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# Sandia National Laboratories, New Mexico
# Environmental Restoration Operations

# Field Implementation Plan for the In-Situ Bioremediation Treatability Study at the Technical Area-V Groundwater Area of Concern

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United States Department of Energy
Sandia Field Office

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## ACRONYMS & ABBREVIATIONS

| | |
|---|---|
| µs/cm | microsiemens per centimeter |
| AOC | Area of Concern |
| ARCOC | analysis request and chain of custody |
| bgs | below ground surface |
| COC(s) | constituent(s) of concern |
| CSSP | Contract-specific Safety Plan |
| Dhc | *Dehalococcoides* |
| DO | dissolved oxygen |
| ERFO | Environmental Resource Field Office |
| ES&H | Environment, Safety and Health |
| $^{o}$F | degrees Fahrenheit |
| FIP | Field Implementation Plan |
| FNPT | female national pipe thread |
| FOP | Field Operating Procedure |
| ft | foot/feet |
| FY | fiscal year |
| gal | gallon(s) |
| gpm | gallons per minute |
| GWQB | Ground Water Quality Bureau |
| HASP | Health and Safety Plan |
| Hg | mercury |
| hr(s) | hour(s) |
| HWB | Hazardous Waste Bureau |
| ID | inside diameter |
| in | inch(es) |
| ISB | in-situ bioremediation |
| JSA | Job Safety Analysis |
| KD | KB-1® Dechlorinator injection dispenser |
| kg | kilogram |
| L | liter |
| lb(s) | pound(s) |
| LTS | Long-Term Stewardship |
| mg/L | milligrams per liter |

## ACRONYMS & ABBREVIATIONS
(continued)

| | |
|---|---|
| mL | milliliter(s) |
| mini-SAP | mini-Sampling and Analysis Plan |
| MNPT | male national pipe thread |
| mV | millivolts |
| NEPA | National Environmental Protection Act |
| NMED | New Mexico Environment Department |
| NPN | nitrate plus nitrite |
| ORP | oxidation reduction potential |
| pH | potential for hydrogen |
| PHS | Primary Hazard Screening |
| psi | pound(s) per square inch |
| PVC | polyvinyl chloride |
| SC | specific conductance |
| SNL/NM | Sandia National Laboratories, New Mexico |
| SOW | Statement of Work |
| SPA | Sampling Port A |
| SPB | Sampling Port B |
| SPC | Sampling Port C |
| SPD | Sampling Port D |
| SPT | Sampling Port - Total |
| SWMU | Solid Waste Management Unit |
| TAL | Target Analyte List |
| TCL | Target Compound List |
| TA-V | Technical Area-V |
| TAVG | Technical Area-V Groundwater |
| TCE | trichloroethene |
| TSM | Tailgate Safety Meeting |
| TOC | total organic carbon |
| vcrA | vinyl chloride reductase |
| VOC(s) | volatile organic compound(s) |
| WMP | Waste Management Plan |

# 1.0 PURPOSE, SCOPE, AND OWNERSHIP

Purpose

This Field Implementation Plan (FIP) was prepared by Sandia National Laboratories, New Mexico (SNL/NM) and provides instruction on conducting a series of in-situ bioremediation (ISB) tests as described in the *Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern,* referred to as the Revised Work Plan in this FIP. The Treatability Study is designed to gravity inject an electron-donor substrate and bioaugmentation bacteria into groundwater via three injection wells to perform bioremediation of the constituents of concern (COCs), nitrate and trichloroethene (TCE), in the regions with the highest concentrations (Figures 1-1 and 1-2) at the Technical Area-V Groundwater (TAVG) Area of Concern (AOC). The Treatability Study will evaluate the effectiveness of bioremediation solution delivery and COC treatment over time.

This FIP is designed for SNL/NM work planning and management. It is not intended to be submitted for regulator's approval. The technical details presented in this FIP are subject to change based on field conditions, availability of equipment and materials, feasibility, and inputs from Sandia personnel and Aboveground Injection System contractor.

Scope

The Treatability Study will consist of an initial small-scale proof of concept test (pilot test) at newly installed injection well TAV-INJ1. Results from this test will be evaluated under Decision #1 of the Revised Work Plan to determine whether to implement a full-scale injection at well TAV-INJ1 and whether to refine procedures. Results from the full-scale test at well TAV-INJ1 will be evaluated under Decision #2 of the Revised Work Plan to determine whether to install two additional injection wells, TAV-INJ2 and TAV-INJ3, and perform full-scale tests at these locations.

This FIP includes procedures or references other procedural documents to perform the various discrete tasks required for conducting the Treatability Study.

Environment, Safety and Health (ES&H) requirements will be coordinated through the Center 6200 ES&H Coordinator. This FIP will serve as the basis for fulfilling and developing ES&H requirements and documents. Work planning and control will also be coordinated with Center 4100 Management and staff, and Technical Area-V (TA-V) Management and Project Controllers.

Ownership

The SNL/NM Environmental Restoration Operations in Department 06234 is responsible for development, approval, distribution, revision, and control of this FIP.

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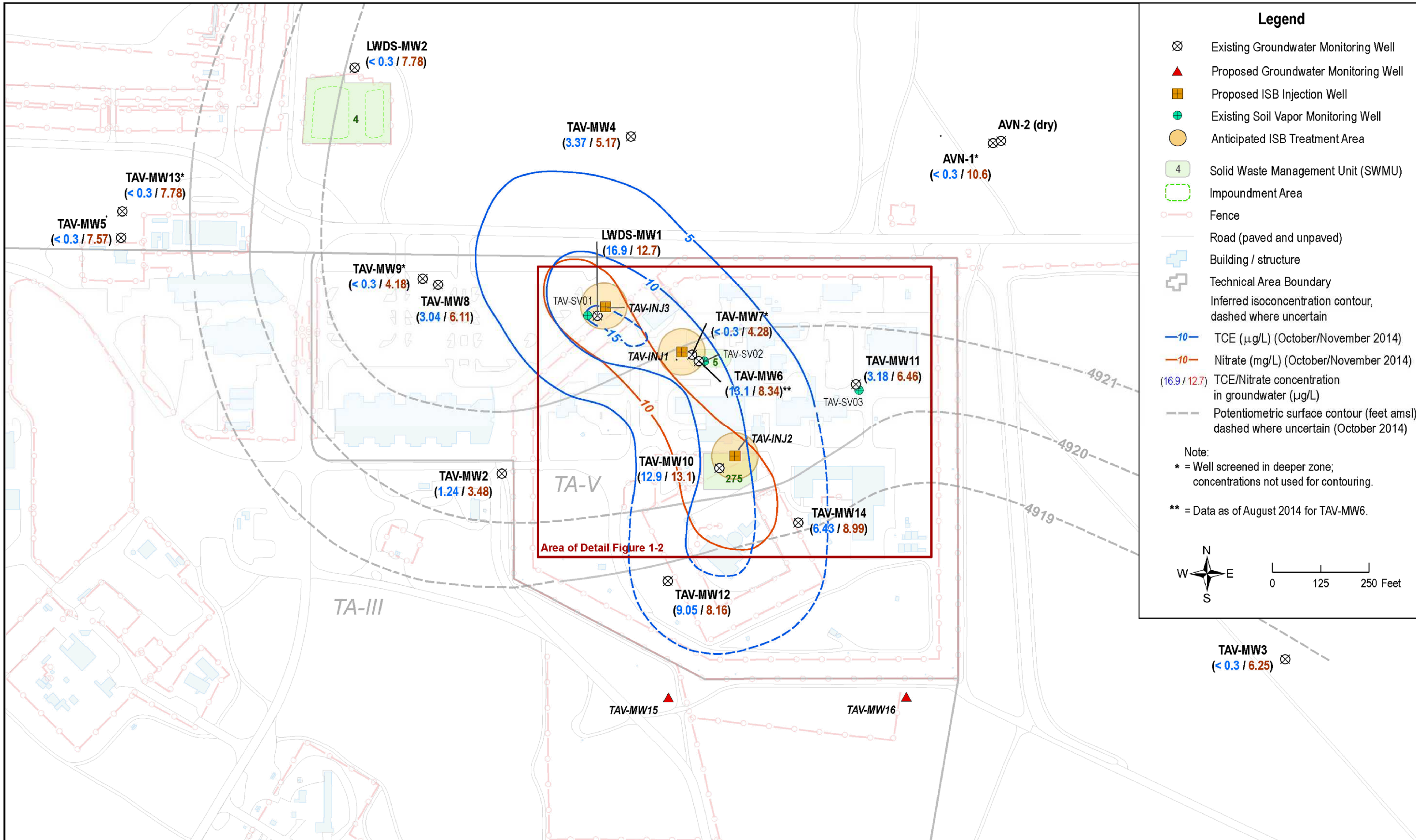


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Figure 1-1
Planned Injection Wells and Additional Groundwater Monitoring Wells

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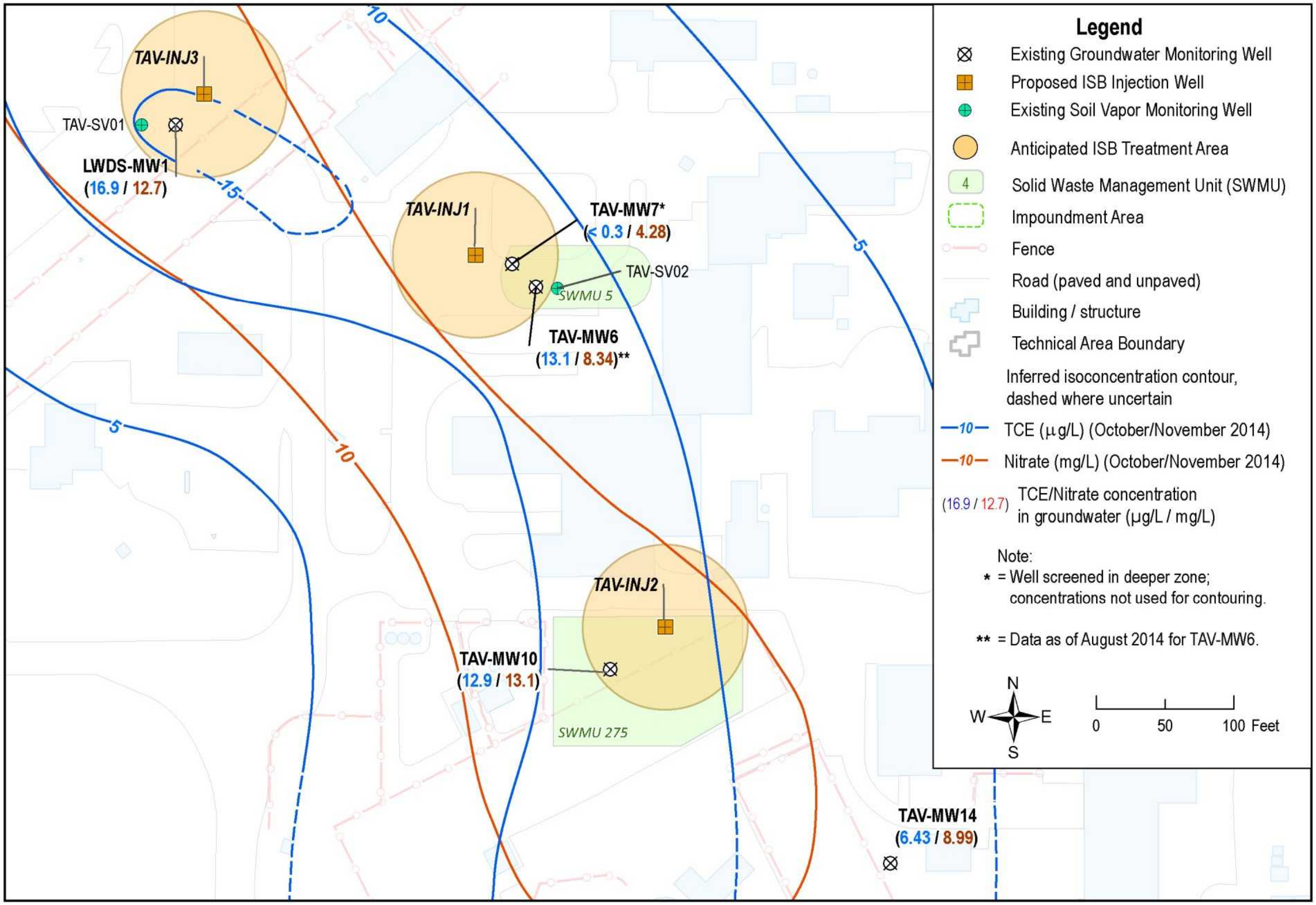


Figure 1-2
Treatability Study In-Situ Bioremediation Treatment Areas

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# 2.0 OVERVIEW OF THE TREATABILITY STUDY

The Treatability Study consists of two phases with primary steps as outlined below:

Phase I

1. Installation of groundwater monitoring wells TAV-MW15 and TAV-MW16 south of TA-V, and injection well TAV-INJ1 near Solid Waste Management Unit (SWMU) 5.
2. Conducting a proof of concept pilot test at well TAV-INJ1 by extracting and reinjecting approximately 3,700 gallons (gal) groundwater mixed with substrate solution and bioaugmentation bacteria (KB-1® Dechlorinator) to evaluate the practicality of ISB and to refine injection procedures if needed. Pilot test injection will be followed by four months of post-injection performance monitoring.
3. Full-scale sequential injection of approximately 530,000 gal of potable water mixed with substrate solution and bioaugmentation bacteria over a 6-month period to treat a 60-foot (ft) radius treatment area around well TAV-INJ1. Full-scale injection will be followed by 24 months of post-injection performance monitoring.

Phase II

1. Installation of injection well TAV-INJ2 near SWMU 275 and injection well TAV-INJ3 near monitoring well LWDS-MW1.
2. Full scale injections at wells TAV-INJ2 and TAV-INJ3, each using approximately 530,000 gal of potable water mixed with substrate solution and bioaugmentation bacteria to treat a 60-ft radius treatment area around the respective injection wells. Each injection will occur over a period of approximately six months. Post-injection performance monitoring will be conducted for 24 months after each injection.

Reporting

Well installation reports and injection test results will be reported to the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) at key decision points during the Treatability Study.

1. Decision Point #1 will occur after completing the pilot test post-injection performance monitoring period to determine if the full-scale test at well TAV-INJ1 should be implemented and how to optimize procedures.
2. Decision Point #2 will occur after completing the full-scale injection and the first six months of post-injection performance monitoring at well TAV-INJ1 to determine if Phase II well installation and full-scale tests should proceed and if further procedure optimization is needed.

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# 3.0 DOCUMENT ORGANIZATION

The following sections of this FIP are organized follows:

Section 4.0: Injection Wells and Aboveground Injection System

This section presents planned construction details for the injection wells and the Aboveground Injection System that will be used to prepare the substrate solution and co-inject it along with the bioaugmentation bacteria to the injection wells.

Section 5.0: Equipment and Materials

This section presents the quantities and mixing ratios of substrate solution components and bioaugmentation bacteria (Table 5-1), the equipment and materials needed for the Aboveground Injection System (Table 5-2), and the equipment for groundwater sampling and field parameter measurements (Table 5-3). Equipment, materials, and implementation procedures are subject to change based on field conditions, availability and feasibility, and inputs from Sandia personnel and Aboveground Injection System contractor.

