection. Water level measurements, field parameter measurements, and groundwater sampling and analysis will be conducted at the injection well and paired groundwater monitoring well ~~at the same frequency as specified for the post~~similarly to those conducted for the full-scale injection ~~performance monitoring~~ in Phase I.

Monitoring will be conducted monthly during injection. Post-injection performance monitoring will be conducted for a total of 24 months at a monthly frequency for three months followed by quarterly monitoring for the remainder of the post-injection monitoring period. Section 5.3 lists the analyses (Table 5-~~45~~) and the field measurements that will be conducted during each performance monitoring event.

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## 6.0 GROUNDWATER MONITORING AT TECHNICAL AREA-V GROUNDWATER AREA OF CONCERN

### 6.1 Groundwater Monitoring during the Treatability Study

The Treatability Study focuses on three groundwater monitoring wells LWDS-MW1, TAV-MW6, and TAV-MW10 that have the highest TCE concentrations. Sampling of deeper well TAV-MW7 that is paired with TAV-MW6 is also included in the Treatability Study. During the course of the Treatability Study, each of the four wells will be monitored quarterly unless it becomes a companion well for an injection well and the monitoring parameters and frequency will then be superseded by the Treatability Study design as specified in section 5.0.

The other wells of the TAVG monitoring network that are not part of the Treatability Study are currently being monitored quarterly or semi-annually for the parameters listed in Table 5-5 of the Calendar Year 2014 Annual Groundwater Monitoring Report (SNL/NM June 2015). Based on the evaluations detailed in the CCM document (SNL/NM September 2015), the following sampling frequency and parameters will be implemented.

- Reduce the sampling frequency of the perimeter wells that are most distant from the contaminant plumes (AVN-1, LWDS-MW2, TAV-MW3, and TAV-MW5) and the sampling frequency of two of the three deep wells (TAV-MW9 and TAV-MW13).
- Reduce the sampling frequency of wells AVN-1, LWDS-MW2, and TAV-MW13 from quarterly to annually.
- Reduce the sampling frequency of wells TAV-MW3, TAV-MW5, and TAV-MW9 from semi-annually to annually.
- The sampling frequency of the third deep monitoring well TAV-MW7 will remain semi-annual.
- Reduce the sampling parameters as described in section 7.3 of the CCM document (SNL/NM September 2015). Along with the parameters intended for monitored natural attenuation (dissolved iron, dissolved manganese, calcium, magnesium, potassium, sodium, sulfide, and total organic carbon), quarterly sampling of the general chemistry parameters (alkalinity, chloride, and sulfate) have also become unnecessary. Consequently, the quarterly sampling parameters will include ~~only~~ NPN and VOCs. Dissolved metals (arsenic, iron, and manganese) will also be analyzed for the eight wells listed in section 5.5 on a quarterly basis.
- Continue annual sampling of general chemistry, radiological screening parameters, and total metals to supplement waste characterization requirements.

Table 6-1 summarizes the proposed sampling parameters and sampling frequency for the future 18-well monitoring network (current 16 plus TAV-MW15 and TAV-MW16) at the TAVG AOC.

For the two newly installed groundwater monitoring wells (TAV-MW15 and TAV-MW16), four quarters of perchlorate analysis will be performed in accordance with the Consent Order (NMED April 2004); in addition to parameters specified in Table 6-1.

Table 6-1  
Parameters Sampled at TAVG Monitoring Wells for  
each Sampling Event during the Treatability Study

First Quarter of a Calendar Year		Second Quarter of a Calendar Year	
Parameter	Monitoring Wells	Parameter	Monitoring Wells
NPN VOCs <u>Dissolved Metals (arsenic, iron, manganese)<sup>a</sup></u>	LWDS-MW1 <sup>ba</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>ba</sup> TAV-MW8 TAV-MW10 <sup>ba</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>cb</sup> TAV-MW16 <sup>cb</sup>	NPN VOCs General Chemistry <sup>de</sup> Radiological Screening Parameters <sup>de</sup> Total Metals <sup>de</sup> <u>Dissolved Metals (arsenic, iron, manganese)<sup>a</sup></u>	AVN-1 LWDS-MW1 <sup>ba</sup> LWDS-MW2 TAV-MW2 TAV-MW3 TAV-MW4 TAV-MW5 TAV-MW6 <sup>ba</sup> TAV-MW7 <sup>ba</sup> TAV-MW8 TAV-MW9 TAV-MW10 <sup>ba</sup> TAV-MW11 TAV-MW12 TAV-MW13 TAV-MW14 TAV-MW15 <sup>cb</sup> TAV-MW16 <sup>cb</sup>
Third Quarter of a Calendar Year		Fourth Quarter of a Calendar Year	
Parameter	Monitoring Wells	Parameter	Monitoring Wells
NPN VOCs <u>Dissolved Metals (arsenic, iron, manganese)<sup>a</sup></u>	LWDS-MW1 <sup>ba</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>ba</sup> TAV-MW8 TAV-MW10 <sup>ba</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>cb</sup> TAV-MW16 <sup>cb</sup>	NPN VOCs <u>Dissolved Metals (arsenic, iron, manganese)<sup>a</sup></u>	LWDS-MW1 <sup>ba</sup> TAV-MW2 TAV-MW4 TAV-MW6 <sup>ba</sup> TAV-MW7 <sup>ba</sup> TAV-MW8 TAV-MW10 <sup>ba</sup> TAV-MW11 TAV-MW12 TAV-MW14 TAV-MW15 <sup>cb</sup> TAV-MW16 <sup>cb</sup>

<sup>a</sup> Eight wells will be monitored: TAV-MW2, TAV-MW4, TAV-MW8, TAV-MW11, TAV-MW12, TAV-MW14, and two of the three monitoring wells (LWDS-MW1, TAV-MW6, and TAV-MW10 inside the treatment zone that are not companion wells for ISB injection).

<sup>ba</sup> Sampling parameters and frequency will be superseded by the Treatability Study design when the well becomes a companion well for ISB injection (see section 5.0).

<sup>cb</sup> Four quarters of perchlorate analysis will be performed for newly installed groundwater monitoring wells in accordance with the Consent Order (NMED April 2004).

<sup>de</sup> Waste characterization parameters for compliance with SNL/NM Corporate Procedures and Policies.

AVN = Area V (North).

LWDS = Liquid Waste Disposal System.

MW = Monitoring well.

NPN = Nitrate plus nitrite (reported as nitrogen).

TAV = Technical Area-V (monitoring well designation).

TAVG = Technical Area-V Groundwater.

the Consent Order = The Compliance Order on Consent.

VOC = Volatile organic compound.



## 6.2 Post-Treatability Study Groundwater Monitoring

The groundwater monitoring program for TAVG AOC will be re-evaluated during the preparation of the Treatability Study report. During report preparation and review, groundwater monitoring will be discontinued at the three injection wells, but continue quarterly at wells LWDS-MW1, TAV-MW6, TAV-MW7, and TAV-MW10.

Factors to be considered in the monitoring program re-evaluation will include but not limited to:

- Groundwater flow direction and gradient.
- Groundwater parameters.
- Remaining COC and associated daughter product concentrations.
- Magnitude of COC concentration rebound or attenuation after treatment.
- Concentrations of other constituents regulated under the NMED GWQB-~~Discharge~~ Permit, if applicable.

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## 7.0 WASTE MANAGEMENT

A project-specific WMP will be prepared upon approval of this Work Plan that will address handling and storage, labeling, profiling, transportation, and disposal of the following categories of waste generated during the Treatability Study.

- Drilling waste.
- Sampling waste (i.e., purge water).
- Excess substrate solution constituents.
- Excess bioaugmentation culture.
- Used personal protective equipment (PPE).
- Trash and used containers or other expendables (e.g., substrate containers/packaging).

Safety procedures related to handling waste generated during decontamination will be incorporated in the Health and Safety Plan.

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## **8.0 HEALTH AND SAFETY**

Level D PPE is required for all personnel performing field activities associated with drilling, well installation and development, and soil sampling.

Level D PPE is also required for all field personnel conducting Treatability Study work involving groundwater extraction, substrate and component handling and injection, and groundwater sampling.

Respiratory protection for dust inhalation is recommended by the manufacturer for field personnel handling the KB-1<sup>®</sup> Primer.

Health and safety records associated with drilling, well installation and development, and the Treatability Study personnel will be maintained on site and will be available from the commencement of respective activities.

All personnel will operate under an SNL/NM HASP and will have SNL/NM-required training including 40-Hour Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) training and subsequent yearly refresher courses. An SNL/NM Subject Matter Expert will perform a safety inspection of the drill rig before drilling commences.

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## 9.0 REPORTING

The results of this Treatability Study will be documented in accordance with the requirements established by the NMED, NMOSE, and SNL/NM FOPs.

Reporting will consist of the following:

- Well Installation Report and Results of Push/Pull Test– documenting well installation activities and the results of push/pull test.
- Technical Memorandum – documenting activities and performance results from Phase I of the Treatability Study and making recommendations regarding the implementation of Phase II and any necessary procedural revisions.
- Treatability Study Report – documenting activities and performance results from Phase II of the Treatability Study, synthesizing conclusions from both phases, and making recommendations for completing remediation of the TAVG AOC.

Additionally, Environmental Restoration Operations continue to submit Consolidated Quarterly Report to the NMED. Progress of the Treatability Study will be documented in the Consolidated Quarterly Report as part of the status reporting for TAVG AOC.

A summary of activities and results during the prior calendar year will be included in the TAVG section of the Annual Groundwater Monitoring Report.

In addition to reporting, verbal or written communications and meetings will be ongoing with NMED as necessary.