Section 6.0: Phase I: Well Installation and Baseline Sampling

This section presents the design and procedures for installing monitoring wells TAV-MW15 and TAV-MW16 and injection well TAV-INJ1, groundwater sampling at the new monitoring wells to incorporate them into the Long-Term Stewardship (LTS) TAVG monitoring network, and protocols for establishing baseline conditions in wells TAV-INJ1, TAV-MW6, and TAV-MW7 before implementing ISB.

Section 7.0: Phase I: Pilot Test at Injection Well TAV-INJ1

This section presents the procedures for conducting the proof of concept pilot test at well TAV-INJ1 including site preparation, equipment set up, data collection, groundwater extraction, addition of substrate and bioaugmentation components, injection, and post-injection performance monitoring.

Section 8.0: Phase I: Full-scale Test at Injection Well TAV-INJ1

This section presents how the pilot injection system is to be expanded for longer-term injection, the substrate solution and bioaugmentation bacteria preparation, injection, and monitoring both during the injection period and during the post-injection performance period.

Sections 9.0 through 10.0: Phase II

These sections discuss procedures for installing injection wells TAV-INJ2 and TAV-INJ3 (Section 9.0) and conducting the associated full-scale tests at wells TAV-INJ2 and TAV-INJ3 (Section 10.0). These sections primarily refer back to prior applicable sections as procedures are assumed to be the same until Phase I is completed. Procedures will be optimized based on lessons learned as the project progresses.

Appendices

Appendix A presents the projected groundwater sampling schedule and an overview for mini-Sampling and Analysis Plan (mini-SAP) to be implemented throughout the Treatability Study.

Appendix B includes field data collection forms to be used during the Treatability Study.

Appendix C provides a detailed series of figures showing the injection process with emphasis on co-injecting the bioaugmentation bacteria (KB-1® Dechlorinator) to supplement the procedure descriptions in Sections 7.0, 8.0, and 10.0.

Other Documents

This FIP is one of the planning and logistics documents to be maintained at the work site while conducting field operations. Documents maintained at the site include but are not limited to:

- This FIP.
- Current Conceptual Model for TAVG AOC and NMED HWB's approval letter.
- Revised Treatability Study Work Plan, Response to NMED HWB's comments, and NMED HWB's approval letter.
- National Environment Policy Act (NEPA) Checklist.
- New Mexico Office of the State Engineer drilling permits.
- NMED Ground Water Quality Bureau (GWQB) Groundwater Discharge Permit.
- SNL/NM Institutional Biosafety Committee Project Registration.
- SNL/NM Technical Work Document.
- Health and Safety Plan (HASP).
- Engineered Safety Review.
- SNL/NM Primary Hazard Screening (PHS).
- Purchase Order / Contract Purchase Agreement between SNL/NM and the drilling contractor.
- Drilling contractor's Contract-Specific Safety Plan (CSSP) and Job Safety Analysis (JSA) forms.
- Training certificates for drilling contractor staff.
- Purchase Order / Contract Purchase Agreement between SNL/NM and the Aboveground Injection System contractor.
- The Aboveground Injection System contractor's CSSP and JSA forms.
- Training certificates for Aboveground Injection System contractor staff.
- Excavation (dig) Permits from Facilities Engineering.
- Hot Work Permits from Facilities Engineering,
- Industrial Hygiene evaluation.
- Drill Rig inspection form(s).
- Tailgate Safety Meeting (TSM) daily forms.
- Environmental Restoration Operations Field Work Punch list.
- Site-specific Waste Management Plan (WMP).
- A list of current phone contacts.

# 4.0 INJECTION WELLS AND ABOVEGROUND INJECTION SYSTEM

This section presents details of injection well construction and the Aboveground Injection System design.

Figure 4-1 shows the planned construction details for the three injections wells. Each injection well consists of two adjacent ("nested") casings placed in the same borehole. The 5-inch (in) nominal diameter casing is referred to as the monitoring casing and the adjacent 1.5-in nominal diameter casing is referred to as the injection casing. The monitoring casing will be used for manual depth-to-water measurements, slug test, groundwater sample collection, downhole field parameter measurements, and to extract groundwater for the pilot test. The injection casing will be used as the conduit for gravity injections of substrate solution and co-injected bioaugmentation bacteria and may be used as an alternate conduit for manual depth-to-water measurements. Specific details for well construction materials and well completion will be incorporated in the drilling contractor Statement of Work (SOW) and will be refined based on field conditions.

Figure 4-2 is a diagram showing the Aboveground Injection System to be used for the Treatability Study. The diagram indicates which parts will be installed for the pilot test and the additional equipment to be installed for a full-scale test. The pilot test will use groundwater extracted from well TAV-INJ1 to mix with substrate components and KB-1® Dechlorinator. The pilot test will not inject unamended potable chase water. System components for potable water and chase water delivery will be added for the full-scale test (after Decision Point #1).

Figure 4-3 presents the diagram details A, B, C, and D as indicated in Figure 4-2. Modifications may be made to these designs based on SNL personnel and Aboveground Injection System contractor input, equipment availability, and field conditions.

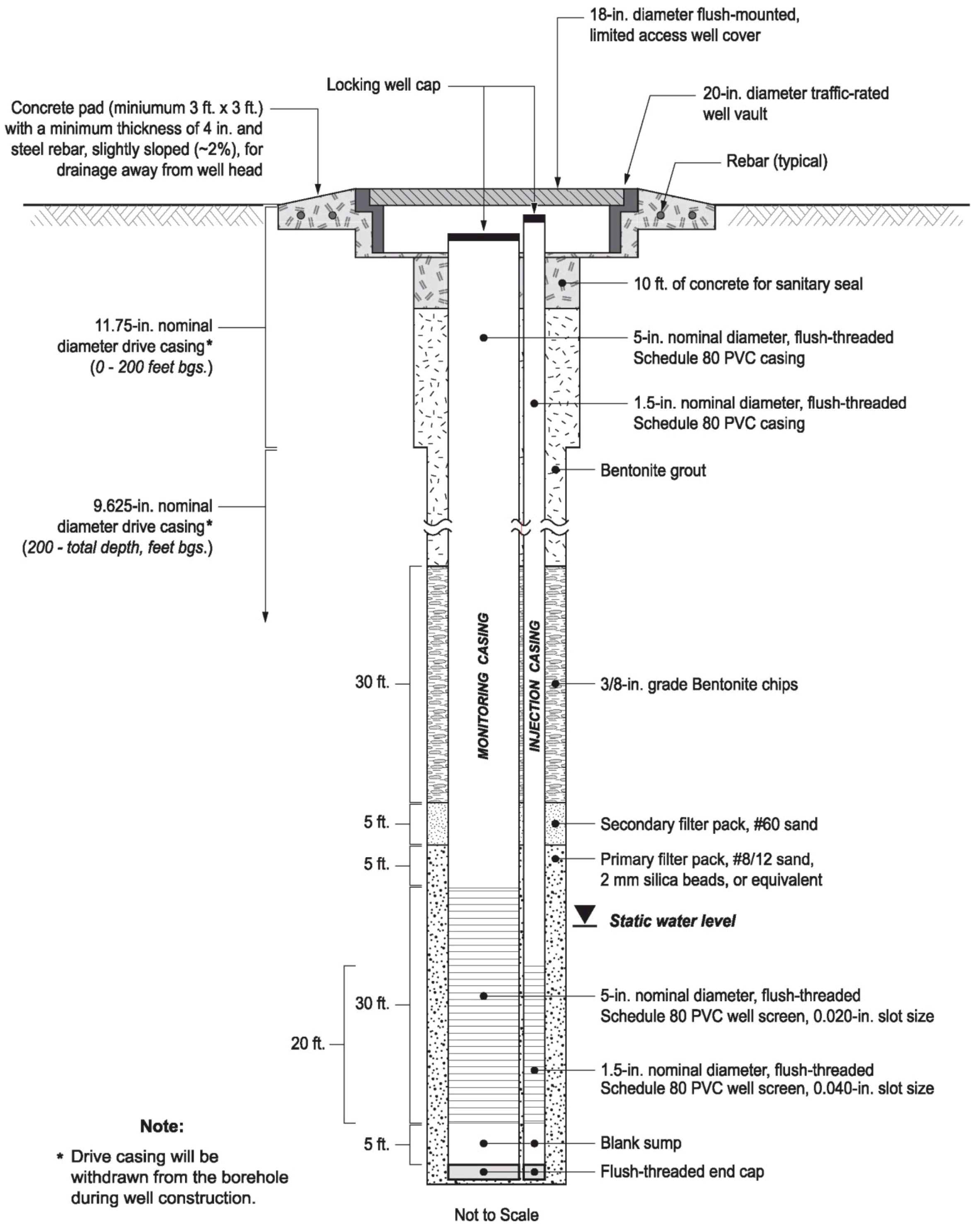


Figure 4-1.
Nested Casing Injection Well Design

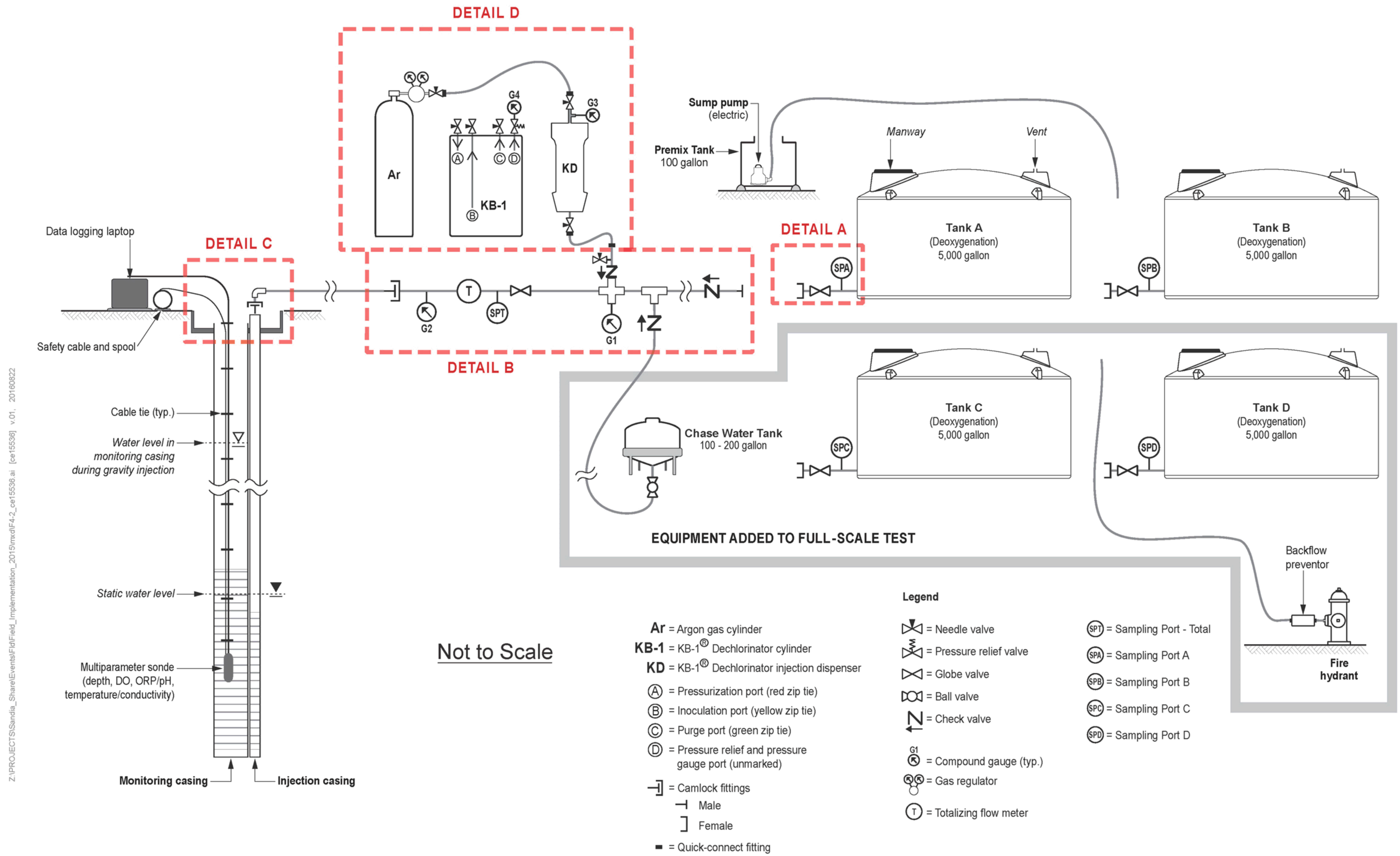


Figure 4-2.
Treatability Study Aboveground Injection System Diagram

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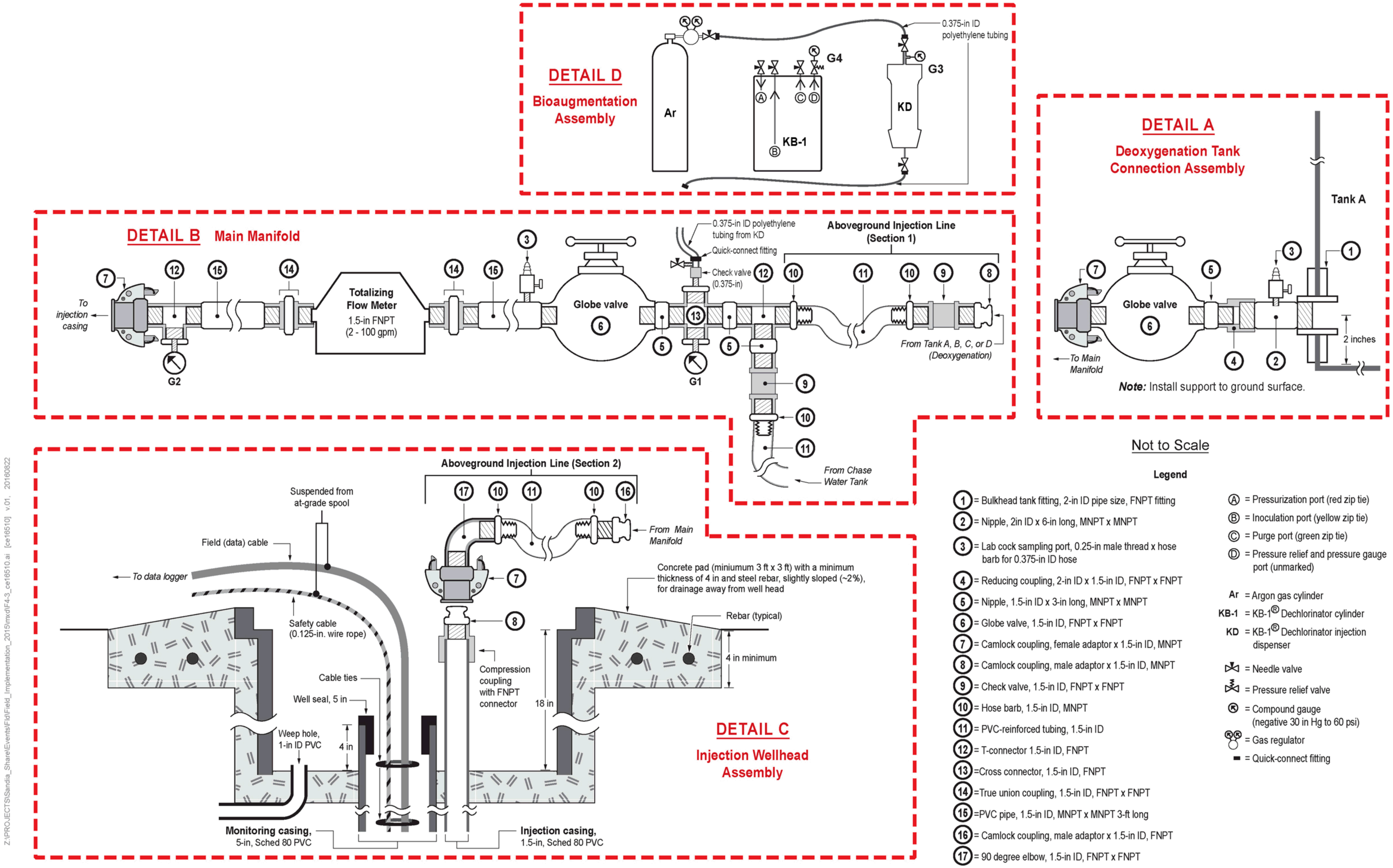


Figure 4-3.
Treatability Study Aboveground Injection System Diagram **– Details**

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# 5.0 EQUIPMENT AND MATERIALS

This section presents the components of the bioremediation solution, the equipment and materials for constructing the Aboveground Injection System, and the equipment for groundwater sampling and field parameter measurements.