### 9.1 Well Installation Report and Results of Push/Pull Test

Well Installation Report will be completed to document well installation field activities. One report will be prepared after wells TAV-INJ1, TAV-MW15, ~~and~~ TAV-MW16, and TAV-INJ1 have been installed and ~~developed~~ the push/pull test has been completed. This report will include well installation and the results of push/pull test. A second well installation report, ~~and another~~ will be prepared for wells TAV--INJ2 and TAV-INJ3 provided they are installed.

The well installation report will document site activities and provide final as-built well completion diagrams. Information to be contained in the report includes: (1) the 37 information elements required in section VIII.D of the Consent Order (NMED April 2004), (2) a description of all materials used, (3) final as-built well diagrams, and (4) documentation of notification of Sandia Geographic Information System group and the appropriate regulatory agencies. The following list of documents and records that are generated as part of the well installation process will be provided to the Sandia Well File Coordinator who, in turn, will submit them to the Sandia Customer Funded Record Center:

- Well file contents checklist.
- Well data summary sheet.

- Statement of Work for drilling the well.
- Drilling permit from NMOSE.
- Lithologic log.
- Well construction diagram and completion parameters.
- Well development data and groundwater parameters.
- Copies of field logbook ~~(geologist, driller)~~.
- Surveyed elevation and location in New Mexico state plane coordinates (with a degree of accuracy of  $\pm 0.01$  ft) from a New Mexico-licensed surveyor.
- Location map.
- Water level measurements.
- Borehole geophysical logs.
- Geophysical logs for completed wells.
- Aquifer test data.
- Analytical data.
- Waste management documentation.
- Photographs.

## 9.2 Technical Memorandum

A Technical Memorandum will be prepared upon the completion of the Phase I performance monitoring. This document will include documentation of field activities and results from the short-term push/pull test and the subsequent full-scale injection and associated performance monitoring. It will also present recommendations for either proceeding with Phase II along with any associated revisions to procedures, or to discontinue the Treatability Study based on Phase I results.

## 9.3 Treatability Study Report

A Treatability Study Report will be prepared upon the completion of the Phase II performance monitoring. It will include documentation of all field activities conducted under the Treatability Study, as well as Treatability Study results and recommendations for completing remediation of the TAVG AOC.



## 10.0 SCHEDULE

Figure 10-1 shows a general flow chart of the Treatability Study with estimated durations. The two primary decision points are shown. Decision Point #1 occurs at the end of the Phase I push/pull test ~~(TAV-INJ1)~~ performance monitoring at TAV-INJ1. Data will be evaluated against the performance criteria to determine if the test should proceed to full-scale injection at TAV-INJ1. Decision Point #2 occurs six months into the performance monitoring after the TAV-INJ1 full-scale injection is complete where data to that point will be evaluated to determine if the test should scale up to Phase II (installation of TAV-INJ2 and TAV-INJ3 and successive full-scale injections at those locations). Regardless of the decision whether to proceed with Phase II or not, the planned 24 months of Phase I post-injection performance and rebound monitoring will be completed.

# PHASE I

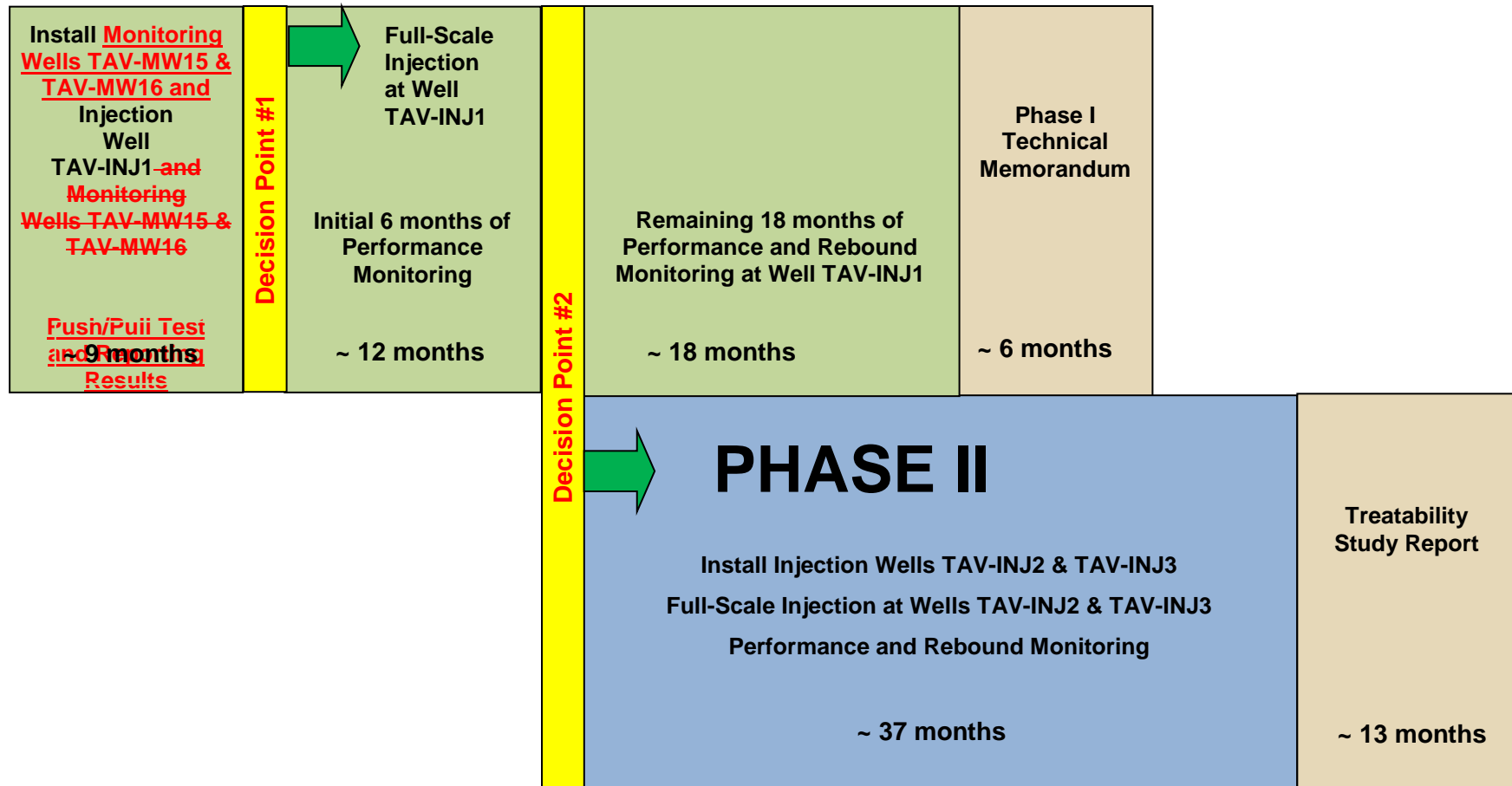


Figure 10-1  
Treatability Study Flow Chart with Estimated Durations (not to Scale)

## 11.0 REFERENCES

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**APPENDIX A**  
**Electron Donor Demand Calculation**



## ELECTRON DONOR DEMAND AND MASS CALCULATIONS

The following spreadsheets present the calculations to estimate the mass of ethyl lactate needed to meet electron donor demand in groundwater and soil within the projected treatment area for each full-scale injection to be implemented during Phase I and Phase II of the Treatability Study.

The spreadsheet first presents the dimensions of the treatment area for one injection location. Each of the three injection locations is assumed to have the same treatment zone dimensions and effective porosity. Electron donor demand also used electron acceptor concentrations from monitoring well LWDS-MW1 where concentrations of nitrate and TCE are highest. Electron donor demand calculations will be performed on a location-specific basis based on initial sampling results from injection wells once they are installed and these results will be used to refine substrate solution constituent ratios prior to injection.

Electron donor demand was divided into three categories that calculate demand based on a stoichiometric ratio:

- Electron donor demand for competing terminal electron acceptors (TEAs).
- Electron donor demand for dissolved volatile organic compounds (VOCs).
- Electron donor demand for VOCs sorbed to saturated soil.

Experience from projects at similar sites shows that the theoretical stoichiometric value is often not sufficient to create the desired conditions. Research (Lee et al. March 2004) shows that only 30 percent of the electron donor is utilized for dechlorination (referred to as the 'McCarty' factor). The McCarty factor was applied to calculate electron donor demand based on stoichiometry. A safety factor of 10 was then applied based on full-scale field experience and to account for low permeability of the saturated sediments at the site.<sup>1</sup>

Estimated delivery timeframe per full-scale injection is also presented based on the assumption that 5,000 gallons per day of potable water mixed with the electron donor, amendments, and bioaugmentation culture could be gravity-injected each work day, plus an additional three weeks to allow for system set up and optimization.

Due to the very low concentrations of VOCs, the total electron donor demand is almost completely governed by concentrations of competing terminal electron acceptors in groundwater (dissolved oxygen, nitrate, iron, manganese, and sulfate). The bulk of electron donor will be adjusted in-situ for reductive dechlorination to take place.

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<sup>1</sup> Brian Timmins (Director, Etec, LLC Environmental Technologies, discussions with Thomas Berry (Senior Geologist, CE2 Corporation, Pleasanton, California contracted to SNL/NM) regarding electron donor selection, demand, and mass calculations (April 2014 through July 2015).