Table 5-1 lists the components to be mixed with either extracted groundwater or potable water prior to being injected and gives the anticipated mixing ratios and quantities. These values are based on the electron donor demand and mass calculations detailed in Appendix A of the Revised Work Plan. Results from baseline groundwater sampling and slug (hydraulic conductivity) tests of injection wells will be compared against the Revised Work Plan assumptions to revise these ratios and quantities if necessary.

Table 5-2 lists the specifications for the primary equipment needed for constructing the Aboveground Injection System. Details such as exact lengths of various tubing, number and type of fittings, etc. will be refined as part of the Aboveground Injection System contractor SOW.

Table 5-3 lists the equipment specifications for groundwater sampling and field parameter measurement.

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Table 5-1. Substrate Solution and Bioaugmentation Bacteria Mixing Quantities

| | **Water Volume for Each Tank** (gal) | **Soil Cuttings** (lbs) | **KB-1® Primer** [a] (number of 800-gram pouches) | **Ethyl Lactate** [b] (gal) | **Diammonium Phosphate** [b] (lbs) | **Yeast Extract** [b] (lbs) | **Sodium Bromide** [c] (grams) | **Total Volume of Substrate Solution Injected per Day** (gal) | **KB-1® Dechlorinator** [d] (mL) |
|---|---|---|---|---|---|---|---|---|---|
| | | Microbe inoculation | Deoxygenation accelerator and substrate substitute | Electron donor (substrate) | Nutrient and pH buffer | Nutrient | Tracer | | Bioaugmentation bacteria |
| **Pilot Test – Injection Well TAV-INJ1** (groundwater in tanks) | | | | | | | | | |
| Premix Tank | 100 | --- | 8 | --- | --- | --- | --- | **3,700** [e] | **800** |
| Tank A | 1,750 | 10 | --- | --- | --- | --- | --- | | |
| Premix Tank | 100 | --- | --- | 2 | 3.5 | 0.6 | 340 | | |
| Tank B | 1,750 | --- | --- | --- | --- | --- | --- | | |
| **Full-scale Tests at Wells TAV-INJ1, TAV-INJ2, and TAV-INJ3** (potable water in tanks) | | | | | | | | | |
| Substrate Solution Preparation for 1st and 2nd Day of Injection | | | | | | | | | |
| Premix Tank | 100 | --- | 10 | --- | --- | --- | --- | **5,000** [f] | **1,100** |
| Tanks A, B, C, D | 2,400 | 15 | --- | --- | --- | --- | --- | | |
| Premix Tank | 100 | --- | --- | 2.5 | 4.75 | 0.75 | 450 | | |
| Tanks A, B, C, D | 2,400 | --- | --- | --- | --- | --- | --- | | |
| Substrate Solution Preparation for 3rd, 5th, 7th, 9th, etc. Day of Injection | | | | | | | | | |
| Premix Tank | 100 | --- | --- | 2.5 | 4.75 | 0.75 | 225 | **5,000** [f] | **1,100** |
| Tanks A and B | 2,400 | --- | --- | --- | --- | --- | --- | | |
| Substrate Solution Preparation for 4th, 6th, 8th, 10th, etc. Day of Injection | | | | | | | | | |
| Premix Tank | 100 | --- | --- | 2.5 | 4.75 | 0.75 | 225 | **5,000** [f] | **1,100** |
| Tanks C and D | 2,400 | --- | --- | --- | --- | --- | --- | | |
| Chase Water per Injection Day [g] | 100 | --- | --- | --- | --- | --- | --- | **100** | **---** |
| Estimated Total per Full-scale Test [h] | --- | 60 | 40 | 530 | 1007 | 159 | 48 (kg) | **540,000** | **117 (L)** |
| Estimated Treatability Study Total [i] | --- | 190 | 128 | 1,592 | 3,025 | 478 | 144 (kg) | **1,625,500** | **351 (L)** |

Notes:

gal = gallons, kg = kilograms, L = liters, lbs = pounds, mL = milliliters

[a] KB-1® Primer is a product manufactured and supplied by SiREM, Guelph, Ontario, Canada. Quantity of KB-1® Primer is based on manufacturer recommendations, but may be increased if DO does not decline to < 0.5 milligrams per liter (mg/L) within a reasonable timeframe (within four hours).

[b] Quantities of substrate solution components are based on anticipated electron donor demand assumptions and associated calculations and mixing ratios discussed in Section 4 and Appendix A of the *Revised Treatability Study Work Plan for In-Situ Bioremediation at the Technical Area-V Groundwater Area of Concern* (March 2016) and subject to change based on actual field conditions determined after the installation and baseline sampling of injection wells.

[c] Quantity of sodium bromide based on a target of approximately 20 mg/L (approximately 0.2 lbs/1,000 gal of water). If results of injection well slug tests indicate that local hydraulic conductivity is significantly higher than predicted, then the concentration of sodium bromide in the substrate solution may be increased as high as 200 mg/L to offset dilution due to higher local groundwater advection.

[d] KB-1® Dechlorinator is a microbial bacteria product manufactured and supplied by SiREM, Guelph, Ontario, Canada. It will be mixed in line with the substrate solution as it is being gravity injected. Mixing quantities may be revised based on injection well baseline and performance monitoring data.

[e] Tank B content is transferred to Tank A before injection of the total volume into well TAV-INJ1.

[f] Each 5,000-gal injection batch of substrate solution to consist of 2,500 gal each discretely injected from Tanks A and B or from Tanks C and D.

[g] Chase water will be unamended potable water.

[h] Each full-scale test is estimated to have 106 injections.

[i] Includes total from one pilot test at well TAV-INJ1 and three full-scale tests at well TAV-INJ1, TAV-INJ2, and TAV-INJ3, respectively.

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Table 5-2. Equipment and Materials for the Aboveground Injection System

| | Equipment | Specifications | Function |
|---|---|---|---|
| **INSTALLED FOR PILOT TEST** | | | |
| 1 | Deoxygenation Tanks A and B | Two 5,000-gal capacity poly water tanks.<br>• Certified for potable water storage.<br>• Diameter: 141-in, height: 86-in.<br>• 2-in FNPT threaded bulkhead outlet fitting.<br>• 1.5-in FNPT threaded bulkhead inlet fitting.<br>• Fitted with transparent sighting tube. | These tanks are used to store mixed substrate solution for deoxygenation and lowering of ORP and are then gravity-drained to inject the solution into the injection well.<br>Tanks A and B will receive extracted groundwater from well TAV-INJ1 for the pilot test and potable water for full scale tests. |
| 2 | Deoxygenation Tank Connection Assemblies | Two assemblies (one each for Tanks A and B).<br>See **Figure 4-3 Detail A.** Includes: | Connects the 2-in tank outlet and the 1.5-in PVC Aboveground Injection Line that leads to the Main Manifold. |
| | | • ① 2-in FNPT threaded bulkhead outlet fitting (part of deoxygenation tank listed above). | Drain outlet from deoxygenation tank (part of shipped tank). |
| | | • ② Nipple, 2-in ID × 6-in long, MNPT × MNPT. | Pipe extension from bulkhead fitting. |
| | | • ③ Labcock valve, 0.25-in male thread × hose barb for 0.375-in ID tubing. | Installed into 2 × 6-in. nipple. Tank-specific sampling port (to be labeled Sampling Port A and Sampling Port B, respectively). Used to collect tank-specific samples for monitoring field parameters or for laboratory analysis. |
| | | • ④ Reducing coupling, 2 × 1.5-in, FNPT × FNPT. | Reduces line diameter consistent with the Aboveground Injection Line and injection casing diameters. |
| | | • ⑤ Nipple, 1.5-in ID × 3-in length, MNPT × MNPT. | Connection into the tank-specific globe valve. |
| | | • ⑥ Globe valve: 1.5-in, FNPT × FNPT. | Controls drainage flow from the tank. During injection periods, this valve will typically be either completely open or shut. Overall injection flow rate will be controlled by the Main Manifold globe valve. |
| | | • ⑦ Camlock coupling, female adaptor × 1.5-in MNPT. | Receives male couple from Main Manifold upstream injection line. |
| 3 | Main Manifold | See **Figure 4-3 Detail B**. Includes: | Central plumbing section that connects injection streams from the active deoxygenation tank, the Bioaugmentation Assembly, and the Chase Water Tank (for full-scale test) into one central line leading to the injection wellhead. Includes means of controlling and measuring total flow and flow rates, sampling the combined injection flow stream, and monitoring injection line pressures. |
| | | Aboveground Injection Line (Section 1).<br>• ⑧ Camlock coupling, male adaptor × 1.5-in MNPT.<br>• ⑨ Check valve, 1.5-in ID, FNPT × FNPT.<br>• ⑩ Two hose barbs, 1.5-in ID, MNPT (one for each end of the PVC tubing).<br>• ⑪ 1.5-in ID PVC-reinforced tubing (length to be determined by system layout). | Conveys substrate solution from the deoxygenation tank connection assembly into the Main Manifold. |
| | | Chase Water Tank tubing connection.<br>• ⑫ T-connector, 1.5-in FNPT.<br>• ⑤ Two nipples, 1.5-in ID × 3-in length, MNPT × MNPT.<br>• ⑨ Check valve, 1.5-in ID, FNPT × FNPT.<br>• ⑩ Hose barb, 1.5-in ID MNPT (downstream end of chase water tubing). | Facilitates connection during the future full-scale test between PVC tubing coming from the Chase Water Tank into the Aboveground Injection Line. The Chase Water Tank will be added to the system during the full-scale test. These connection components are integrated into the Main Manifold and therefore more efficiently installed when the Main Manifold is assembled for the pilot test. |
| | | Bioaugmentation Assembly tubing connection.<br>• ⑬ Cross connector, 1.5-in. FNPT | Connects compound gauge G1, bioaugmentaiton tubing, into injection line. Downstream of chase water and upstream of the Main Manifold globe valve. |

Continued next page.

Table 5-2. Equipment and Materials for the Aboveground Injection System (continued)

| | Equipment | Specifications | Function |
|---|---|---|---|
| 3 | Main Manifold (continued) | Compound gauge (G1): Negative 30-in Hg to 60 psi. Located at the cross-connector ⑬ connecting the Bioaugmentation Assembly tubing upstream of the Main Manifold globe valve.<br>• G1 fits into the cross connector ⑬ with 0.25-in. FNPT to 1.5-in MNPT reducing couplings (or equivalent). | Measure pressure or vacuum upstream and downstream of the Main Manifold globe valve. |
| | | Needle valve (stainless steel) and associated fittings between the Bioagumentation Assembly discharge line and the 0.375-in check valve leading into the cross-connector. | Used to vent argon gas during preparation for injection of KB-1® Dechlorinator. |
| | | Check valve (0.375-in). | Prevents backflow from Aboveground Injection Line back into Bioaugmentation Assembly. |
| | | Main Manifold globe valve ⑥: 1.5-in FNPT × FNPT. | Serves as the primary injection flow valve. Used to start and stop injection and to regulate flow rate of total solution mixture into the injection well. |
| | | Labcock valve ③, 0.25-in male thread × hose barb for 0.375-in ID tubing. Installed in piping section downstream of the Main Manifold globe valve, but upstream of totalizing flow meter. | Sample Port-Total. Used to measure field parameters and collect samples for analysis of total combined injection stream. |
| | | Totalizing flow meter, 1.5-in MNPT, 2-100 gpm range (Neptune T-10 or functional equivalent).<br>• Two sections of 1.5-in ID MNPT pipe at least 2 ft in length. Each connected to the flow meter via a true union connection ⑭. One upstream of the flow meter connecting to the Main Manifold globe valve outlet and one downstream of the flow meter. | Records cumulative total injected volume and can be used to calculate flow rates and incremental injection volumes.<br>True union connections allow easy removal for maintenance or replacement of the flow meter if necessary. |
| | | Two, PVC pipe sections ⑮, 1.5-in ID, MNPT X MNPT, 3-ft long each. | Installed upstream and downstream of the totalizing flow meter to ensure accurate readings. |
| | | Compound gauge (G2): Negative 30-in. Hg to 60 psi. Located downstream of the totalizing flow meter<br>• T-connector ⑫, 1.5-in ID FNPT downstream end of flow meter pipe for connecting compound gauge G2.<br>• G2 fits into the T- connector ⑫ with 0.25-in FNPT to 1.5-in MNPT reducing couplings (or equivalent). | Measures injection pressure. For full-scale test, G2 also will measure any vacuum created when injection is interrupted as the Main Manifold globe valve is close and injection stream equilibrates in injection casing. |
| | | Camlock coupling ⑦, female adaptor × 1.5-in MNPT. | Connects to Aboveground Injection Line (Section 2). |
| 4 | Injection Wellhead Assembly | See **Figure 4-3 Detail C.** | Connects the injection line to the injection casing using camlock fittings. |
| | | Aboveground Injection Line (Section 2).<br>• ⑪ 1.5-in ID PVC-reinforced tubing (length to be determined by system layout).<br>• ⑩ Two hose barbs, 1.5-in ID, MNPT (one for each end of the PVC tubing).<br>• ⑯ Camlock coupling, male adaptor x 1.5-in FNPT.<br>• ⑰ 90 degree elbow, 1.5-in ID, FNPT × FNPT | Conveys substrate solution from the Main Manifold to the injection wellhead, connecting to the injection casing. |
| | | Top of injection casing.<br>• Injection casing compression fitting collar with female camlock connector ⑦ (fits onto 1.5-in nominal diameter injection casing).<br>• ⑧ Camlock coupling, male adaptor, 1.5-in MNPT. | Connects to the Aboveground Injection Line (Section 2) at the wellhead. Forms a seal. Compression fitting allows for fitting to be removed to allow well vault lid to close properly when the Aboveground Injection Line is not connected to the injection casing. |
| | | Top of monitoring casing.<br>• One-hole well seal (or functional equivalent). | Allows data logging field cable and the wire rope safety cable connected to the downhole multi-parameter sonde to daylight while sealing the monitoring casing top from the elements. Must allow manual movement of cables up and down in monitoring casing. |
| | | Well vault (to be installed by drilling contractor).<br>• 18 x 18-in square by 18-in deep.<br>• Traffic-rated steel cover.<br>• 1-in diameter, PVC weep hole piping installed at base of vault slightly above concrete floor extending horizontally ≥ 1 ft away from the base of the vault wall into adjacent native soil or backfill. | Protects the injection wellhead and provides ground level access.<br>Weep hole piping to drain away possible accumulation of precipitation during rain events when vault is open during injection test. |

Continued next page.