## Electron Donor (Ethyl Lactate) Demand and Mass Calculations

### Dimensions of Treatment Area (one injection well)

Delivery Radius	60	ft	Effective Porosity	0.25	
Area	11,310	ft <sup>2</sup>	Volume of soil matrix	7,854	CY
Thickness	25	ft	Pore Volume (PV)	70,688	ft <sup>3</sup>
Total Target Volume	282,750	ft <sup>3</sup>	Pore Volume (PV)	2,001,661	L
Total Target Volume	10,472	CY	<b>Pore Volume (PV)</b>	<b>528,783</b>	<b>gal</b>

### Electron Donor Demand for Competing Terminal Electron Acceptors (TEAs)

TEA	Concentration (mg/L) <sup>a</sup>	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol TEA)	Electron Donor Demand (mg/L)
Dissolved oxygen	7.28	32	1/6	4.478
Nitrate	12.7	62	5/24	5.040
Iron	20	55.9	1/24	1.761
Manganese	20	54.9	1/12	3.585
Sulfate	41.5	96	1/3	17.018
<b>Electron donor: ethyl lactate</b>		<b>118.1</b>		
Total electron donor demand (mg/L)				31.882
Treatment area pore volume (L)				2,001,661
Total electron donor demand (mg)				63,816,956
<b>Total electron donor demand for competing TEAs (lbs) – rounded to nearest 0.1 lb.</b>				<b>140.7</b>



### Electron Donor Demand for Dissolved Volatile Organic Compounds (VOCs)

VOC	Concentration (µg/L) <sup>a</sup> November 2014	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol VOC)	Electron Donor Demand (µg/L)
PCE	0	165.8	1/3	0.000
TCE	16.9	131.4	1/4	3.797
cis-1,2-DCE	3.45	96.9	1/6	0.701
VC	0	62.5	1/12	0.000
Subtotal electron donor demand (µg/L) (based on ethyl lactate)				4.498
Treatment area pore volume (L)				2,001,823
Total electron donor demand (µg)				9,004,510
<b>Total electron donor demand for dissolved VOCs (lbs)</b>				<b>0.020</b>

### Electron Donor Demand for VOCs Sorbed to Saturated Soil

VOC	Concentration in groundwater (µg/L) <sup>a</sup>	Koc (mL/g) <sup>b</sup>	foc <sup>c</sup>	Concentratio n sorbed to soil (µg/kg)	Molecular Weight (g/mol)	Molar Ratio (mol electron donor / mol VOC)	Electron Donor Demand (µg/kg)
PCE	0	265	0.000539	0	165.8	1/3	0
TCE	16.9	94.3		0.859	131.4	1/4	0.193
cis-1,2-DCE	3.45	35.5		0.066	96.9	1/6	0.013
VC	0	18		0	62.5	1/12	0
Subtotal electron donor demand (µg/kg) (based on ethyl lactate)							0.206
Treatment area soil volume (CY)							7,854
Soil bulk density (kg/cm <sup>3</sup> )							0.0018
Soil bulk density (kg/CY)							1,376
Treatment area soil mass (kg)							10,808,642
Total electron donor demand (µg)							2,231,123
Total electron donor demand for VOCs sorbed to saturated soil (lbs)							0.008

### Mass of Electron Donor to be Injected

Total electron donor demand for competing TEAs (lbs)	140.7
Total electron donor demand for dissolved VOCs (lbs)	0.020
Total electron donor demand for VOCs sorbed to saturated soil (lbs)	0.005
<b>Total electron donor demand as ethyl lactate</b>	<b>140.7</b>
Adjusted total accounting for the McCarty Factor (30% efficiency) (lbs) <sup>d</sup>	469
Safety factor for Low K Sediment	10
<b>Total electron donor to be Injected in one pore volume (lbs)</b>	<b>4,690</b>
<b>Total electron donor to be Injected per 1,000 gallons of water (lbs)</b>	<b>8.9</b>

### Injection timeframe

Target Volume (gal)	<b>528,783</b>
# Injection Wells	1
Total Injection Volume (gal)	528,783
Batch volume (gal)	5,000
Batches/day	1
<b>Estimated injection rate (gpd)</b>	<b>5,000.00</b>
Total injection batches for one pore volume (rounded up to nearest whole batch)	106
Total injection timeframe (days)	106
<b>Total injection timeframe (weeks) - assume 5 days/week + 3 weeks for system set up, optimization, and demobilization</b>	<b>24</b>

**Acronyms & Abbreviations:**

µg/kg	= Micrograms per kilograms.
µg/L	= Micrograms per liter.
CY	= Cubic yard.
DCE	= Dichloroethene.
foc	= Fraction of organic carbon.
ft	= Feet/foot.
ft <sup>2</sup>	= Square feet.
ft <sup>3</sup>	= Cubic feet.
g/mol	= Grams per mole.
gal	= Gallons.
gpd	= Gallons per day.
K	= Hydraulic conductivity.
kg/cm <sup>3</sup>	= Kilograms per cubic centimeter.
kg/CY	= Kilograms per cubic yard.
Koc	= Soil organic carbon-water partitioning coefficient.
L	= Liter.
lbs	= Pounds.
mg	= Milligrams.
mg/L	= Milligrams per liter.
mL/g	= Milliliters per gram.
mol	= Mole(s).
PCE	= Tetrachloroethylene.
TEA	= Terminal electron acceptor.
TCE	= Trichloroethene.
VC	= Vinyl chloride.
VOCs	= Volatile organic compounds.

**Notes:**

See footnote 1 on page A-1.

<sup>a</sup> Concentrations in LWDS-MW1 from November 2014 groundwater sampling event. Iron and manganese concentrations are estimated values under anaerobic conditions based on field experience.

<sup>b</sup> Koc values taken from 1996 EPA Soil Screening Criteria.

<sup>c</sup> SNL/NM Site-Wide Hydrogeologic Characterization Project (February 1998), Table 3.2.3-1 Mean TOC = 539 mg/kg = 0.000539 foc. Based on samples collected at Chemical Waste Landfill (and a few from Mixed Waste Landfill).

<sup>d</sup> Lee, Il-Su, Joe-Ho Bae, Yanru Yang, Perry L. McCarty, March 2004. "Simulated and Experimental Evaluation of Factors Affecting the Rate and Extent of Reductive Dehalogenation of Chloroethenes with Glucose," Journal of Contaminant Hydrogeology, 74: pp. 313-331.

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**APPENDIX B**  
**Safety Data Sheets**

**Ethyl lactate**  
**Diammonium phosphate**  
**Yeast extract**  
**Sodium bromide**  
**KB-1<sup>®</sup> Primer**  
**KB-1<sup>®</sup> Dechlorinator**



## Ethyl-(S)-Lactate

REVISION DATE 07/05/07  
REF. SD0310/2007-01

### 1. IDENTIFICATION OF THE SUBSTANCE / PREPARATION AND THE COMPANY / UNDERTAKING

<b>Product name</b>	PURASOLV® EL, PURASOLV® ELECT		
<b>Use of the Substance</b>	Solvent, Flavour, Specialty chemical		
<b>Supplier</b>	PURAC biochem Arkelsedijk 46 NL-4206 AC Gorinchem The Netherlands	PURAC bioquímica Gran Vial 19 -25 08160 Montmelo-Barcelona Spain	
<b>Telephone</b>	++31 183 695695	++34 93 568 6300	
<b>Fax</b>	++31 183 695604	++34 93 568 3955	
<b>Emergency telephone</b>	++31 183 695695	++34 93 568 6300 (Ext 222)	

### 2. COMPOSITION / INFORMATION ON INGREDIENTS

<b>Chemical name of the substance</b>	Ethyl (S)-2-Hydroxy Propanoate			
<b>Synonyms</b>	Lactic Acid Ethyl Ester, Ethyl-L-Lactate			
<b>Components</b>	<b>CAS-No.</b> 687-47-8	<b>EC-No.</b> 211-694-1	<b>RTECS-No.</b> OD5075000	<b>Weight, %</b> 100
<b>Hazard classification</b>	R10, R37, R41. For details see chapter 15.			

### 3. HAZARDS IDENTIFICATION

<b>Most important hazards</b>	Risk of serious damage to eyes. Irritating to eyes. Combustible liquid.
<b>Specific hazards</b>	May degrease the skin. Effects of skin contacts may include erythema.

### 4. FIRST AID MEASURES

<b>General advice</b>	Show this safety data sheet to the doctor in attendance.
<b>Inhalation</b>	Move to fresh air.
<b>Skin contact</b>	Wash off immediately with plenty of water.
<b>Eye contact</b>	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes.
<b>Ingestion</b>	Induce vomiting if person is conscious. Consult a physician.
<b>Major effects of exposure</b>	Inhalation of vapors is irritating to the respiratory system, and may cause coughing. Irritating to eyes. May degrease the skin.
<b>Protection of firstaiders</b>	Wear tightly fitting safety goggles.

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## Ethyl-(S)-Lactate

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### 5. FIRE-FIGHTING MEASURES

<b>Suitable extinguishing media</b>	Water spray, carbon dioxide (CO <sub>2</sub> ), dry powder, AFFF, foam.
<b>Extinguishing media which must not be used for safety reasons</b>	None.
<b>Specific hazards</b>	Thermal decomposition can lead to release of irritating gases and vapors.
<b>Special protective equipment for firefighters</b>	None.
<b>Specific methods</b>	Standard procedure for chemical fires. Cool containers / tanks with water spray.

### 6. ACCIDENTAL RELEASE MEASURES

<b>Personal precautions</b>	Remove all sources of ignition. Wear tightly fitting safety goggles.
<b>Environmental precautions</b>	No special environmental precautions required.
<b>Methods for cleaning up</b>	Soak up with inert absorbent material (e.g. sand, silica gel, universal binder, sawdust). Shovel into suitable container for disposal. After cleaning, flush away traces with water.

### 7. HANDLING AND STORAGE

<b>Handling</b>	
<b>Technical measures/Precautions</b>	Remove all sources of ignition. Avoid temperatures above 139°F (59°C).
<b>Safe handling advice</b>	Wear tightly fitting safety goggles. Handle in accordance with good industrial hygiene and safety practice.
<b>Storage</b>	
<b>Technical measures/Storage conditions</b>	Keep container tightly closed. In order to prevent oxidation, the product is supplied under a nitrogen or argon blanket. After opening the packaging, it is recommended to use or store the product under inert conditions (e.g. nitrogen or argon).
<b>Packaging material</b>	High density polyethylene containers.



## Ethyl-(S)-Lactate

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### 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

<b>Engineering measures to reduce exposure</b>	Insure adequate ventilation, especially in confined areas.
<b>Control parameters</b>	None.
<b>Personal protection equipment</b>	
<b>Respiratory protection</b>	In case of insufficient ventilation wear suitable respiratory equipment.
<b>Hand protection</b>	Solvent-resistant gloves (PVA / H4).
<b>Eye protection</b>	Tightly fitting safety goggles.
<b>Skin and body protection</b>	Solvent-resistant apron.
<b>Hygiene measures</b>	When using, do not eat, drink or smoke. Remove and wash contaminated clothing before re-use.

### 9. PHYSICAL AND CHEMICAL PROPERTIES

<b>Form</b>	liquid
<b>Color</b>	colorless
<b>Odor</b>	mild, characteristic
<b>Odor Threshold</b>	0.18 ppm
<b>pH</b>	not applicable
<b>Molecular Weight</b>	118.15
<b>Boiling point/range</b>	307°F (153°C)
<b>Melting point/range</b>	26.6°F (-3 °C)
<b>Decomposition temperature</b>	> 307°F (153°C)
<b>Autoignition temperature</b>	752°F (400°C)
<b>Flash point</b>	139°F (59°C) (Tested according to: ISO 2719, closed cup)
<b>Explosion limits</b>	- lower: 1.5% @ 212°F (100°C) - upper: 11.4% @ 212°F (100°C)
<b>Density</b>	1.033 g/ml @ 68°F (20°C)
<b>Vapor density</b>	4.07 (Air = 1)
<b>Vapor pressure</b>	2.7 mbar @ 68°F (20°C), 172 mbar @ 212°F (100°C)
<b>Solubility</b>	Water solubility: completely miscible, miscible with most organic solvents Partition coefficient (n-octanol/water) log Pow = 0.06
<b>Viscosity</b>	2.8 mPa.S @ 68°F (20°C)
<b>Surface Tension</b>	30.6 mN/m @ 77°F (25°C)

### 10. STABILITY AND REACTIVITY

<b>Stability</b>	Stable at normal conditions. Hydrolyses in presence of water, acids, bases.
<b>Conditions to avoid</b>	Avoid temperatures above 139°F (59°C).
<b>Materials to avoid</b>	None.
<b>Hazardous decomposition products</b>	Carbon oxides.

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### 11. TOXICOLOGICAL INFORMATION

<b>Acute toxicity</b>	LD50/oral/mouse = 2500 mg/kg LC50/inhalation/8h/rat > 5400 mg/m <sup>3</sup>
<b>Sub acute Toxicity (28 day inhalation)</b>	NOAEL (systemic toxicity) 600mg/m <sup>3</sup> , NOAEL (local toxicity) 200 mg/m <sup>3</sup>
<b>Local effects</b>	Effects of skin contacts may include erythema. Irritating to eyes. Risk of serious damage to eyes. May cause irritation of the mucous membranes. Inhalation of high vapor concentrations can cause CNS-depression and narcosis.
<b>Specific effects</b>	Based on tests with L-lactic acid and its esters, there is no evidence to suggest carcinogenic nor mutagenic properties from lactic acid itself nor from the lactate portion of its esters. Developmental toxicity in rats: No effect at 3.619 g/kg/day.
<b>Long term toxicity</b>	Repeated or prolonged exposure may cause irritation of eyes and skin.
<b>Further information</b>	Lactate esters are readily hydrolyzed in vivo.

### 12. ECOLOGICAL INFORMATION

<b>Mobility</b>	Completely miscible in water.
<b>Persistence / degradability</b>	Readily biodegradable, according to appropriate OECD test. Biochemical oxygen demand (BOD)=1.43 mg O <sub>2</sub> /mg Chemical oxygen demand (COD)=1.66 mg O <sub>2</sub> /mg.
<b>Bioaccumulation</b>	Unlikely, hydrolyses in presence of: water, acids, bases.
<b>Ecotoxicity</b>	EC50/48h/Daphnia = 683mg/l LC50/48h/Fish = 320 mg/l EC50/Algae = 2200 mg/l

### 13. DISPOSAL CONSIDERATIONS

<b>Waste from residues / unused products</b>	Subject to disposal regulations US EPA 40 CFR 2 62.
<b>Contaminated packaging</b>	Clean container with water. Empty containers should be taken for local recycling, recovery or waste disposal.

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## Ethyl-(S)-Lactate

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### 14. TRANSPORT INFORMATION

**HI/UN No:** 30/1192  
**ADR/RID** Class 3 Item 31°(c) ADR/RID-Labels 3  
Proper shipping name Ethyl Lactate, 3,31°(c)  
**IMO** Class 3.3 IMDG Page 3343 IMO-Labels Flammable liquid  
Packaging group. III EmS. F-E S-D MFAG. 330  
Proper shipping name Ethyl Lactate, UN 1192  
**ICAO** Class 3 UNID No. 1192 ICAO-Labels Flammable liquid  
Packing group III  
Proper shipping name Ethyl Lactate, UN 1192  
**US DOT (see further information below)**  
UN 1192 Class 3 DOT Labels Flammable liquid  
Packaging group. III  
Maximum quantity (passenger aircraft): 60 liters Maximum quantity (cargo aircraft): 220 liters

#### Further information

In the US, PURASOLV EL is a combustible liquid, and not regulated for non bulk shipments (truck). It is regulated for air and rail shipments.

### 15. REGULATORY INFORMATION

**US Regulations** TSCA Inventory Status: Y  
SARA III: N  
California Proposition 65: N  
Carcinogen status: OSHA: N. NTP: N, IARC: N  
Gras as food flavor, ADI not specified.  
Massachusetts Substances List: Y  
Pennsylvania Right to Know List: Y  
According to National equivalent of EC-Dir. 67/548, as amended, the product is labeled as follows:  
**EU Status**  
**Symbol** Xi - Irritant  
**R-Phrases** R41 - Risk of serious damage to eyes  
R37 - Irritation to respiratory system  
R10 - Flammable  
**S-Phrases** S24 - Avoid contact with skin.  
S26 - In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.  
S39 - Wear eye/face protection.

## Ethyl-(S)-Lactate

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REF. SD0310/2007-01

## 16. OTHER INFORMATION

**NFPA Ratings (Scale 0-4):** 2(health)-2(flammability)-0(reactivity)  
**HMIS Rating:** 1(health)-2(flammability)-0(reactivity)-B (protective equipment)

For further information on the safety assessment of lactic acid esters, see the paper titled: Safety Assessment of Lactate Esters, published in Regulatory Toxicology and Pharmacology, 27, 88-97, 1998.

Additional data on the calculated ecotoxicity of lactic acid and its salts and esters can be obtained in a report entitled 'The ecotoxicity and biodegradability of lactic acid, alkyl lactate esters and lactic acid salts' by Bowmer et al.  
(Reference: Chemosphere 37: 1317-1333 (1998)).

This information only concerns the above mentioned product and is not valid if used with other product(s) or in any process. The information is to our best present knowledge correct and complete and is given in good faith but without warranty. It remains the user's own responsibility to make sure that the information is appropriate and complete for his special use of this product.

# Indicates updated section.



## Material Safety Data Sheet

### DIAMMONIUM PHOSPHATE

Date Prepared: 11/01/07

Supersedes Date: 8/13/04

#### 1. PRODUCT AND COMPANY DESCRIPTION

Innophos  
PO Box 8000  
259 Prospect Plains Road  
Cranbury NJ 08512-8000

**Emergency Phone Numbers:**

FOR EMERGENCIES INVOLVING A SPILL, LEAK, FIRE, EXPOSURE OR ACCIDENT CONTACT: CHEMTREC (800-424-9300 within the United States or 703-527-3887 for international collect calls) or INNOPHOS ECT (Emergency Communication Team) at 615-386-7816.

**For Product Information:**

(609) 495-2495

**Chemical Name or Synonym:**

AMMONIUM PHOSPHATE, SECONDARY; DAP; AMMONIUM PHOSPHATE, DIBASIC

**Molecular Formula:**

$(\text{NH}_4)_2\text{HPO}_4$

#### 2. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS Reg Number	OSHA Hazard	Percentage
DIAMMONIUM PHOSPHATE	7783-28-0	Y	100

#### 3. HAZARDS IDENTIFICATION

**A. EMERGENCY OVERVIEW:**

**Physical Appearance and Odor:**

white powder solid, ammonia-like odor.

**Warning Statements:**

CAUTION! MAY CAUSE SKIN AND EYE IRRITATION.

**B. POTENTIAL HEALTH EFFECTS:**

**Acute Eye:**

May cause irritation.

**Acute Skin:**

Skin absorption not likely. May cause irritation.

**Acute Inhalation:**

May cause upper respiratory tract irritation.

**Acute Ingestion:**

Ingestion of large quantities may cause nausea, vomiting, diarrhea, abdominal cramps.

**Chronic Effects:**

This product does not contain any ingredient designated by IARC, NTP, ACGIH or OSHA as probable or suspected human carcinogens.

## 4. FIRST AID MEASURES

**FIRST AID MEASURES FOR ACCIDENTAL:****Eye Exposure:**

Hold eyelids open and flush with a steady, gentle stream of water for at least 15 minutes. Seek medical attention if irritation develops or persists or if visual changes occur.

**Skin Exposure:**

In case of contact, immediately wash with plenty of soap and water for at least 5 minutes. Seek medical attention if irritation develops or persists. Remove contaminated clothing and shoes. Clean contaminated clothing and shoes before re-use.

**Inhalation:**

If respiratory irritation or distress occurs remove victim to fresh air. Seek medical attention if respiratory irritation or distress continues.