Table 5-2. Equipment and Materials for the Aboveground Injection System (continued)

| | Equipment | Specifications | Function |
|---|---|---|---|
| 5 | Bioaugmentation Assembly | See **Figure 4-3 Detail D**. To be supplied by vendor (SiREM). Includes:<br>• Gas regulator (Linde BASELINE C1061 Single Stage Regulator or functional equivalent).<br>• KB-1® Dechlorinator cylinder and associated valves and compound gauge (negative 30-in Hg to 60 psi) G4.<br>• KB-1® Dechlorinator injection dispenser (KD) (500 ml) with a compound gauge (30-in Hg to 60 psi) G3.<br>• Digital scale (not shown in **Figure 4-3**).<br>• 0.5-in OD, 0.375-in ID polyethylene tubing.<br>• Valves and quick-connect fittings (stainless steel). | Delivers measured amounts of bioaugmentation bacteria (KB-1® Dechlorinator) into the gravity injection stream. Connected to the Main Manifold with 0.375-in ID polyethylene tubing. (see **Figure 4-3 Detail B**).<br><br><u>Note</u>: Argon gas cylinder is also used to connect to tubing used for sparging chase water during full-scale tests.<br><u>Note</u>: For full-scale tests, the 500 mL KD may be substituted with a larger capacity chamber or multiple chambers. |
| 6 | Premix Tank | One poly tank ~ 100 gal capacity with ≥ 18-in diameter opening at top. Low enough profile to allow easy access to top opening while standing on the ground. | Used for mixing substrate components with potable water prior to pumped transfer into deoxygenation tanks. |
| 7 | Sump pump | One portable electric sump pump (powered by a portable generator). >20 gpm discharge capacity.<br>Dedicated inlet and outlet hoses. | Transfers groundwater from Tank B to Tank A (one time event).<br>Used to consolidate and empty residual water from tanks.<br>For the full-scale tests, this is used to transfer mixed substrate solution from the Premix Tank to the deoxygenation tanks. |
| **ADDED FOR FULL-SCALE TESTS** | | | |
| 1 | Deoxygenation Tanks C and D | Two 5,000-gal capacity poly water tank.<br>Same specifications as Tanks A and B (see pilot test equipment). | During the full-scale test each tank receives potable water from fire hydrant and substrate solution transferred from the Premix Tank.<br>Substrate solution is gravity drained from these tanks. |
| 2 | Deoxygenation Tank Connection Assemblies | Two assemblies (one each for Tanks C and D).<br>Same specifications as assemblies for Tanks A and B (see pilot test equipment). | Connects the 2-in tank outlet and the 1.5-in PVC injection line that leads to Main Manifold. Includes a sampling port, globe valve, and camlock connector. |
| 3 | Chase Water Tank | One poly tank >100 gal capacity with inlet opening at top and drain fitting at bottom (e.g., cone bottom tank, or elevated tote).<br>• Ball valve at the tank outlet.<br>• 1.5-in ID PVC-reinforced tubing (length to be determined by system layout) ⑪.<br>• Two hose barbs, 1.5-in ID, MNPT (one for each end of the PVC tubing) ⑩. | Used to store and sparge potable water that is periodically gravity drained through the injection line as "chase water" during the full-scale injection tests.<br>Connects to T-connector ⑫ upstream of Main Manifold globe valve. |
| 4 | Sparge tubing | 0.375-in ID polyethylene tubing cut to length to reach from argon gas cylinder to bottom of Chase Water Tank.<br>Obtain extra tubing for contingency downhole sparging (>550 ft) | Used to sparge Chase Water Tank. May be needed to sparge deoxygenation tanks or injection well column to accelerate drop in DO.<br>Short lengths needed for sampling ports and for inerting headspace of ethyl lactate drums. |
| 5 | Backflow preventer | Reduced Pressure Zone Assembly<br>Supplied by SNL/NM Facilities Engineering<br>(Watts Model RP 2-in LF909M1-QT) | Connects to fire hydrant to prevent backflow into water supply. |

Continued next page.

Table 5-2. Equipment and Materials for the Aboveground Injection System (concluded)

Notes:

Equipment, materials, and implementation procedures are subject to change based on field conditions, availability and feasibility, and inputs from Sandia personnel and Aboveground Injection System contractor.

Pipe and fittings should be Schedule 80 PVC with threaded connections and Teflon tape. No glued fittings. No thread compound (pipe dope).

All parts of the injection system should be rated for potable water use.

① = Circled numbers refer to correspondingly labeled parts shown in Figure 4-3 Treatability Study Aboveground Injection System Diagram - Details
DO = dissolved oxygen
FNPT = female national pipe thread
ft = foot/feet
gal = gallon/gallons
gpm = gallons per minute
Hg = mercury
ID = inside diameter
In = inch/inches
MNPT = male national pipe thread
ORP = oxidation reduction potential
psi = pound(s) per square inch
PVC = polyvinyl chloride

Table 5-3. Equipment for Groundwater Sampling and Field Parameter Measurement

| | Equipment | Specifications | Function |
|---|---|---|---|
| **Groundwater sampling** | | | |
| 1 | Groundwater sampling truck | One set of piston pump sampling equipment and flow cell for groundwater field parameter measurement per **FOP 05-01.** | Collection of groundwater samples from injection well monitoring casing and nearby monitoring wells.<br>Sampling pump will not be dedicated to any given well, therefore, one pump system can be used for all downhole sampling during the tests. |
| 2 | Water level indicator | ≥ 550 ft length. | Static water level measurements in wells. |
| **Treatability Study Field parameter measurement** | | | |
| 3 | Flow cell | One. Accommodates attachment of a multi-parameter sonde. | Connected to the sampling ports in the Aboveground Injection System (Tanks A, B, C, D and the Aboveground Injection Line). |
| 4 | Multi-parameter sondes (downhole in wells)<br><br>Multi-parameter sonde (for the Aboveground Injection System) | Total of six sondes:<br>Phase I: three downhole and one aboveground<br>Phase II: add two more sondes<br>Four-port multi-parameter sondes (YSI EXO1 sonde and associated supplies or functional equivalent)<br>• With calibration cup and sensor guard.<br>• Battery powered option.<br>• Real time downloadable data collection via USB connection to laptop (one sonde will download to handheld display).<br>• Logging software (for PC). | Used for downhole measurement of field parameters:<br>• One in the injection well monitoring casing.<br>Phase I test: Well TAV-INJ1 (Sonde 1.)<br>Phase II test: Well TAV-INJ2 followed by well TAV-INJ3 (move one of Sondes [1, 2, or 3] to well TAV-INJ2 or well TAV-INJ3.<br>• One each in nearest monitoring well(s) as follows:<br>Phase I test: Wells TAV-MW6 and TAV-MW7 (Sonde 2 and Sonde 3).<br>Phase II test: WellsTAV-MW10 (Sonde 4) and LWDS-MW1Sonde 5.)<br>One for aboveground measurements (Sonde 6) of the Aboveground Injection System (Tanks A, B, C, D, and the Aboveground Injection Line). |
| 5 | Parameter sensors | Six sets of parameter sensors (one set per sonde). Each set of sensors consists of the following:<br>• Depth sensor (may be incorporated into sonde body) – submergence range > 600 ft. Not vented.<br>Port-connected sensors with guards and replaceable solution modules as applicable.<br>• Optical DO.<br>• pH/ORP sensor.<br>• Conductivity (µs/cm) / temperature (C°.) | Depth sensor: monitors water level (submergence) throughout test. Used to ensure water column height does not exceed 335 ft.<br>Depth sensor on Sonde 6 will not be used.<br>Measures field parameters to track tank water and groundwater conditions amenable to bioremediation. |
| 6 | Field data cables (long) | Five cables (for Sondes 1 through 5).<br>Length ≥ 750 ft.<br>Non-vented. | Transmits data from the multi-parameter sonde to the laptop PC via a USB connection. |
| 7 | Field data cable (short) | One cable (for Sonde 6).<br>Data cable to connect from sonde to handheld display).<br>Length : ~25 ft. | Transmits data from the multi-parameter sonde (attached to the flow cell) to handheld display. |
| 8 | Sonde safety cable assemblies | Five assemblies (for Sondes 1 through 5).<br>Each includes:<br>• 0.125-in stainless steel wire rope. Matches the length of the field data cable.<br>• Carabiner.<br>• Wire rope clips or Swage® lock fittings. | Safety cable is clipped to the multi-parameter sonde bail to avoid placing stress on the field cable while it is deployed, hung in the well, and retrieved. Anchored above ground. |

Continued next page.

Table 5-3. Equipment for Groundwater Sampling and Field Parameter Measurement (concluded)

| | Equipment | Specifications | Function |
|---|---|---|---|
| 9 | Spools | Five spools (for Sondes 1 through 5).<br>Accommodates up to 750 ft of bundled field data cable, sonde safety cable, and possible sparge tubing. | Used to deploy, anchor, and retrieve, the multi-parameter sonde and associated safety cable. |
| 10 | USB adapters | Five adaptors (for Sondes 1 through 5). | Signal output adaptor. Connects field data cable end to USB port enabling connection to the laptop. |
| 11 | Laptop PC and data logging software | Sonde manufacturer-specific software for sensor set up, calibration, and data logging.<br>Software must allow for tracking up to seven multi-parameter sondes of data. | Used to log measurement and calibration data from downhole multi-parameter sondes. |
| 12 | Hand-held display equipped with logging software | Sonde manufacturer-specific software for sensor set up, calibration, and data logging. | Used to log measurement and calibration data from aboveground sonde (Sonde 6). |

Notes:

Equipment, materials, and implementation procedures are subject to change based on field conditions, availability and feasibility, and inputs from Sandia personnel and Aboveground Injection System contractor.

µs/cm = microsiemens per centimeter
DO = dissolved oxygen
ft = foot/feet
ORP = oxidation reduction potential
pH = potential for hydrogen
psi = pound(s) per square inch
PVC = polyvinyl chloride

# 6.0 PHASE I: WELL INSTALLATION AND BASELINE SAMPLING

Phase I of the Treatability Study includes installing two groundwater monitoring wells, TAV-MW15 and TAV-MW16, outside the southern boundary of TA-V, and injection well TAV-INJ1 near the center of TA-V in the vicinity of SWMU 5.

Multiple contractors will perform the various functions related to well installation as summarized in Table 6-1. Details of the tasks are presented in SOW for each contractor and incorporate applicable SNL/NM Field Operating Procedures (FOPs).

Table 6-1. Contractor Scopes for Well Installation

| Contractor category | Scope of work |
|---|---|
| Drilling contractor | • Borehole drilling<br>• Well construction<br>• Well development |
| Geophysical logging contractor | • Downhole geophysical logging of the borehole or well casing |
| Surveying contractor | • Surveying well location and elevation |

Initial groundwater sampling and slug test will be conducted by SNL/NM field staff after well development following appropriate SNL/NM FOPs.

Disposition of generated waste is detailed in the project WMP.

If significant delays are encountered in the schedule, declining groundwater levels will need to be evaluated and the planned depths for wells screens adjusted accordingly.

## 6.1 Install and Sample Monitoring Wells TAV-MW15 and TAV-MW16

Figure 1-1 shows the planned locations for monitoring wells TAV-MW15 and TAV-MW16. Monitoring well design is specified in the Revised Work Plan and SOW for the drilling contractor. Table 6-2 shows the anticipated well design specifications.

Table 6-2. 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 | 517 - 542 | 507 - 547 | 547 |
| TAV-MW16 | 535 [a] | 533 - 558 | 523 - 563 | 563 |

[a] Assumes well TAV-MW16 ground surface elevation is approximately 12 ft higher and water table is 2 ft lower than at well TAV-MW15.
bgs = below ground surface.
ft = feet.

After each new well has been developed, SNL/NM field staff will collect the initial static groundwater water level measurements and groundwater samples in accordance with Field Operating Procedure (FOP) 03-02 and FOP 05-01, respectively, and will decontaminate sampling equipment prior to placement in each well and after each sampling event in accordance with FOP 05-03.

Groundwater samples from wells TAV-MW15 and TAV-MW16 will be collected and analyzed as follows:

- Quarterly for Nitrate plus Nitrite (NPN).
- Quarterly for volatile organic compounds (VOCs) - Target Compound List.
- Annually for general chemistry [a].
- Annually for radiological screening parameters [a].
- Annually for total metals - Target Analyte List (TAL) [a].
- Quarterly for perchlorate for four quarters after installation [b].

[a] Waste characterization parameters for compliance with SNL/NM Corporate Procedures and Policies.
[b] Required by the Consent Order for all new groundwater monitoring wells.

The sample schedule and analyses are incorporated in the overview for TAVG mini-SAPs included in Appendix A. The sample schedule and analyses are subject to revision by SNL personnel to accommodate project schedule changes, Discharge Permit requirements, and SNL policies and procedures.

Purge water from these two wells may need to be segregated until analytical results confirm they can be disposed of as the same waste stream in accordance with FOP 05-04.

SNL/NM personnel will conduct slug test in accordance with FOP 09-05.

## 6.2 Install Injection Well TAV-INJ1

Figures 1-1 and 1-2 show the planned locations for installation of the three injections wells. Injection well TAV-INJ1 will be installed first and used for Phase I of the Treatability Study. Installation of injection wells TAV-INJ2 and TAV-INJ3 are contingent upon successful results from Phase I.

Table 6-3 shows the anticipated well design specifications for injection wells TAV-INJ1, TAV-INJ2, and TAV-INJ3. Table 6-3 also shows the construction details of the neighboring monitoring wells currently in place that will be used for performance monitoring during each respective injection test.

Soil core retrieved from the screened interval of well TAV-INJ1 that is not used for analytical samples will be stored in sealed plastic tubing or bags to retain moisture. This core will be used to inoculate substrate solution with indigenous microbes in the first batch of substrate solution for both pilot and full-scale tests.

The injection well will be installed by a drilling contractor in accordance with a contract-specific SOW and in accordance with applicable SNL/NM FOPs. Well development will be conducted by the drilling contractor in accordance with FOP 94-41. Waste generated during the well installation and subsequent development will be stored, profiled, and disposed of in accordance with the project WMP.

SNL/NM personnel will conduct slug test in accordance with FOP 09-05.

Table 6-3. Anticipated Injection Well Design Specifications

| Treatment Area and Well Description | Well Name | Estimated Depth to Water 2016-2017 (ft bgs) | Monitoring Casing Screen Interval [a] (ft bgs) | Filter Pack Interval (ft bgs) | Total Casing Depth (ft bgs) |
|---|---|---|---|---|---|
| **Phase I** | | | | | |
| Planned Injection Well | TAV-INJ1 | 513 | 508 - 538 [a] | 498 - 543 | 543 |
| Existing Monitoring Well | TAV-MW6 | 513 | 507 - 527 | 498 - 534 | 532 |
| Existing Monitoring Well | TAV-MW7 | 516 | 597 - 617 | 586.5 – 644 | 622 |
| **Phase II** | | | | | |
| Planned Injection Well | TAV-INJ2 | 519 | 514 - 544 [a] | 504 - 549 | 549 |
| Existing Monitoring Well | TAV-MW10 | 519 | 508 - 528 | 494 – 539 | 533 |
| Planned Injection Well | TAV-INJ3 | 505 | 500 - 530 [a] | 490 - 535 | 535 |
| Existing Monitoring Well | LWDS-MW1 | 505 | 495 – 515 | 495 - 525 [b] | 520.3 |

[a] Screen interval shown is for the monitoring casing screen. Top of the adjacent injection casing screen is 10 ft lower with same bottom depth as the monitoring casing.
[b] LWDS-MW1 well log indicates "plug back" beneath well casing from 520.3-525 ft bgs, but does not specify material. It is assumed to be a combination of filter pack sand and slough.
bgs = below ground surface.
ft = feet.

## 6.3 Establish Baseline Conditions

To confirm that there are sufficient VOC and nitrate concentrations present to justify performing the pilot test in well TAV-INJ1, the groundwater sampling schedule in Appendix A calls for sampling TAV-INJ1 for VOCs and NPN and reviewing the results in advance of installing the gravity injection system. Rush turnaround is specified for these analyses. Additionally, collect and analyze a sample for sulfate. Compare the sulfate, VOCs, and nitrate concentrations to those assumed in the Revised Work Plan electron donor mass calculation (Appendix A of the Revised Work Plan) to determine if the amount and mixture of substrate solution components needs to be revised.

Establishing Baseline Purge Volume

Per FOP 05-01, at least one saturated casing volume will be purged and stabilization of field parameters must be observed prior to sample collection. Record the total volume purged for each sampled well for future sampling events to reference as this will establish the well-specific purge volumes going forward during the Treatability Study.

Record the depth of the sampling pump intake below the top of PVC casing and the purging flow rate on the *Field Measurement Log for Groundwater Sample Collection* (Appendix B).

Use a consistent well-specific pump intake depth, purging flow rate, and purge volume for subsequent sampling regardless of field parameter stability. Field parameter stabilization will not be required for sample collection at an injection well or its paired monitoring well(s) after baseline sampling has been conducted because the injection in of itself is intended to cause changes in some of those field parameters. It is a more defensible sampling protocol to maintain a consistent purge volume from event to event in the case of in-situ treatment.

Dispose of purge water in accordance with FOP 05-04 and the project WMP.

Field Parameter Measurements

FOP 05-01 also calls for measuring the following field parameters during groundwater purging:

- Dissolved oxygen (DO).
- Oxidation reduction potential (ORP).
- Potential for hydrogen (pH).
- Specific conductance (SC)
- Temperature.
- Turbidity.

With the exception of turbidity, these parameters will be used to compare against downhole measurements collected prior to initiating groundwater re-injection for the pilot test.

Baseline Groundwater Sampling

Collect baseline samples for the full set of test performance analyses and initiate downhole field parameter measurements from wells TAV-INJ1, TAV-MW6, and TAV-MW7 within three months of starting the pilot test. Follow the sampling protocol for using non-dedicated sampling pumps described in FOP 05-01.

Baseline groundwater samples will be analyzed for the following performance monitoring analytical constituents:

- Alkalinity (total, bicarbonate, and carbonate).
- Ammonia (as nitrogen).
- Anions (bromide, chloride, fluoride, nitrite, and sulfate).
- *Dehalococcoides* (Dhc) and, if Dhc is present, vinyl chloride reductase (vcrA).
- Dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, and sodium).
- Methane/ethene/ethane.
- NPN.
- Orthophosphate (as phosphorus).
- Total organic carbon (TOC).
- Sulfide.
- VOCs (Target Compound List [TCL]).

This suite of constituents will continue to be monitored throughout the Treatability Study to assess ISB performance. Appendix A presents the groundwater sampling schedule and an overview of mini-SAPs for the entire anticipated duration of the Treatability Study. These mini-SAPs will be reviewed and updated as the Treatability Study proceeds.

Additional constituents will be analyzed for the initial sampling of well TAV-INJ1 to complete the required annual, well-specific purge water disposal profiling. These include:

- Total metals (TAL).
- Radiological screening parameters (gamma spectroscopy [short-list], gross alpha and beta, and tritium).

It is anticipated the annual waste profiling sampling would be conducted in the same baseline sampling event for wells TAV-INJ1, TAV-MW6, and TAV-MW7.

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# 7.0 PHASE I: PILOT TEST AT INJECTION WELL TAV-INJ1

This section presents the procedures for implementing the Treatability Study pilot test at injection well TAV-INJ1. It assumes that results from baseline groundwater sampling and slug test of well TAV-INJ1 will be sufficiently consistent with assumptions made in the Revised Work Plan to proceed with the pilot test at this location.

It is organized by the chronologic sequence of field work as follows:

7.1 Equipment Cleaning

7.2 Site Preparation and Equipment Set Up

7.3 Sampling and Data Collection

7.4 Groundwater Extraction and Injection

7.5 KB-1® Dechlorinator Injection

7.6 Preparation for Post-Injection Performance Monitoring

7.7 Post-Injection Performance Monitoring

Where applicable, SNL/NM Field Operating Procedures are referenced rather than repeating their content.

Implementation of the ISB injections and associated data collection will be assigned to the Aboveground Injection System contractor team (the System Operation Team) and the team of SNL/NM field personnel (the Groundwater Sampling Team):

1. The System Operation Team will perform the majority of field operations during the Treatability Study after the Aboveground Injection System has been installed, including:
   - With the equipment and help of the Groundwater Sampling Team, setting up and operating the downhole multi-parameter sondes and associated logging equipment, including sonde deployment, retrieval, calibration, and maintenance during the injection periods.
   - Preparing and monitoring the deoxygenation of the substrate solution.
   - Collecting grab groundwater samples from the Aboveground Injection Line.
   - Performing co-injection of the bioaugmentation bacteria and recording usage.
   - Performing injection of the bioremediation solution including substrate solution and bioaugmentation bacteria, and recording usage.
   - Recording flow rates and totalizer readings.
2. The Groundwater Sampling Team will collect groundwater samples in accordance with the sampling schedule and mini-SAP tables before and after injection (pilot test injection is a one-time event).

All tasks described in the following sections are performed by the contracted System Operation Team with the exception of groundwater sampling and any associated waste/wastewater disposal. This Groundwater Sampling Team will take over operation of the downhole multi-parameter sondes and associated data collection during the post-injection monitoring periods.

## 7.1 Equipment Cleaning and Inspection

Clean all equipment prior to it being put into use, according to the protocols listed below in Table 7-1.

Inspect the equipment to ensure it is in good condition and working properly.

## 7.2 Site Preparation and Equipment Set Up

Figure 7-1 shows a preliminary site plan layout for the pilot test at injection well TAV-INJ1.

Primary components of the Aboveground Injection System are shown including:

- The two 5,000 gal deoxygenation tanks located on the unpaved central island north of well TAV-MW7.
- The Mixing Area to include the Bioaugmentation Assembly and the Premix Tank.
- The Aboveground Injection Line that will deliver substrate solution and bioaugmentation bacteria to the TAV-INJ1 wellhead.

An Aboveground Injection System contractor will be employed to assemble the Aboveground Injection System off site. Specific assembling requirements will be developed as part of the contractor SOW.

Table 7-1. Equipment Cleaning Protocols

| Equipment | Protocol |
|---|---|
| **Sampling and field measurement equipment** | |
| Portable non-dedicated piston pump system including flow cell and associated tubing | • Follow FOP 05-03: *Groundwater Monitoring Equipment Decontamination* (latest revision) prior to each time the pump is placed in the well. |
| Field parameter measurement equipment | • See manufacturer's instruction manual. If not described, then gently wash exterior with 1% Liquinox (or functional equivalent) and potable water solution.<br>• Rinse with potable water. |
| **Aboveground equipment** | |
| Poly tanks<br>• Deoxygenation (Tanks A, B, C, and D)<br>• Premix Tank<br>• Chase Water Tank (full-scale test) | • Pressure wash tank interiors with potable water.<br>• Drain rinsate and allow to air dry.<br>• Fitting threads that will contact treatment water, should be hand scrubbed with 1% Liquinox (or functional equivalent) prior to installation. |
| Aboveground Injection System components:<br>• Piping sections<br>• Connection fittings (tees, elbows, true unions, camlock fittings, etc.)<br>• Injection hose (aboveground portion)<br>• Valves, sample ports, and instrumentation (flow meters and pressure gauges) | • Wash interior surfaces that will contact the injection stream with 1% Liquinox (or functional equivalent) and potable water solution. Be sure surfaces are free of machining oils or other lubricants and any debris.<br>• Rinse with potable water.<br>• Use Teflon tape for pipe fitting threads. No PVC cement or other adhesives are permitted.<br>• Cleaned materials should be stored in plastic (e.g., bags or wrapped in sheeting) until ready for assembly. |

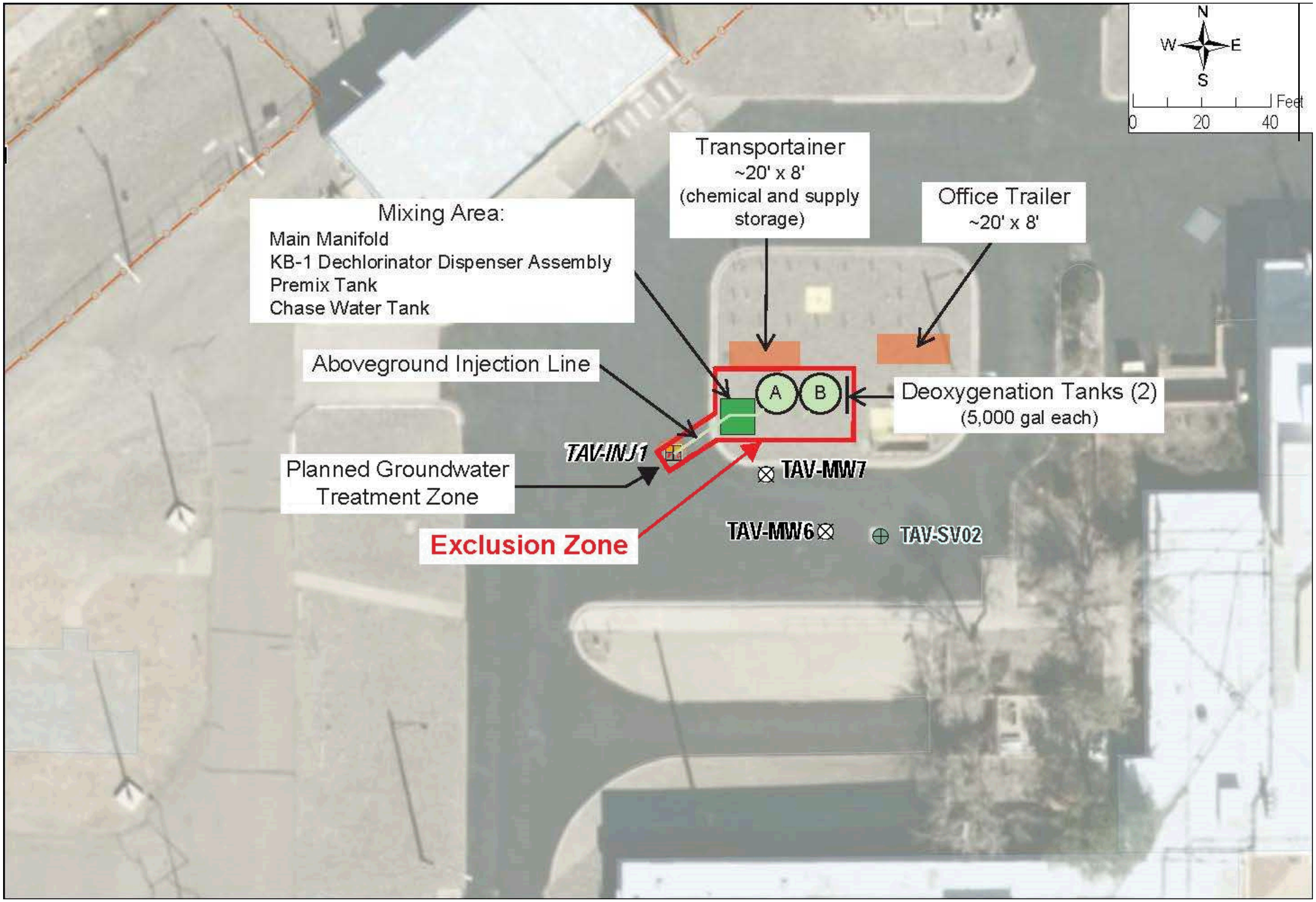


Figure 7-1
Site Layout Plan – Pilot Test at Injection Well TAV-INJ1

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### 7.2.1 Site Staging

Set up the pilot-test work site according to the three area categories as shown in Figure 7-1 and as summarized in Table 7-2 below:

Table 7-2. Site Staging Areas

| Area | Components | Delineation |
|---|---|---|
| **Exclusion Zone** | • Deoxygenation tanks<br>• Mixing area (Main Manifold, Bioaugmentation Assembly, Premix Tank, and underlying spill containment)<br>• Aboveground Injection Line<br>• TAV-INJ1 wellhead and downhole field parameter sonde | Delineated with Jersey barriers (plastic or concrete) and/or caution tape. |
| **Office and storage** | • Office trailer (~20 ft X 8 ft)<br>• Chemical and supply storage transportainer (~20 ft X 8 ft) | Located in close proximity to but outside of the Exclusion Zone. No special delineation. |
| **ISB performance monitoring wells** | • TAV-MW6 wellhead<br>• TAV-MW7 wellhead<br>• Downhole field parameter sondes | Delineated with moveable traffic bollards or cones. |

The project area is defined by the Exclusion Zone, the office trailer, storage transportainer, and any additional area needed for the Treatability Study. The project area will be more accurately defined as the system is set up and may differ from the system layout plans.

Implement pedestrian and vehicular traffic controls such as extra walkways, barricades, and signage at the direction of Facilities Engineering.

### 7.2.2 Exclusion Zone Components

Delineate the extent of the Exclusion Zone. The Exclusion Zone dimensions can be modified in the field as necessary.

The Aboveground Injection System will be installed and operated by a contractor in accordance with their SOW. The following instructions are guidance for installing the main components and the System will be installed in the order deemed most efficient and appropriate by the Aboveground Injection System contractor.