**Ingestion:**

Do not induce vomiting, unless directed to do so by a physician. If victim is conscious and alert, give 2-3 glasses of water to drink. Seek immediate medical attention. Do not leave victim unattended. To prevent aspiration of swallowed product, lay victim on side with head lower than waist. Vomiting may occur spontaneously. If vomiting occurs and the victim is conscious, give water to further dilute the chemical. Also see Note To Physician.

**MEDICAL CONDITIONS POSSIBLY AGGRAVATED BY EXPOSURE:**

Inhalation of product may aggravate existing chronic respiratory problems such as asthma, emphysema or bronchitis. Skin contact may aggravate existing skin disease.

**NOTES TO PHYSICIAN:**

All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this product may have occurred.

Ingestion of large quantities of phosphate salts (over 1.0 grams for an adult) may cause an osmotic catharsis resulting in diarrhea and probable abdominal cramps. Larger doses such as 4-8 grams will almost certainly cause these effects in everyone. In healthy individuals most of the ingested salt will be excreted in the feces with the diarrhea and, thus, not cause any systemic toxicity. Doses greater than 10 grams hypothetically may cause systemic toxicity. Treatment should take into consideration both anionic and cation portion of the molecule. The following treatments should be considered for the specific group(s) of phosphate salts found in this product:

--All phosphate salts, except calcium salts, have a hypothetical risk of hypocalcemia, so calcium levels should be

monitored.

--Ammonium salts have a hypothetical risk of ammonia toxicity. In addition to calcium levels, ammonia and phosphate levels should be monitored.

--Potassium salts have a hypothetical risk of hyperkalemia which can cause cardiac arrhythmia. In addition to calcium levels, potassium and phosphate levels should be monitored. Also consider continuous EKG monitoring to detect hyperkalemia.

--Sodium salts have a hypothetical risk of hypernatremia. In addition to calcium levels, sodium and phosphate levels should be monitored.

## 5. FIRE FIGHTING MEASURES

### FIRE HAZARD DATA:

#### Flash Point:

Not Applicable

#### Extinguishing Media:

Not combustible. Use extinguishing method suitable for surrounding fire.

#### Special Fire Fighting Procedures:

Firefighters should wear NIOSH/MSHA approved self-contained breathing apparatus and full protective clothing. Dike area to prevent runoff and contamination of water sources. Dispose of fire control water later.

#### Unusual Fire and Explosion Hazards:

Not combustible.

#### Hazardous Decomposition Materials (Under Fire Conditions):

ammonia  
oxides of nitrogen  
oxides of phosphorus

## 6. ACCIDENTAL RELEASE MEASURES

### Evacuation Procedures and Safety:

Wear appropriate protective gear for the situation. See Personal Protection information in Section 8.

### Containment of Spill:

Dike or retain dilution water or water from firefighting for later disposal. Follow procedure described below under Cleanup and Disposal of Spill.

### Cleanup and Disposal of Spill:

Sweep or vacuum up and place in an appropriate closed container (see Section 7: Handling and Storage). Avoid creation of dusty conditions. Clean up residual material by washing area with water and detergent.

### Environmental and Regulatory Reporting:

Runoff from fire control or dilution water may cause pollution. Prevent material from entering public sewer system or any waterways. Spills may be reportable to the National Response Center (800-424-8802) and to state and/or local agencies.

## 7. HANDLING AND STORAGE

### Minimum/Maximum Storage Temperatures:

Not Available

### Handling:

Keep containers closed when not being used. Avoid breathing dusts or vapors. Avoid direct or prolonged contact with skin and eyes.

### Storage:

Store in an area that is cool, dry, well-ventilated, Store in closed containers. This product is hygroscopic and tends to cake on storage.

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### Introductory Remarks:

These recommendations provide general guidance for handling this product. Because specific work environments and material handling practices vary, safety procedures should be developed for each intended application. While developing safe handling procedures, do not overlook the need to clean equipment and piping systems for maintenance and repairs. Waste resulting from these procedures should be handled in accordance with Section 13: Disposal Considerations.

Assistance with selection, use and maintenance of worker protection equipment is generally available from equipment manufacturers.

### Exposure Guidelines:

Exposure limits represent regulated or recommended worker breathing zone concentrations measured by validated sampling and analytical methods, meeting the regulatory requirements. The following limits apply to this material, where, if indicated, S=skin and C=ceiling limit:

#### PARTICULATES NOT OTHERWISE REGULATED RESPIRABLE FRACTION

	Notes	TWA	STEL
OSHA		5 mg/cu m	

#### PARTICULATES NOT OTHERWISE REGULATED TOTAL DUST

	Notes	TWA	STEL
OSHA		15 mg/cu m	

### Engineering Controls:

Where engineering controls are indicated by use conditions or a potential for excessive exposure exists, the following traditional exposure control techniques may be used to effectively minimize employee exposures: general area dilution/exhaust ventilation.

### Respiratory Protection:

When respirators are required, select NIOSH/MSHA approved equipment based on actual or potential airborne concentrations and in accordance with the appropriate regulatory standards and/or industrial recommendations.

Under normal conditions, in the absence of other airborne contaminants, the following devices should provide protection from this material up to the conditions specified by the appropriate OSHA, WHMIS or ANSI standard(s): dust/mist filtering respirator.



**Eye/Face Protection:**

Eye and face protection requirements will vary dependent upon work environment conditions and material handling practices. Appropriate ANSI Z87 approved equipment should be selected for the particular use intended for this material.

Eye contact should be prevented through use of chemical safety glasses with side shields or splash proof goggles. An emergency eye wash must be readily accessible to the work area.

**Skin Protection:**

Skin contact should be minimized through use of gloves and suitable long-sleeved clothing (i.e., shirts and pants). Consideration must be given both to durability as well as permeation resistance.

**Work Practice Controls:**

Personal hygiene is an important work practice exposure control measure and the following general measures should be taken when working with or handling this material:

- (1) Do not use, and/or consume foods, beverages, tobacco products, or cosmetics in areas where this material is stored.
- (2) Wash hands and face carefully before eating, drinking, using tobacco, applying cosmetics, or using the toilet.
- (3) Wash exposed skin promptly to remove accidental splashes or contact with this material.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical and Chemical properties here represent typical properties of this product. Contact the business area using the Product Information phone number in Section 1 for its exact specifications.

**Physical Appearance:**

white powder solid.

**Odor:**

ammonia-like odor.

**pH:**

8 at 1 wt/wt%.

**Specific Gravity:**

Not Available

**Water Solubility:**

soluble 41 wt/wt% at 20 C (68 F).

**Melting Point Range:**

Not Available

**Boiling Point Range:**

Not Available

**Vapor Pressure:**

Not Available

**Vapor Density:**

Not Available

**Molecular Weight:**

132.06

## 10. STABILITY AND REACTIVITY

### **Chemical Stability:**

This material is stable under normal handling and storage conditions described in Section 7.

### **Conditions To Be Avoided:**

dusting conditions  
extreme heat  
extreme humidity

### **Materials/Chemicals To Be Avoided:**

strong bases  
sodium hypochlorite

### **Decomposition Temperature Range:**

155 C (311 F)

### **The Following Hazardous Decomposition Products Might Be Expected:**

#### **Decomposition Type: thermal**

ammonia  
phosphoric acid  
oxides of nitrogen  
oxides of phosphorus

### **Hazardous Polymerization Will Not Occur.**

### **Avoid The Following To Inhibit Hazardous Polymerization:**

not applicable

## 11. TOXICOLOGICAL INFORMATION

### **Acute Eye Irritation:**

No test data found for product.

### **Acute Skin Irritation:**

#### **Toxicological Information and Interpretation:**

skin - skin irritation, rabbit. Mildly irritating.

### **Acute Dermal Toxicity:**

No test data found for product.

### **Acute Respiratory Irritation:**

No test data found for product.

### **Acute Inhalation Toxicity:**

No test data found for product.

### **Acute Oral Toxicity:**

**Toxicological Information and Interpretation:**

LD50 - lethal dose 50% of test species, > 1000 mg/kg, rat.

**Chronic Toxicity:**

This product does not contain any substances that are considered by OSHA, NTP, IARC or ACGIH to be "probable" or "suspected" human carcinogens.

## 12. ECOLOGICAL INFORMATION

**Ecotoxicological Information:****Ecotoxicological Information and Interpretation:**

LC50 - lethal concentration 50% of test species, 155 mg/l/96 hr, fish: Pimephales promelas.

**Chemical Fate Information:**

No data found for product.

## 13. DISPOSAL CONSIDERATIONS

**Waste Disposal Method:**

Chemical additions, processing or otherwise altering this material may make the waste management information presented in this MSDS incomplete, inaccurate or otherwise inappropriate. Please be advised that state and local requirements for waste disposal may be more restrictive or otherwise different from federal laws and regulations. Consult state and local regulations regarding the proper disposal of this material.

**EPA Hazardous Waste - NO**

## 14. TRANSPORTATION INFORMATION

**Transportation Status: IMPORTANT! Statements below provide additional data on listed DOT classification.**

The listed Transportation Classification does not address regulatory variations due to changes in package size, mode of shipment or other regulatory descriptors.

**US Department of Transportation**

Shipping Name:

NOT REGULATED

## 15. REGULATORY INFORMATION

**Inventory Status**

Inventory	Status
UNITED STATES (TSCA)	Y
CANADA (DSL)	Y
EUROPE (EINECS/ELINCS)	Y

AUSTRALIA (AICS)	Y
JAPAN (MITI)	Y
SOUTH KOREA (KECL)	Y

Y = All ingredients are on the inventory.

E = All ingredients are on the inventory or exempt from listing.

P = One or more ingredients fall under the polymer exemption or are on the no longer polymer list. All other ingredients are on the inventory or exempt from listing.

N = Not determined or one or more ingredients are not on the inventory and are not exempt from listing.

## FEDERAL REGULATIONS

### Inventory Issues:

All functional components of this product are listed on the TSCA Inventory.