<u>Deoxygenation Tanks A and B</u>

Each test location requires site preparation for placement of the 5,000-gal poly tanks used for substrate solution deoxygenation. For the pilot test, two tanks will be used (Tank A and Tank B). Figure 7-2 shows a typical poly tank installation but the Aboveground Injection System contractor must follow the specific tank manufacturer installation instructions to best ensure the tank is not damaged either during transportation, installation, or while in use.

In particular:

- Inspect the condition of the tanks upon delivery.
- Place and orient the tanks in a manner to avoid interfering with placement and operation of two additional 5,000-gal tanks to be installed for the full-scale test.
- Orient the tanks to ensure proper placement of a ladder to access the top manway and ready access to the drain outlet and sighting tube of each tank.

  **Important Note: No personnel entry through the manway is planned or allowed during this project.**
- Ensure the ladder used for accessing the top of tanks is/can be securely affixed to each tank as prescribed in the HASP.
- Set up an elevated, level platform with sufficient clearance and orientation to accommodate being moved when needed (e.g., with a forklift). The platform footprint must extend sufficiently past the outer edge of each tank to meet manufacturer specifications although slots may be cut to accommodate forklift access if necessary. Use crusher dust or compacted road base and surround each pad with edging to prevent material slumping or washing away and the tank becoming unstable. Alternatively, a concrete pad may be installed if necessary and with approval of Facilities Engineering. Tank installation on uncompacted fill is not recommended, as over time subsidence may occur causing the water-filled tank to distort. While this is unlikely to be an issue during the short term of the pilot test, it may occur during the full-scale tests.

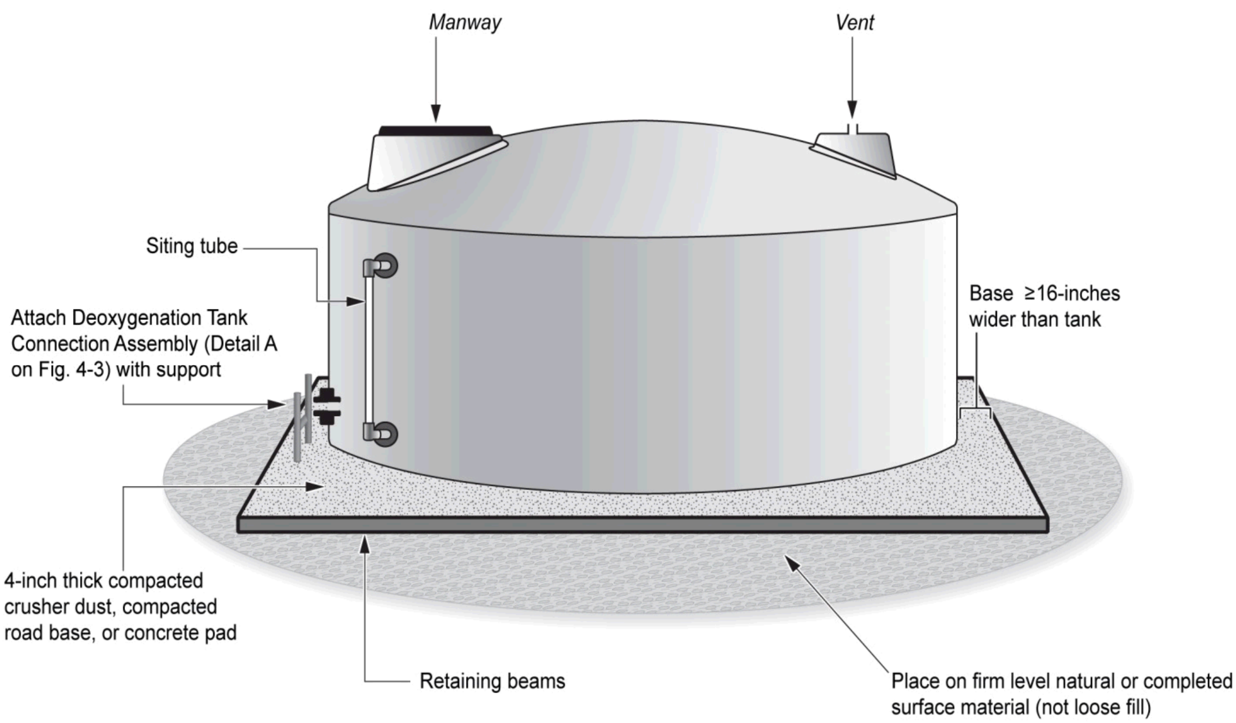



Figure 7-2.
Set Up for Deoxygenation Tanks (typ)

<u>Mixing Area</u>

The Mixing Area includes three main components:

- Main Manifold.
- Bioaugmentation Assembly.
- Premix Tank.
- Spill Control.

Set up the Mixing Area components inside spill control and in close proximity to the deoxygenation tanks.

*Main Manifold*

Detail B in Figure 4-3 shows the layout of the Main Manifold. It consists of valves, pressure gauges, and a totalizing flow meter. It connects various injection sources (Deoxygenation Tanks, Bioaugmentation Assembly, and Chase Water Tank) to the injection wellhead. The Main Manifold controls and monitors the injection stream before it reaches to the injection wellhead (Detail C in Figure 4-3).

It is important to install the Main Manifold at an elevation lower than the Deoxygenation Tank and Chase Water Tank discharge valves (but above the well head) to facilitate gravity drainage without having to prime the lines.

*Bioaugmentation Assembly*

Detail D in Figure 4-3 shows the layout of the Bioaugmentation Assembly. Components include the KB-1® Dechlorinator cylinder, KB-1® Dechlorinator injection dispenser (KD), and tubing and fittings to connect an inlet argon gas supply and outlet connection to the Main Manifold. With the exception of the argon gas cylinder and regulator, these components will be supplied by SiREM. The Bioaugmentation Assembly will be connected to the Main Manifold shortly before the substrate solution is ready for injection.

*Premix Tank*

Set up the Premix poly tank with a capacity of at least 100 gal in the Mixing Area. This tank will be used to manually mix substrate solution components with extracted groundwater for the pilot test and potable water for full-scale tests prior to being transferred into the deoxygenation tanks. A sump pump powered by a portable generator or nearby power outlet will be used to transfer this mixture from the Premix Tank to the deoxygenation tanks while they are being filled with extracted groundwater or potable water.

The Premix Tank must have a low enough profile to allow the field technician easy access to an opening at the top of the tank. This tank opening must be large enough to allow the hose and sump pump to enter and for grab water sampling if necessary.

Inspect, leak check, and set up the Premix Tank in the mixing area on a firm, level surface with spill control underneath. Make sure there is sufficient room to access the tank and to pour in substrate components.

If a portable generator is used, set up the electric generator in a location that will not obstruct access to the rest of the system and to minimize trip hazard from the electrical cord that will power the sump pump.

Stage the sump pump nearby. It will be used mostly for the Premix Tank, but will occasionally be used to pump out sampling purge water or residual substrate solution from Tanks A, B, C, and D as necessary.

*Spill Control*

When staging ethyl lactate for mixing substrate solution preparation, place the ethyl lactate container(s) in spill containment with a capacity of at least 110% of the total ethyl lactate volume.

Lay down plastic sheeting under the Main Manifold to protect the ground from potential minor spillage during sample collection or from manifold connections.

Set the other substrate solution components and the KB-1® Dechlorinator container and associated injection assembly on plastic sheeting while staged in the Mixing Area.

For safety reasons, keep the footprint of the plastic sheeting to a minimum to avoid field personnel having to walk on it.

Also, maintain onsite spill kits consisting of absorbent pads, bleach, and water with a five-gallon bucket.

<u>Aboveground Injection Line</u>

Set up the Aboveground Injection Line with associated valves, sampling ports, a totalizing flow meter, pressure and vacuum gauges, and other fittings per Figure 4-2 and associated Details A, B, and C (Figure 4-3). Exact specifications and materials are subject to revision by the Aboveground Injection System contractor.

Use Teflon tape on all threaded fittings. No polyvinyl chloride (PVC) glue/primer is to be used on any fittings that will contact fluids.

<u>TAV-INJ1 Wellhead</u>

Extend the Exclusion Zone out to include the TAV-INJ1 wellhead during groundwater extraction and subsequent reinjection. Use moveable traffic bollards during performance monitoring to protect equipment connected to the downhole field parameter sonde or groundwater sampling equipment.

### 7.2.3 Office Trailer and Storage

A portable office trailer and storage transportainer (each approximately 20 ft X 8 ft) will be staged at the site in conjunction with installation of the Aboveground Injection System.

The transportainer will be temperature controlled and provide storage for supplies used during Treatability Study including:

- Soil cores from injection well boring from well screen depth interval.
- KB-1® Primer.
- Ethyl lactate.
- Diammonium phosphate.
- Yeast extract.
- Sodium bromide.

- KB-1® Dechlorinator.
- Argon gas cylinders (stored in racks affixed to the outside of the transportainer).

Ethyl lactate will require secondary containment capacity of ≥110% of the stored volume (up to 5 gal stored ethyl lactate volume for the pilot test, but at least one 55-gal drum of ethlyl lactate for full-scale tests).

With the exception of KB-1® Dechlorinator, keep these components in storage until it is ready to prepare the substrate solution.

**Important Note:**

**The KB-1® Dechlorinator has a shelf life of only two weeks.** Coordinate supplier delivery to the site to coincide with the anticipated substrate solution deoxygenation so it will not spoil before the substrate solution is ready for injection.

KB-1® Dechlorinator is provided in a stainless steel six-liter cylinder under low pressure (~1 pound per square inch [psi]). One container will be used for the pilot test and no more than two will be in storage at one time during the full-scale tests. Storage must be at a temperature between 32-86 degrees Fahrenheit ($^{o}$F).

### 7.2.4 Wellhead Protection

Monitoring wells TAV-MW6 and TAV-MW7 will be used to gather ISB performance data including field parameters and groundwater samples for the pilot test. Use moveable traffic bollards during performance monitoring to protect equipment connected to the downhole field parameter sonde or groundwater sampling equipment.

### 7.2.5 Stormwater Pollution Prevention

Stormwater pollution prevention has been evaluated by the SNL Subject Matter Expert. Install best management practices and pollution prevention measures requested by the Subject Matter Expert in the April 10, 2015 memorandum from Kathie Deal to Jun Li re: *NPDES Stormwater Permit Coverage Not Required for Treatability Study of Bioremediation at TA-V Groundwater Area of Concern; Stormwater and Pollution Prevention Controls Requested.*

These include:

- Install sediment controls for any storm drains or drop inlets within the boundary of the project area. The drain/inlet controls will be designed, installed and maintained to limit or prevent the discharge of debris, chemicals, sediments or other pollutants in stormwater runoff generated by the construction project. Controls will be installed such that sediment is prevented from entering the drain/inlet while allowing stormwater to pass through, avoid flooding. Be mindful that storm drain/inlet controls can create traffic hazards; use safety markers where appropriate. Where drain/inlet controls pose a traffic risk, install alternative controls upgradient of the storm drain.
- Cover and/or containerize chemicals stored outdoors to prevent contact with precipitation and provide spill containment to prevent contact with stormwater.
- Secure portable toilets to prevent tipping (e.g., stake with rebar or bolt to trailer).
- Wash containers and trucks containing paint, concrete, or other building products into an appropriate waste container. Discharges to sanitary sewer, storm drain or ground surface are prohibited.

### 7.2.6 Calibrate and Install the Downhole Multi-parameter Sondes

Downhole (in-situ) measurements listed in Section 6.3 are needed throughout the Treatability Study to monitor test performance. Three downhole multi-parameter sondes will be used for the pilot test. Each is to be numbered and dedicated to a specific well as follows:

- Sonde 1: Injection well TAV-INJ1.
- Sonde 2: Monitoring well TAV-MW6.
- Sonde 3: Monitoring well TAV-MW7.

To avoid issues of getting equipment stuck or tangled in the wells, **do not place a groundwater sampling pump and a downhole sonde in a well at the same time**. For most of the test period, sondes will be installed inside the wells. They will be temporarily removed periodically to perform maintenance and calibrations. This can be conducted during the short-term deployment of the groundwater sampling pump. After sampling, the sondes will be put back in the well.

Deploy the three downhole sondes at least one month before conducting the pilot test groundwater extraction to collect background measurements and observe their natural variability over time.

Instructions for deploying the multi-parameter sondes are as follows.

1. Thoroughly clean all equipment that will either be placed in the injection well or monitoring wells, or will come in contact with extracted or reinjected groundwater. See Table 7-1 for equipment-specific cleaning procedures.
2. Take a manual depth-to-water measurement of static water levels in wells TAV-INJ1, TAV-MW6, and TAV-MW7 in accordance with FOP 03-02.
3. Prepare downhole multi-parameter sondes for each of the three wells:
   a. Label the lines.
   b. Attach a 0.125-in diameter stainless steel wire rope safety cable to the sonde bail located at the top of the sonde body.
   c. Prepare cable ties to tie the safety cable to the sonde cable at intervals sufficient to keep the two lines from bunching up and becoming a tangling risk (estimating every 10-20 ft of length). Continuous tape may be used instead of cable ties.
   d. Set up the laptop computer and program associated sonde monitoring supplied by the manufacturer.
   e. Connect the sonde cable from each sonde individually to the laptop and check that the batteries are working.

      Connection will likely require going through a USB adaptor provided by the sonde supplier.
   f. Calibrate the sensors in accordance with manufacturer specifications and document calibration results both in the manufacturer-supplied software and on form LTS GS-2012-002 – *Groundwater Sample Collection Field Equipment Check Log* (Appendix B).
   g. Set logging frequency for each sonde to once/hour.

4. Deploy each sonde into its respective well, set the water depth sensor at the mid-point of the submerged well screen, and secure the sonde cable at each wellhead through the well seal using the spool to anchor the cable.
    a. Determine the depth of submergence required to set the water depth sensor at the screen mid-point (See the sonde manufacturer literature regarding location of the water depth sensor on the sonde. For the EXO1, it is located about midway in the body of the sonde itself).
    b. While lowering the sonde into the well to its designated depth, use cable ties to bundle the safety cable and sonde cable together at between 10 to 20 ft intervals to prevent tangling in future retrieval and redeployment. Continuous tape may be used instead of cable ties.
    c. Secure the bundle at the wellhead.
5. Initiate downhole field parameter data logging for each well and record the time and initial readings of all recorded parameters in the field log book.

## 7.3 Sampling and Data Collection

Data collection responsibilities for the Treatability Study are assigned to two separate functional teams of SNL/NM personnel with different sets of responsibilities as outlined below.

### 7.3.1 System Operation Team

The System Operation Team is responsible for monitoring and recording all field parameter measurements, collecting grab samples, and associated equipment calibration, maintenance, and operation.

Samples from the Aboveground Injection System will be collected from sampling ports as shown in Figure 4-2 and labeled as follows:

- SPT = Sampling Port – Total. This is located downstream of the KB-1® Dechlorinator injection point. This port will be used to collect samples for laboratory analysis and field parameter measurement representing the makeup of what is being injected into the well, referred to as the injection stream. Analytical parameters for the injection stream will mirror those in the baseline groundwater monitoring listed in Section 6.3.
- SPA, SPB, SPC, and SPD = sampling ports located at the drain outlets of Tanks A, B, C, and D, respectively, and are used to collect grab samples representative of the content of the tank. These ports will primarily be used for collecting field parameter measurement samples to track the status and progress of substrate solution deoxygenation in order to determine when the tank content is ready to be injected.

Sonde 6, attached to a flow cell, will be used to measure field parameters in grab samples collected from these sampling ports. Sensor calibration is to follow the same procedures as used for the other sondes (although water depth will not be applicable).

The operational sample and field measurement collection schedule is dependent on system performance and discharge permit requirements. Forms for recording operational data such as field parameter measurements, flow rates, and sample collection details are included in Appendix B.

Field measurements will also be taken from the Chase Water Tank (during full-scale tests) and may be taken from the Premix Tank by lowering Sonde 6 directly into these tanks.

Table 7-3 provides a summary of sampling and data collection activities of the System Operation Team.

Table 7-3. System Operation Team Sampling and Data Collection

| Location | Frequency | Sampling method | Parameters |
|---|---|---|---|
| SPA, SPB, SPC, SPD | Periodically during deoxygenation | Flow cell. Parameters measured with Sonde 6 | Field parameters (section 6.3) until DO < 0.5 mg/L and/or ORP < negative 75 mV |
| SPT | Pilot test: Once<br>Full-scale tests: Field parameters: daily sample collection in accordance with Table 8-1 and Discharge Permit requirements. | Flow cell. Parameters measured with Sonde 6 and sample collected from flow cell effluent. | Field Parameters and laboratory analyses (section 6.3) |
| Chase Water Tank | Pilot test: Not applicable<br>Full-scale tests: Before injecting chase water | Flow cell. Parameters measured with Sonde 6 | Until DO < 0.5 mg/L |
| Premix Tank | As needed to establish knowledge of the mixture | Flow cell. Parameters measured with Sonde 6 | Field parameters (section 6.3) |

DO = dissolved oxygen
mg/L = milligrams per liter
mV = millivolts

The System Operation Team will also collect and record all other operational data including flow rates and totalizer flow meter readings, details about substrate solution preparation, and substrate solution and bioaugmentation bacteria injection. During full-scale test injections, the scope of the System Operation Team will expand to also include downhole sonde measurements.

Field forms are included in Appendix B. The System Operation Team should also use a dedicated field log book to record information particularly not covered by the field forms. These records will help the System Operation Team to fulfill reporting requirements per their contract.

### 7.3.2 Groundwater Sampling Team

Groundwater sampling will be performed by the Groundwater Sampling Team staffed by SNL Environmental Resource Field Office (ERFO) personnel. A groundwater sampling schedule and an overview of mini-SAPs for all TAVG wells are included in Appendix A. This includes groundwater sampling conducted from wells as part of the Treatability Study and from surrounding wells as part of the ongoing LTS monitoring program.

The schedule in Appendix A starts at the beginning of Fiscal Year (FY) 2017 to coincide with the anticipated installation of monitoring wells TAV-MW15 and TAV-MW16. The schedule is forecasted through the end of FY2022, after the anticipated conclusion of performance monitoring for the third full-scale test. This schedule assumes that the pilot test and all three subsequent full-scale tests are implemented. It is subject to revision based on results of data collected during each phase of the Treatability Study and implementation logistics throughout this project.

In the event that the installation of well TAV-INJ1 is delayed, the monitoring of TAVG wells will follow Table 6-1 of the Revised Treatability Study Work Plan (without the monitoring parameters for Treatability Study performance monitoring). Once the Treatability Study is underway with the installation of well TAV-INJ1, the schedule in Appendix A will be revised accordingly. LTS monitoring is likely to continue beyond FY2022, but the details of that program will be reevaluated after results of the Treatability Study are reviewed in the context of a long-term strategy for the site.

## 7.4 Groundwater Extraction and Injection

The Treatability Study pilot test consists of injecting approximately 3,700 gal of substrate solution into well TAV-INJ1, followed by a series of groundwater sampling events over a four-month monitoring period. The pilot test uses groundwater extracted from well TAV-INJ1 as make up water for the substrate solution. Tank A initially receives 1,750 gal of extracted groundwater followed by another 100 gal which is routed through the Premix Tank to add in KB-1® Primer.

While this 1,850 gal in Tank A deoxygenates, 1,750 gal of groundwater is pumped into Tank B and 100 gal of groundwater is pumped into the Premix Tank for mixing with substrate components. After deoxygenating the water in Tank A with KB-1® Primer, the 1,750 gal in Tank B along with the 100 gal of substrate solution in the Premix Tank are transferred to Tank A.

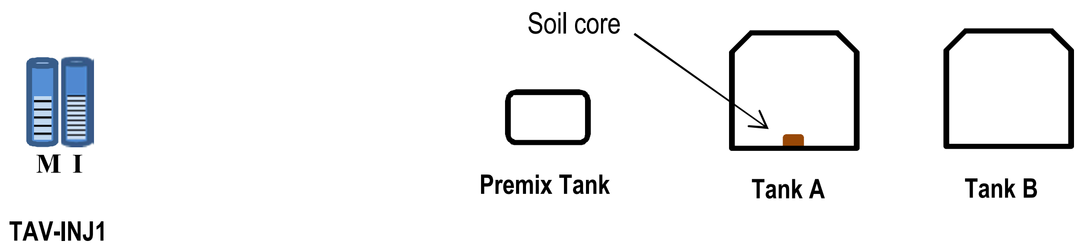
When the DO and ORP for the total 3,700 gal of water in Tank A has dropped below 0.5 mg/L and negative 75 millivolts (mV), respectively, it will be gravity injected back into TAV-INJ1 while co-injecting the bioaugmentation bacteria (KB-1® Dechlorinator). Record the time it takes to reach the DO and ORP limits, after the contents of Tank B are added to Tank A.

Groundwater extraction will be performed by the drilling contractor. Prior to installing the extraction pump into well TAV-INJ1, the System Operation Team will suspend data logging from Sonde #1, retrieve it from the well, recalibrate it, redeploy it after groundwater has been extracted.

The procedures for performing the pilot test groundwater extraction, deoxygenation and substrate component mixing, and subsequent gravity reinjection are discussed below in ten primary steps.

Step 1: Place Soil Core into Tank A

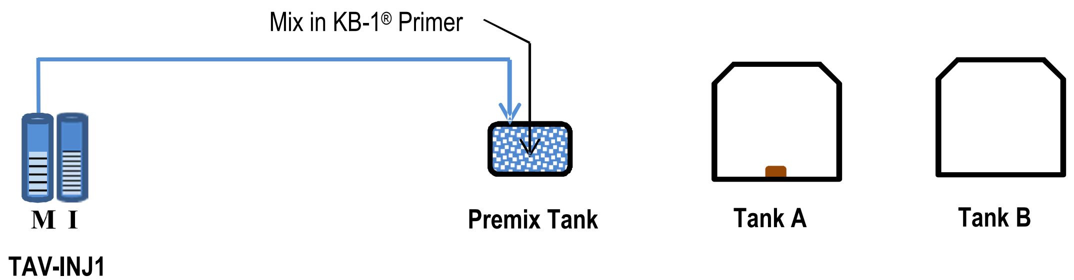
Immediately prior to initiating groundwater extraction, place approximately 10 lbs of well TAV-INJ1 soil core into the bottom of Tank A. This core should be from the screened interval of well TAV-INJ1 collected during borehole drilling (from saturated zone) and sealed in an acetate sleeve. Reseal remaining soil core as it will be used for the future full-scale test.




Step 2: Fill the Premix Tank and Mix In KB-1® Primer

Extract 100 gal of groundwater from well TAV-INJ1 and pump it into the Premix Tank. The drilling contractor will perform tasks associated with extraction pump decontamination, installation, operation, and retrieval.

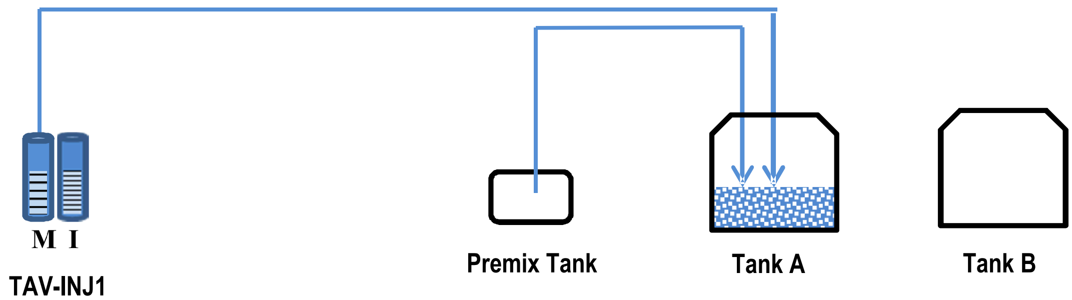
1. Take a static water level measurement from well TAV-INJ1 in accordance with FOP 03-02. Measure the depth to water in both the monitoring and injection casings of well TAV-IN1 to compare them with each other. Additional weight may need to be added to the probe to keep it from getting hung up on the injection casing wall due to condensation. The injection casing has a 1.5-in inner diameter (ID), so be sure any added weight has sufficient room to pass in and out of the casing without getting stuck.
2. Install the groundwater extraction pump in injection well TAV-INJ1. Set the pump intake at the bottom of the well screen. Set the discharge end of the pump tubing near the bottom of the Premix Tank.
3. Initiate groundwater extraction from well TAV-INJ1 and discharge 100 gal into the Premix Tank while mixing in eight (8) 800-gram pouches of KB-1® Primer (as shown in Table 5-1).




4. Suspend pumping and move the discharge hose from the Premix Tank into Tank A, hanging the end near the bottom of the tank. Secure the hose to the tank to ensure it does not become dislodged during pumping.

Step 3: Fill Tank A to Half-Full and Monitor Deoxygenation

1. Resume groundwater extraction into Tank A keeping the hose end submerged to minimize aeration.
2. Pump 1,750 gal of groundwater from well TAV-INJ1 into Tank A. While filling Tank A, use a sump pump and hose to transfer the content of the Premix Tank into Tank A. Keep the discharge end submerged to minimize aeration.




3. Maximize the groundwater extraction rate without daylighting the pump. The maximum pumping rate will depend on the pump capabilities. Well yield will likely be less than 10 gpm and can be estimated from prior well development observations. Monitor the approximate depth to water in the adjacent injection well casing using the stand-alone water level meter probe. Suspend pumping outside of work-day shift hours and continue the following business day if necessary.
4. After Tank A has received a total of 1,850 gal (including the 100 gal from the Premix Tank), suspend pumping and move the discharge hose to Tank B.
5. Record the data on a *Substrate Preparation Log* (Appendix B).
6. Monitor the drop in DO and ORP in Tank A starting right after the 1,850 gal are pumped in and then hourly thereafter collecting grab samples in a flow cell attached to sample port SPA and taking measurements using Sonde 6. Record time and readings on a *Tank Deoxygenation Log* (Appendix B). Store the small volume of water drained from Tank A for these measurements in a clean 55-gal drum. This water and subsequent grab sampling purge water will eventually be included in an injection cycle.

   Use the procedure outlined in Table 7-4 below for collecting all aboveground system grab samples and laboratory samples.

7. If DO does not decline to less than 0.5 mg/L in Tank A within four hours of mixing in the KB-1® Primer solution from the Premix Tank, discuss field conditions with the Project Lead. More KB-1® Primer may need to be added.

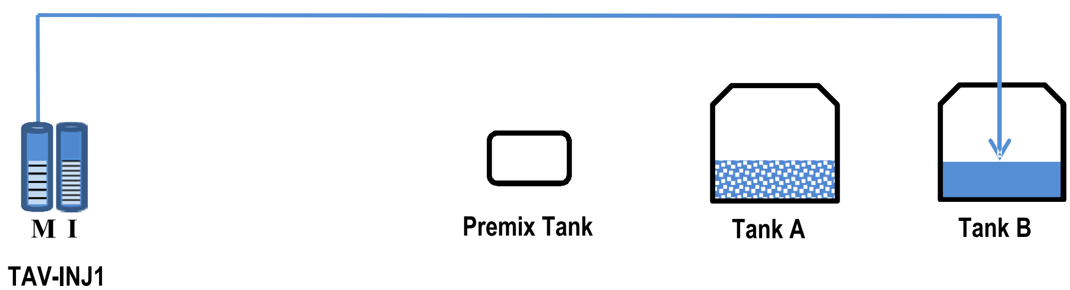
   Note: A drop in ORP is not important until after the next step, but the data is useful to record as a basis of comparison.

Table 7-4. Procedure for Collecting Aboveground Injection System Grab Samples

| | |
|---|---|
| i | Connect the sampling port to the flow cell influent port and the flow cell discharge port to a clean, 55-gallon drum using 0.375-in ID polyethylene tubing |
| ii | Connect Sonde 6 to the sampling flow cell (ensure it has recently been cleaned and calibrated). |
| iii | Allow at least four flow cell volumes to pass through the flow cell prior to recording field parameters or collecting laboratory samples to ensure the flow cell is sufficiently purged. Store excess water from sampling in a clean, 55-gal drum. This will receive all extra grab sampling water and will be added back into Tank A during injection. |
| iv | Record the DO, ORP, pH, temperature, and specific conductance in the flow cell at the time of sample collection. |
| v | Store, label, and submit samples to the analytical laboratory in accordance with SNL/NM procedures (not applicable to sampling done only for field parameter measurement). |

Step 4: Fill Tank B with Groundwater

1. Continue groundwater extraction into Tank B, hanging the end near the bottom of the tank. Secure the hose to the tank to ensure it does not become dislodged during pumping.
   **Do not** amend Tank B water.

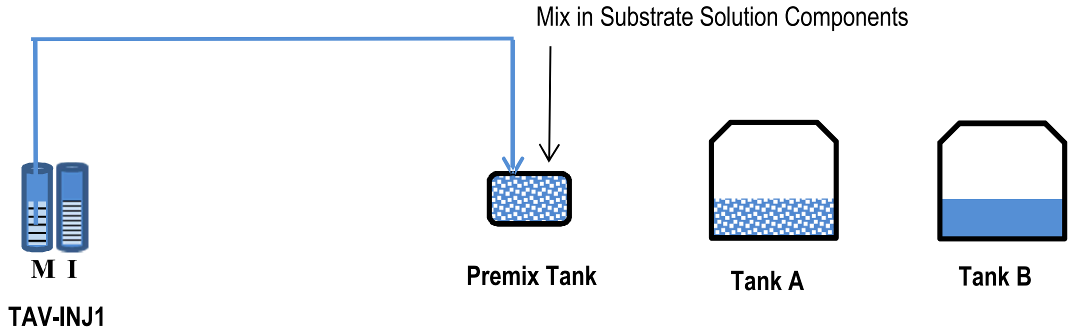



2. After 1,750 gal of groundwater has been collected in Tank B, transfer the extraction hose to Premix Tank.
3. Measure the DO and ORP in Tank B by collecting a grab sample in a flow cell attached to sample port SPB and taking measurements using Sonde 6 per Table 7-3.

Step 5: Fill the Premix Tank and Mix In Substrate Solution Components

1. Continue to extract 100 gal of groundwater from well TAV-INJ1 and pump it into the Premix Tank while mixing in substrate solution components in the quantities specified in Table 5-1 and record the data on the *Substrate Preparation Log* (Appendix B).