### SARA Title III Hazard Classes:

Fire Hazard	- NO
Reactive Hazard	- NO
Release of Pressure	- NO
Acute Health Hazard	- YES
Chronic Health Hazard	- NO

## OTHER FEDERAL REGULATIONS:

### FDA Status:

This product meets the compositional requirements of:  
21 CFR 184.1141B AMMONIUM PHOSPHATE, DIBASIC

### STATE REGULATIONS:

This product does not contain any components that are regulated under California Proposition 65.

## 16. OTHER INFORMATION

### National Fire Protection Association Hazard Ratings--NFPA(R):

1	Health Hazard Rating--Slight
0	Flammability Rating--Minimal
0	Instability Rating--Minimal

### National Paint & Coating Hazardous Materials Identification System--HMIS(R):

1	Health Hazard Rating--Slight
0	Flammability Rating--Minimal
0	Reactivity Rating--Minimal

### Reason for Revisions:

Change and/or addition made to Section 4, Section 12.

### Key Legend Information:

ACGIH - American Conference of Governmental Industrial Hygienists  
OSHA - Occupational Safety and Health Administration  
TLV - Threshold Limit Value  
PEL - Permissible Exposure Limit  
TWA - Time Weighted Average

STEL - Short Term Exposure Limit  
NTP - National Toxicology Program  
IARC - International Agency for Research on Cancer  
ND - Not determined  
RPI - INNOPHOS Established Exposure Limits

**Disclaimer:**

The information herein is given in good faith but no warranty, expressed or implied, is made.

**\*\* End of MSDS Document \*\***

# Material Safety Data Sheet

## Yeast Extract

ACC# 08515

### Section 1 - Chemical Product and Company Identification

**MSDS Name:** Yeast Extract

**Catalog Numbers:** AC611801000, AC611805000, S80245-1, S80245-2, S80245-3, BP1422-100, BP1422-2, BP1422-500

**Synonyms:** None known.

**Company Identification:**

Fisher Scientific

1 Reagent Lane

Fair Lawn, NJ 07410

**For information, call:** 201-796-7100

**Emergency Number:** 201-796-7100

**For CHEMTREC assistance, call:** 800-424-9300

**For International CHEMTREC assistance, call:** 703-527-3887

### Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
8013-01-2	Yeast, extract	100.0	232-387-9

### Section 3 - Hazards Identification

#### EMERGENCY OVERVIEW

Appearance: yellow-white to yellow-orange solid.

**Caution!** May cause eye, skin, and respiratory tract irritation. This is expected to be a low hazard for usual industrial handling.

**Target Organs:** None known.

#### Potential Health Effects

**Eye:** May cause eye irritation.

**Skin:** May cause skin irritation. Low hazard for usual industrial handling.

**Ingestion:** May cause irritation of the digestive tract. Low hazard for usual industrial handling.

**Inhalation:** May cause respiratory tract irritation. Low hazard for usual industrial handling.

**Chronic:** No information found.

## Section 4 - First Aid Measures

**Eyes:** Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation develops, get medical aid.

**Skin:** Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

**Ingestion:** Do not induce vomiting. Get medical aid if irritation or symptoms occur.

**Inhalation:** Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

**Notes to Physician:** Treat symptomatically and supportively.

## Section 5 - Fire Fighting Measures

**General Information:** As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts may be an explosion hazard if mixed with air at critical proportions and in the presence of an ignition source.

**Extinguishing Media:** Use water spray, dry chemical, carbon dioxide, or chemical foam.

**Flash Point:** Not applicable.

**Autoignition Temperature:** Not applicable.

**Explosion Limits, Lower:** Not available.

**Upper:** Not available.

**NFPA Rating:** (estimated) Health: 0; Flammability: 1; Instability: 0

## Section 6 - Accidental Release Measures

**General Information:** Use proper personal protective equipment as indicated in Section 8.

**Spills/Leaks:** Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation. Do not let this chemical enter the environment.

## Section 7 - Handling and Storage

**Handling:** Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Avoid ingestion and inhalation.

**Storage:** Store in a cool, dry place. Store in a tightly closed container.

## Section 8 - Exposure Controls, Personal Protection

**Engineering Controls:** Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

### Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Yeast, extract	none listed	none listed	none listed

**OSHA Vacated PELs:** Yeast, extract: No OSHA Vacated PELs are listed for this chemical.

### Personal Protective Equipment

**Eyes:** Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

**Skin:** Wear appropriate protective gloves to prevent skin exposure.

**Clothing:** Wear appropriate protective clothing to prevent skin exposure.

**Respirators:** Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

## Section 9 - Physical and Chemical Properties

**Physical State:** Solid

**Appearance:** yellow-white to yellow-orange

**Odor:** characteristic odor

**pH:** Not available.

**Vapor Pressure:** Not applicable.

**Vapor Density:** Not applicable.

**Evaporation Rate:**Not available.

**Viscosity:** Not applicable.

**Boiling Point:** Not available.

**Freezing/Melting Point:**Not available.

**Decomposition Temperature:**Not available.

**Solubility:** 20% in water.

**Specific Gravity/Density:**Not available.

**Molecular Formula:**Variable.

**Molecular Weight:**Not available.

## Section 10 - Stability and Reactivity



**Chemical Stability:** Stable under normal temperatures and pressures.

**Conditions to Avoid:** Incompatible materials, dust generation.

**Incompatibilities with Other Materials:** Strong oxidizing agents.

**Hazardous Decomposition Products:** Carbon monoxide, carbon dioxide.

**Hazardous Polymerization:** Has not been reported.

## Section 11 - Toxicological Information

**RTECS#:**

**CAS#** 8013-01-2: ZF6610000

**LD50/LC50:**

Not available.

**Carcinogenicity:**

CAS# 8013-01-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

**Epidemiology:** No information found

**Teratogenicity:** No information found

**Reproductive Effects:** No information found

**Mutagenicity:** No information found

**Neurotoxicity:** No information found

**Other Studies:**

## Section 12 - Ecological Information

**Ecotoxicity:** No data available. No information available.

**Environmental:** No information found.

**Physical:** No information found.

**Other:** Do not empty into drains.

## Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

**RCRA P-Series:** None listed.

**RCRA U-Series:** None listed.

## Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated.	Not regulated.
Hazard Class:		
UN Number:		
Packing Group:		

## Section 15 - Regulatory Information

### US FEDERAL

#### TSCA

CAS# 8013-01-2 is listed on the TSCA inventory.

#### Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

#### Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

#### Section 12b

None of the chemicals are listed under TSCA Section 12b.

#### TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

#### CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

#### SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

**Section 313** No chemicals are reportable under Section 313.

#### Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

#### Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

#### OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

#### STATE

CAS# 8013-01-2 is not present on state lists from CA, PA, MN, MA, FL, or NJ.

#### California Prop 65

California No Significant Risk Level: None of the chemicals in this product are listed.

## **European/International Regulations**

### **European Labeling in Accordance with EC Directives**

#### **Hazard Symbols:**

Not available.

#### **Risk Phrases:**

#### **Safety Phrases:**

S 24/25 Avoid contact with skin and eyes.

#### **WGK (Water Danger/Protection)**

CAS# 8013-01-2: 0

#### **Canada - DSL/NDSL**

CAS# 8013-01-2 is listed on Canada's DSL List.

#### **Canada - WHMIS**

This product has a WHMIS classification of Not controlled..

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

#### **Canadian Ingredient Disclosure List**

## **Section 16 - Additional Information**

**MSDS Creation Date:** 7/16/1999

**Revision #6 Date:** 9/25/2007

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.*



## Material Safety Data Sheet

### Sodium bromide

MSDS# 21060

#### Section 1 - Chemical Product and Company Identification

MSDS Name: Sodium bromide

Catalog AC205130000, AC205130010, AC205130050, AC205131000, AC246900000, AC246900025

Numbers: AC246900025, AC246901000, AC246905000, S255-3, S255-500

Synonyms: Bromide salt of sodium.

Company Identification:

Fisher Scientific  
One Reagent Lane  
Fair Lawn, NJ 07410

For information in the US, call:

201-796-7100

Emergency Number US:

201-796-7100

CHEMTREC Phone Number, US:

800-424-9300

#### Section 2 - Composition, Information on Ingredients

-----  
CAS#: 7647-15-6  
Chemical Name: Sodium bromide  
%: >99  
EINECS#: 231-599-9  
-----

Hazard Symbols: None listed

Risk Phrases: None listed

#### Section 3 - Hazards Identification

##### EMERGENCY OVERVIEW

Caution! Hygroscopic (absorbs moisture from the air). Causes mild eye irritation. Target Organs: Central nervous system.

##### Potential Health Effects

Eye: Causes mild eye irritation.

Skin: May cause skin irritation. May be harmful if absorbed through the skin.

Ingestion: May cause irritation of the digestive tract. Symptoms may include: headache, excitement, fatigue, nausea, vomiting, stupor, and coma. May be harmful if swallowed.

Inhalation: Inhalation of high concentrations may cause central nervous system effects characterized by nausea, headache, dizziness, unconsciousness and coma. May cause respiratory tract irritation. May be harmful if inhaled.

Chronic: Chronic ingestion may cause central nervous system failure.

#### Section 4 - First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid immediately.

Skin: Get medical aid. Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.

Ingestion: Get medical aid immediately. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician: Treat symptomatically and supportively.

#### Section 5 - Fire Fighting Measures

As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH

General Information: (approved or equivalent), and full protective gear.

Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.

Autoignition  
Temperature: Not available

Flash Point: Not applicable.

Explosion Limits: N/A  
Lower:

Explosion Limits: N/A  
Upper:

NFPA Rating: health: 1; flammability: 1; instability: 1;

#### Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation.

#### Section 7 - Handling and Storage

Handling: Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Avoid ingestion and inhalation.

Storage: Store in a cool, dry place. Store in a tightly closed container. Store protected from moisture.

#### Section 8 - Exposure Controls, Personal Protection

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Sodium bromide	none listed	none listed	none listed

OSHA Vacated PELs: Sodium bromide: None listed

Engineering Controls:

Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

#### Section 9 - Physical and Chemical Properties

Physical State: Crystalline powder

Color: white

Odor: Not available

pH: 5-8.8 (5% aq soln)

Vapor Pressure: Not applicable.

Vapor Density: Not available

Evaporation Rate: Not applicable.

Viscosity: Not available

Boiling Point: 1390 deg C @ 760 mmHg ( 2,534.00°F)

Freezing/Melting Point: 755 deg C ( 1,391.00°F)

Decomposition Temperature:

Solubility in water: 95g/100 ml water (25°C)

Specific Gravity/Density: 3.208

Molecular Formula: BrNa

Molecular Weight: 102.89

#### Section 10 - Stability and Reactivity

Chemical Stability:	Hygroscopic: absorbs moisture or water from the air.
Conditions to Avoid:	Incompatible materials, dust generation, heating to decomposition, exposure to moist air or water.
Incompatibilities with Other Materials	Strong oxidizing agents, strong acids.
Hazardous Decomposition Products	Hydrogen bromide, sodium oxide, bromine fumes.
Hazardous Polymerization	Has not been reported.

#### Section 11 - Toxicological Information

RTECS#:	CAS# 7647-15-6: VZ3150000
	RTECS:
LD50/LC50:	<b>CAS# 7647-15-6:</b> Oral, mouse: LD50 = 7 gm/kg; Oral, rat: LD50 = 3500 mg/kg;
	.
Carcinogenicity:	Sodium bromide - Not listed as a carcinogen by ACGIH, IARC, NTP, or CA Prop 65.
Other:	See actual entry in RTECS for complete information.

#### Section 12 - Ecological Information

Ecotoxicity:	Fish: Bluegill/Sunfish: >1000 mg/L; 96 h; LC50 Daphnia: Daphnia: >1000 mg/L; 48 h; LC50
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#### Section 13 - Disposal Considerations

Dispose of in a manner consistent with federal, state, and local regulations.

#### Section 14 - Transport Information

US DOT

Shipping Name: Not regulated

Hazard Class:

UN Number:

Packing Group:

Canada TDG

Shipping Name: Not regulated as a hazardous material

Hazard Class:

UN Number:

Packing Group:

#### Section 15 - Regulatory Information

##### European/International Regulations

##### European Labeling in Accordance with EC Directives

Hazard Symbols: Not available

Risk Phrases:

Safety Phrases:

S 24/25 Avoid contact with skin and eyes.

##### WGK (Water Danger/Protection)

CAS# 7647-15-6: 1

##### Canada

CAS# 7647-15-6 is listed on Canada's DSL List

Canadian WHMIS Classifications: Not available

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

CAS# 7647-15-6 is listed on Canada's Ingredient Disclosure List

US Federal

TSCA

CAS# 7647-15-6 is listed on the TSCA  
Inventory.

Section 16 - Other Information

MSDS Creation Date: 12/12/1997

Revision #9 Date 7/20/2009

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# SAFETY DATA SHEET

## 1. CHEMICAL IDENTIFICATION AND COMPANY INFORMATION

**PRODUCT NAME:** KB-1<sup>®</sup> Primer  
**COMPANY INFO:** SiREM Laboratories  
130 Research Lane, Suite 2, Guelph, Ontario, Canada, N1G 5G3  
Phone: Toll Free, North America: 1-866-251-1747  
Main Line: 519-822-2265  
Fax: 519-822-3151  
[www.siremlab.com](http://www.siremlab.com)

**EMERGENCY PHONE NUMBER:** 519-515-0840 (for 24/7 assistance, contact poison center hotline in your jurisdiction)

**RECOMMENDED USE:** For preparation of anaerobic water for use in groundwater remediation

**RESTRICTIONS ON USE:** KB-1<sup>®</sup> products are intended for laboratory research and field applications for groundwater remediation. Products are not intended to be used as human or animal therapeutics, cosmetics, agricultural or pesticidal products, food additives, or as household chemicals.

## 2. HAZARDS IDENTIFICATION

### GHS Classification:

H302 - Acute toxicity, Oral (Category 4)

H319 - Eye irritant, (Category 2)

### GHS Label elements, including hazard and precautionary statements:



**Pictogram:**

**Signal Word:** Warning

### Hazard Statements:

H302 - Harmful if swallowed.

H315 - Causes skin irritation.

H319 - Causes serious eye irritation.

H335 - May cause respiratory irritation.

H402 - Harmful to aquatic life.

### Precautionary Statements:

P264 - Wash hands thoroughly after handling.

P270 - Do not eat, drink or smoke when using this product.

P273 - Avoid [unintended or indiscriminate] release to the environment.

P280 - Wear protective gloves/protective clothing/eye protection/face protection.

P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell.

P308 + P313 - If exposed or concerned: Get medical advice/attention.



P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses. Continue rinsing.

P337+P313 If eye irritation persists: Get medical advice/attention

P330 – Rinse mouth.

P501 – Dispose of contents/container in accordance with local/regional/national regulations.

HMIS Rating:	Health	Flammability	Physical Hazard	Personal Protection
	1	0	0	E*
NFPA Rating:	Health	Flammability	Reactivity	Special Hazard
	1	0	0	N/A

\* E = Safety Glasses, Gloves, Dust Respirator

### 3. COMPOSITION/INFORMATION ON INGREDIENTS

Amino Acid (proteinogenic):	50-70%, C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub> S
Potassium Bicarbonate:	25-50%, KHCO <sub>3</sub> , CAS No. 298-14-6
Sodium Sulfit:	5-20%, Na <sub>2</sub> O <sub>3</sub> S, CAS No. 7757-83-7

### 4. FIRST AID MEASURES

Route of Entry	Symptoms	First Aid Procedures
Ingestion	Irritation of digestive tract	DO NOT INDUCE VOMITING. Rinse mouth. Give plenty of water to drink, do not give active carbon. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin contact	Skin irritation– reddening, itching or inflammation.	Remove contaminated clothes. Wash skin with plenty of water and soap.
Eye contact	Eye irritation – redness, tearing, blurred vision.	Rinse immediately with plenty of water for 15 – 20 minutes, lifting lower and upper eyelids occasionally (remove contact lenses if easily possible) and seek medical advice.
Inhalation of dust	Respiratory irritation, coughing	Safely remove victim to fresh air. If not breathing, institute cardiopulmonary resuscitation (CPR). If breathing is difficult, ensure clear airway and give oxygen. Get medical attention.

### 5. FIRE FIGHTING MEASURES

Suitable extinguishing media:	Water in copious quantities, carbon dioxide, dry chemical powder, or appropriate foam. Use extinguishing media suitable for surrounding fire.
Special protective equipment and precautions for firefighters:	In the event of a fire, wear full protective clothing and NIOSH approved self-contained breathing apparatus. Evacuate the area and fight fire from a safe distance.
Hazardous combustion products:	May emit toxic fumes under fire conditions.
Toxic gases produced:	Carbon monoxide, carbon dioxide, nitrogen oxides, potassium oxides, sulfur oxides
Shock/impact sensitivity:	Not shock sensitive.

### 6. ACCIDENTAL RELEASE MEASURES

Ventilation:	If released in ventilated fume hood, ensure fume hood is on. If released in general room environment, open windows and provide adequate ventilation.
Eye/skin protection:	Have eye-washing facilities readily available where eye contact can occur. Wear chemical safety goggles. Use appropriate chemical protective gloves when handling. Showering and changing into street clothes after work is recommended.

Protective equipment for airborne dust:

A NIOSH/MSHA approved air purifying respirator is recommended where airborne concentrations are expected to exceed exposure limits. Protection provided by purifying respirators is limited. Wear suitable protective clothing and a self-contained breathing apparatus if available.

Method of containment and cleanup:

Wear suitable protective clothing. Avoid dust formation. Avoid breathing dust. Carefully sweep up and remove. Place material in a dry container and cover. Remove from the area. Flush spill area with water. Do not let products enter drains.

## 7. HANDLING AND STORAGE

Storage and handling precautions:

Store in a tightly sealed container in a cool, dry and well-ventilated place. Store away from direct light. Avoid generation of dust. Do not breathe dust. Wash thoroughly after handling. In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable protective clothing.

Incompatibilities:

Segregate from strong oxidizing agents, acids, bases.

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

OSHA Permissible Exposure Limits (PELs):

Not established

ACHIH Threshold Limit Values (TLVs):

Not established.

Engineering controls:

Generally not required under normal conditions of use. If method of use will result in significant dust generation, use in lab hood or under conditions of adequate ventilation.

Work practices:

Use good hygiene practices, avoid dust generation,

Personal protective equipment (PPE):

Under normal conditions of use, wear safety glasses and protective gloves. For laboratory use, wear lab coat. For higher risk of eye contact, wear safety goggles or face shield, as appropriate.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:

White to off-white powder or granules.

Odor:

Odorless

Solubility:

Soluble in water

pH:

6 – 8

Melting range

No data

Vapor density:

N/A

Vapor pressure:

N/A

Relative density:

2.4 to 2.6 g/cm<sup>3</sup>, depending on formulation

Evaporation rate:

N/A

Initial Boiling point, boiling range

N/A

Flammability

N/A

Partition coefficient	N/A
Auto-ignition temperature	N/A
Decomposition temperature:	No data, decomposes by heating.
Flash point	N/A
Flammable limits	N/A

## 10. STABILITY AND REACTIVITY

Reactivity:	Stable under normal conditions. Hygroscopic – absorbs moisture from air, affecting product quality. Possible decomposition at high temperatures.
Chemical stability	Stable under normal conditions.
Possibility of hazardous reactions:	Stable. Spontaneous hazardous chemical reactions/decomposition will not occur. Hygroscopic – absorbs moisture from air, affecting product quality. Reacts with acids, bases, oxidizing agents, chlorine trifluoride, magnesium, metals, carbon, calcium oxide.
Conditions to avoid:	Incompatibles, may be sensitive to light and moist air
Incompatible materials:	Strong oxidizing agents, bases
Hazardous decomposition products:	Carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, potassium oxides.
Shock sensitivity:	Not shock sensitive; will not decompose and form shock sensitive compounds.

## 10. TOXICOLOGICAL INFORMATION

*The toxicological properties of this product have not been thoroughly investigated.*

<i>The toxicological properties of this product have not been thoroughly investigated.</i>		Amino Acid	Potassium Bicarbonate	Sodium Sulfite
Toxicity:	LD50 (Oral-Rat)(mg/kg):	1890	2064	2610-3560
	LD50 (IV-Rat)(mg/kg):	1140	No data	No data
	LD50 (Oral-Mouse)(mg/kg):	660	No data	No data
	LC50 (Inhalation-Rat)(mg/m <sup>3</sup> )	No data	>4880	>5500
	LD50 (Dermal-Rat)(mg/kg)	No data	No data	>2000
Carcinogenicity:	NTP:	No component of this product is identified as a probable, possible or confirmed human carcinogen.		
	IARC:			
	OSHA Z List:			
	OSHA Reg:			
Teratogenicity:	Not established – the chemical structures of components do not suggest a specific alert for these effects.			
Mutagenicity:				
Reproductive:				
Respiratory or skin sensitization:	Not established			
Specific target organ toxicity:	Respiratory, skin, eye irritant, bladder, kidney			
Effects of overexposure:	Irritation, itching, gastrointestinal upset, respiratory discomfort, blurred vision.			
Medical conditions aggravated by exposure	Chronic lung conditions, dry eye			



Section 313 Ingredients: No

Section 304 (EHS/CERCLA) Ingredients: No

#### SARA TITLE III NOTIFICATION INFORMATION

Acute Health Hazard: No

Chronic Health Hazard: No

Fire Hazard: No

Sudden Release of Pressure Hazard: No

#### 16. OTHER INFORMATION

SiREM® provides the information contained herein for hazard communication and safety planning purposes, based on existing information on each of the product components available in the literature; no independent testing was conducted on the final product. The above information is intended to be used only as a guide to the appropriate precautionary handling of this material by a properly trained person.

Revision Date: November, 2014



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## **KB-1<sup>®</sup> Dechlorinator Material Safety Data Sheet**

### **Section 1: Material Identification**

**Trade Name:** KB-1<sup>®</sup> Dechlorinator

**Chemical Family:** bacterial mixture

**Chemical name:** No IUC name for mixture is known to exist

**Manufacturer/Supplier:** SiREM  
130 Research Lane, Suite 2,  
Guelph, Ontario,  
Canada N1G 5G3

**For Information call:** 519-822-2265 / 1-866-251-1747

**Emergency Number:** 519-822-2265

**Description:** Microbial inoculum (non-pathogenic, non-hazardous)

**Trade Name:** KB-1<sup>®</sup> Dechlorinator

**Product Use:** Bioremediation of contaminated groundwater.

**Date Prepared:** 2 February 2005

### **Section 2: Composition, Information on Ingredients**

KB-1<sup>®</sup> Dechlorinator is a microbial culture grown in an aqueous dilute mineral salt solution media containing no hazardous ingredients.

The microbial composition of KB-1<sup>®</sup> Dechlorinator (as determined by phylogenetic analysis) is listed in Table 1. Identification of organisms was obtained by matching 16S rRNA gene sequence of organisms in KB-1<sup>®</sup> Dechlorinator to other known organisms. The characteristics of related organisms can be used to identify potential or likely characteristics of organisms in KB-1<sup>®</sup> Dechlorinator.

***Table 1. Genus' identified in KB-1<sup>®</sup> Dechlorinator Microbial Inoculum***

<b>Genus</b>
<i>Dehalococcoides</i> sp.
<i>Geobacter</i> sp.
<i>Methanomethylovorans</i> sp.

### **Section 3: Hazards Identification:**

A review of the available data does not indicate any known health effects related to normal use of this product.

### **Section 4: First Aid Measures:**

Avoid direct contact with skin and eyes. In any case of any exposure which elicits a response, a physician should be consulted immediately.



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**Eye Contact:** Flush eyes with water for at least 15 minutes, occasionally lift upper and lower eyelids, if undue irritation or redness occurs seek medical attention.

**Skin Contact:** Remove contaminated clothing and wash skin thoroughly with water and antibacterial soap. Seek medical attention if irritation develops or open wounds are present.

**Ingestion:** Do not induce vomiting, drink several cups of water, seek medical attention.

**Inhalation:** Remove to fresh air. If not breathing give artificial respiration. In case of labored breathing give oxygen. Call a physician.

### **Section 5 - Fire Fighting Measures:**

Non-flammable

Flash Point: not applicable

Upper flammable limit: not applicable

Lower flammable limit: not applicable

### **Section 6 – Accidental Release Procedures**

Spilled KB-1<sup>®</sup> Dechlorinator should be soaked up with sorbant and saturated with a 10% bleach solution (prepared by making a one in ten dilution of diluted standard bleach [normally sold at a strength of 5.25% sodium hypochlorite] to disinfect affected surfaces. Sorbant should be double bagged and disposed of as indicated in section 12. After removal of sorbant, area should be washed with 10% bleach solution to disinfect. If liquid from the culture vessel is present on the fittings, non-designated tubing or exterior of the stainless steel pressure vessel liquid should be wiped off and the area washed with 10% bleach solution.

### **Section 7 - Handling and Storage**

KB-1<sup>®</sup> Dechlorinator is shipped in stainless steel pressure vessels and connected to injection lines and inert gas is used to pressurize the vessel to displace the contents. KB-1<sup>®</sup> Dechlorinator should be handled with care to avoid any spillage. Vessels are shipped with 1 pound per square inch (psi) pressure; valves should not be opened until connections to appropriate lines for subsurface injection are in place.

**Storage Requirements:** Avoid exposing stainless steel pressure vessels to undue temperature extremes (i.e., temperatures less than 0°C or greater than 30°C may result in harm to the microbial cultures and damage to the vessels). All valves should be in the closed position when the vessel is not pressurized to prevent the escape of gases and to maintain anaerobic conditions in the vessel. Avoid exposure of the culture to air as the presence of oxygen will kill dechlorinating microorganisms.

### **Section 8 - Exposure Controls/Personal Protection**

#### **Personal protective equipment:**

Skin: Protective gloves (latex, vinyl or nitrile) should be worn.

Eye Protection: Wear appropriate protective eyeglasses or goggles when opening pressure vessels valves or when pressurizing vessels to inject contents into the subsurface.

Respiratory: No respiratory protection is required.

Engineering Controls: Good general room ventilation is expected to be adequate.



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### **Section 9: Physical and Chemical Properties:**

Physical State: liquid  
 Odour: skunky odour  
 Appearance: dark grey, slightly turbid liquid under anaerobic conditions, pink if exposed to air (oxygen).  
 Specific gravity: not determined  
 Vapor pressure: not applicable  
 Vapor density: not applicable  
 Evaporation rate: not determined  
 Boiling point: ~100° C  
 Freezing point/melting point: ~ 0°C  
 pH: 6.5-7.5  
 Solubility: fully soluble in water

### **Section 10 – Stability and Reactivity Data**

Stable and non-reactive.  
 Maintain under anaerobic conditions to preserve product integrity.  
 Materials to avoid: none known

### **Section 11 - Toxicological Information**

Potential for Pathogenicity:

KB-1<sup>®</sup> Dechlorinator has tested negative (i.e., the organisms are not present) for a variety of pathogenic organisms listed in Table 2. While there is no evidence that virulent pathogenic organisms are present in KB-1<sup>®</sup> Dechlorinator, there is potential that certain organisms in KB-1<sup>®</sup> Dechlorinator may have the potential to act as opportunistic (mild) pathogens, particularly in individuals with open wounds and/or compromised immune systems. For this reason standard hygienic procedures such as hand washing after use should be observed.

**Table 2, Results of Human Pathogen Screening of KB-1<sup>®</sup> Dechlorinator**

<b>Organism</b>	<b>Disease(s) Caused</b>	<b>Test result</b>
<i>Salmonella</i> sp.	Typhoid fever, gastroenteritis	Not Detected
<i>Listeria monocytogenes</i>	Listeriosis	Not Detected
<i>Vibrio</i> sp.,	Cholera, gastroenteritis	Not Detected
<i>Campylobacter</i> sp.,	Bacterial diarrhea	Not Detected
<i>Clostridia</i> sp.,	Food poisoning, Botulism, tetanus, gas gangrene	Not Detected
<i>Bacillus anthracis</i>	Anthrax	Not Detected
<i>Pseudomonas aeruginosa</i>	Wound infection	Not Detected
<i>Yersinia</i> sp.,	Bubonic Plague, intestinal infection	Not Detected
Yeast and Mold	Candidiasis, Yeast infection etc.	Not Detected
Fecal coliforms	Indicator organisms for many human pathogens diarrhea, urinary tract infections	Not Detected
<i>Enterococci</i>	Various opportunistic infections	Not Detected





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### **Section 12. Disposal Considerations**

Material must be disinfected or sterilized prior to disposal. Consult local regulations prior to disposal.

### **Section 13 – Transport Information**

Non-hazardous, non-pathogenic microbial inoculum – Biosafety Risk Group 1.

Chemicals, Not Otherwise Indexed (NOI), Non-hazardous

Not subject to TDG or DOT guidelines.

### **Disclaimer:**

The information provided on the MSDS sheet is based on current data and represents our opinion based on the current standard of practice as to the proper use and handling of this product under normal, reasonably foreseeable conditions.

Last revised: 24 June 2008