   Note: Quantities in Table 5-1 are subject to revision based on analytical results from TAV-INJ1 baseline sampling.

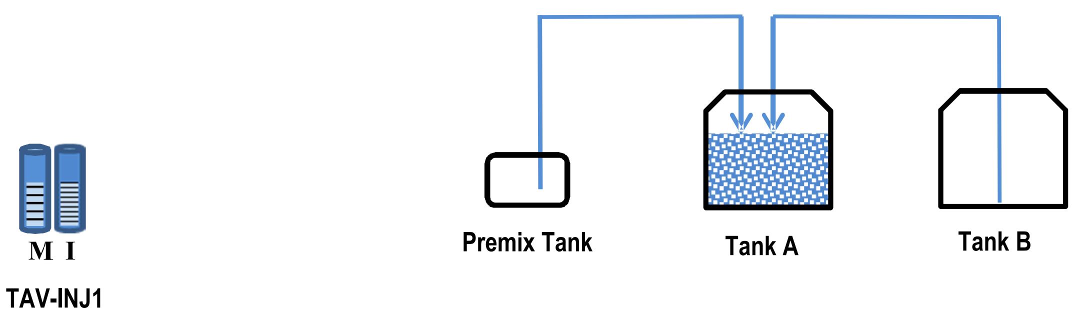



2. Discontinue pumping and retrieve the extraction pump from well TAV-INJ1.

Step 6: Fill Tank A to Full-Tank and Monitor Deoxygenation

After DO drops to below 0.5 mg/L in Tank A;

1. Transfer the content of the Premix Tank into Tank A then the 1,750 gal in Tank B into Tank A. Use the sump pump and keep the discharge end of the hose submerged for each transfer. Record the time at the beginning and end of the transfers on the *Substrate Solution Preparation Log*. Pumping rate is anticipated to be approximately 10 gpm and can be higher from Tank B.




2. Tank A will now have approximately 3,700 gal of substrate solution and Tank B will be empty. Leave the Tank B manway open to air dry the tank. Cover the opening with mesh to comply with NEPA requirements to prevent animal entry.
3. Continue monitoring DO and ORP drop in Tank A approximately hourly. Measurements may be suspended during non-business hours and resumed the following business day.

   Note: DO and ORP will likely rise initially after mixing with water from Tank B.

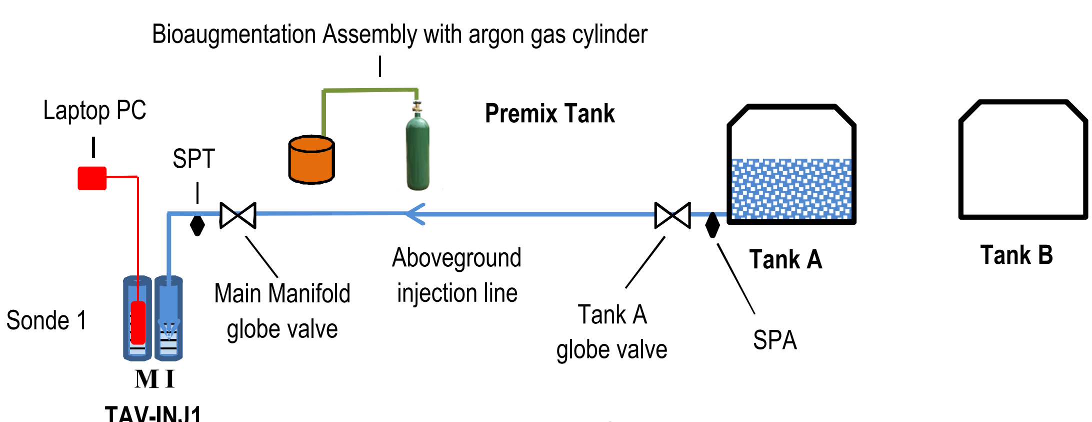
Step 7: Prepare Equipment for Substrate Solution and KB-1® Dechlorinator Injection

1. Take a manual depth to water measurement in the well TAV-INJ1 monitoring casing and, if possible, in the adjacent injection casing.
2. Replace the batteries, calibrate, and redeploy Sonde 1 into the well TAV-INJ1 monitoring casing. Check to see if the manual depth measurement in TAV-INJ1 reconciles with the depth of submergence measured by Sonde 1.
3. Sondes 2 and 3 should already be deployed in wells TAV-MW6 and TAV-MW7, respectively. Check that they are working properly and continuing to log data at hourly intervals. If they have not been inspected the past month, retrieve, clean, and recalibrate them, install new batteries and redeploy them.
4. Monitor DO and ORP in Tank A via SPA approximately hourly until the DO concentration returns to below 0.5 mg/L **and** the ORP drops below negative 75mV. Once this is achieved, the substrate solution is ready for gravity injection. Continue recording data on the *Tank Deoxygenation Log*.
5. Set up and connect the Bioaugmentation Assembly and the argon gas cylinder.
6. Set up the Aboveground Injection Line to the TAV-INJ1 wellhead and extend the Exclusion Zone delineation out around the well as shown in Figure 7-1. Connect it to the Main Manifold and in turn, to the Tank A connection assembly.

Step 8: Inject Initial Substrate Solution to Lower DO Content in TAV-INJ1 Water Column

Use a *Daily Injection Log* (Appendix B) to record measurements (field parameters, total flow volumes, and flow rates, etc.).

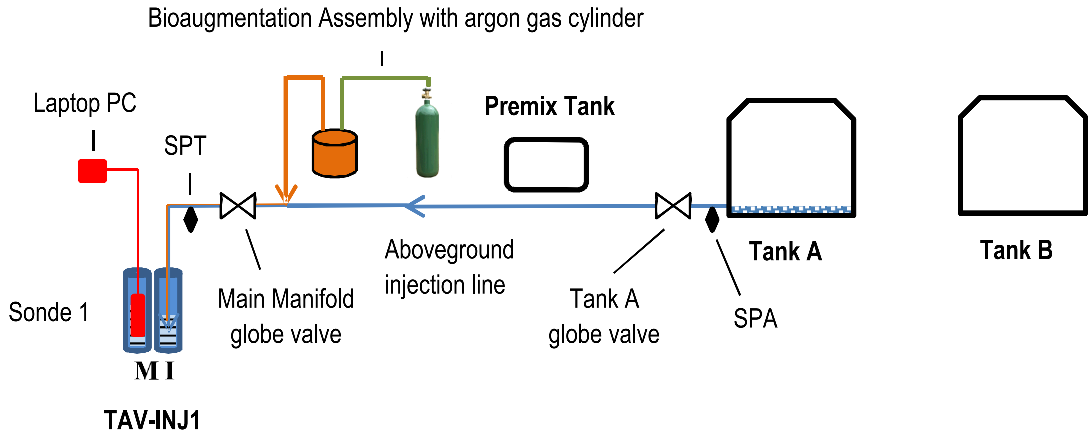
1. On the injection day, reset the data logging frequency for Sonde 1 to once per minute and initiate logging again.
2. Record the time (24 hour [hr]), and the Sonde 1 readings with special attention to DO, ORP and water depth. Calculate the saturated casing volume (per FOP 05-01). Volume will be approximately 60 gal.
3. Record the initial total gallons reading on the totalizing flow meter (will likely not be zero due to some initial calibration and testing).
4. Open the Main Manifold globe valve part way, then gradually open the Tank A globe valve. Inject three times the saturated casing volume (total of approximately 180 gal) of substrate solution into the TAV-INJ1 injection casing via the Aboveground Injection Line. Adjust the flow rate to approximately 20 gpm with the Main Manifold globe valve. **Do not** co-inject KB-1® Dechlorinator with this volume.



5. Monitor DO from Sonde 1 until it has dropped to less than 0.5 mg/L. If DO has not dropped significantly within 30 minutes, inject another saturated casing volume (~60 gal) checking DO at SPT and downhole again. Contact the Project Lead if 0.5 mg/L is not reached downhole within an hour of injection.

Step 9: Inject Substrate Solution and KB-1® Dechlorinator into Well TAV-INJ1

1. When DO has dropped below 0.5 mg/L, inject the remaining content of Tank A while co-injecting 800 mL of KB-1® Dechlorinator as summarized in Section 7.5 and presented in detail in Appendix C.




Observe the water level rise measurements indicated by Sonde 1. If the water level approaches a rise of 300 ft above static level, reduce the flow rate accordingly to prevent water level rise over 335 ft.

2. Collect a laboratory sample and duplicate of the combined injection stream at SPT while the KB-1® Dechlorinator is being injected. Follow the sample collection procedure presented in Table 7-3. Analytical parameters for the injection stream are the same as those for baseline groundwater sampling presented in Section 6.3.
3. Make sure the full volume of KB-1® Dechlorinator gets injected before Tank A content stops gravity draining as there may be some residual volume left in the tank that does not drain.

Step 10: Post Injection

1. Pump residual substrate solution in Tank A out into the Premix Tank using a sump pump. Combine with the accumulated system sampling purge water. Inject this solution into well TAV-INJ1 via the Chase Water Tank connection to the Main Manifold.
2. It is anticipated the entire pilot test injection volume can be injected into well TAV-INJ1 within a few hours. When the injection is complete, close the Tank A globe valve, disconnect the Aboveground Injection Line from Tank A allowing final content to drain into well TAV-INJ1, the disconnect the line from the TAV-INJ1 wellhead.
3. Make note of the ORP value from Sonde 1 (in well TAV-INJ1) right after injection has been completed. This value will be compared to the value the next day to determine if short-term contingency groundwater sampling is to be conducted.
4. Reset the Sonde 1 data logging frequency to once per hour and confirm that data logging is continuing from all three downhole sondes (Sondes 1, 2, and 3).

## 7.5 KB-1® Dechlorinator Injection

The KB-1® Dechlorinator is injected under pressure into the Aboveground Injection Line via a T-connector during gravity injection of the substrate solution. Oxygen is toxic to the critical bioaugmentation bacteria within KB-1® Dechlorinator, *Dehalococcoides mccartyii.* Therefore it is **important to minimize any exposure of the injected KB-1® Dechlorinator to air**.

A number of steps throughout both the pilot test and the full-scale tests are taken to eliminate oxygen from the injection stream pathway between the KB-1® Dechlorinator cylinder and the in-situ groundwater. These measures include only mixing the KB-1® Dechlorinator with deoxygenated substrate solution during injection, purging empty injection lines either with deoxygenated substrate solution or with an inert gas (argon), and displacing the injection well water column with deoxygenated substrate solution or purging with argon gas. Additionally, potable chase water injected as part of the full-scale test, is sparged with argon gas to deoxygenate it before it is injected.

Appendix C provides a narrative and graphical representation of the detailed steps for injecting the KB-1® Dechlorinator along with the substrate solution. Sonde 1 will be in place in the monitoring casing of well TAV-INJ1 to log water depth and other parameters throughout the injection period.

Appendix C depicts the injection system components involved with substrate solution and KB-1® Dechlorinator injection (Figure C-1) and then details the procedural steps as summarized below:

1. Bleed pressure from the KD to 1 pound per square inch (psi) (Figure C-2).
2. Purge KB-1® Dechlorinator lines and the KD with argon gas (Figure C-3).
3. Fill the KD with the First Aliquot of KB-1® Dechlorinator (Figure C-4).
4. Displace the injection well water column with substrate solution (Figure C-5).
5. Inject remaining substrate solution and KB-1® Dechlorinator - first aliquot (Figure C-6).
6. Interrupt injection (Figure C-7).
7. Refill the KD with the remainder of KB-1® Dechlorinator injection volume - second aliquot (Figure C-8).
8. Inject remaining substrate solution and KB-1® Dechlorinator - second aliquot (Figure C-9).
9. Drain the Aboveground Injection Line (Figure C-10).

Record details of the KB-1® Dechlorinator injection on the *Daily Injection Log* (Appendix B).

## 7.6 Preparation for Post-Injection Performance Monitoring

Once injection of the Tank A content and associated KB-1 Dechlorinator is complete, the Aboveground Injection System is to be partially dismantled, cleaned, and properly stored while post-injection performance monitoring is conducted.

1. Demobilize the Bioaugmentation Assembly in accordance with the HASP and WMP.
2. Record remaining pressure in the argon gas cylinder in the field log book and with a tag or label on the cylinder itself. Store the cylinder securely. If close to empty, return it to the supplier.
3. Ship the KB-1® Dechlorinator cylinder, including remaining content back to the supplier along with the KD and associated tubing and fittings in accordance with supplier and SNL/NM procedures.
4. Disconnect and clean the Aboveground Injection Line, Main Manifold, and transfer pump(s).
5. Clean out Tanks A and B in accordance with the cleaning procedure described in Table 7-1. Make sure manways, vents, and valves are closed after interior surfaces have had time to air dry. Dispose of wash water according to the WMP.
6. Secure and store this equipment in place to the degree permissible by Facilities Management in anticipation of the future full-scale injection test. Store equipment until Decision Point #1 determines the full-scale test is to proceed at well TAV-INJ1.

## 7.7 Post-Injection Performance Monitoring

Initiate four months of post-injection performance monitoring after the target volume of substrate solution and bioaugmentation bacteria has been injected.

<u>Field Parameter Measurements</u>

The Groundwater Sampling Team shall continue collection of field parameter measurements as follows.

Field parameters including water level, DO, ORP, pH, temperature, and specific conductance are to be electronically logged continuously with Sondes 1, 2, and 3. Confirm the data loggers are still operating for Sondes 1, 2, and 3. Keep the logging interval at hourly for TAV-MW6 and TAV-MW7. Reduce the logging interval to hourly for TAV-INJ1. Data logging is to be conducted throughout the four months of the post-injection performance monitoring period.

**Pay special attention to ORP measurements from Sonde 1 (in well TAV-INJ1) for the first day after injection is performed. If the ORP drops by more than 50 mV, contingent groundwater sampling during the first week is triggered (see Groundwater Sampling below).**

Check logging equipment status and perform data downloads at least weekly during the four-month performance monitoring period. Plot the data to observe changes of the field parameters with time. Adjust the logging interval as necessary.

At least weekly, briefly and gently move the sondes up and down a few feet in the water column to ensure the sensors are monitoring representative water conditions and to remove potential accumulation of bubbles on the sensors. This helps to mitigate unrepresentative drift in DO readings.

Prior to deploying the groundwater sampling pump assembly down a well, suspend sonde data logging, and retrieve the sonde.

Each time a sonde is removed from the well, inspect, clean, and recalibrate the sensors in accordance with manufacturer's instructions. Function check the instruments in accordance with FOP 05-02. Replace the batteries in the sonde at least monthly. The EXO1 takes two D-cell batteries.

Once the sonde is removed from the well, take a manual water level from the well in accordance with FOP 03-02. Use the monitoring casing for water level measurements in well TAV-INJ1.

Redeploy the sonde to its prior depth after the sampling pump is removed and resume logging.

If the groundwater sampling interval is longer than a month, incorporate at least monthly retrieval of the sondes to perform visual inspection, maintenance, battery replacement, cleaning, and recalibrations of the sensors.

Groundwater Sampling

The Groundwater Sampling Team is in charge of collecting groundwater samples from wells. Collect groundwater samples in accordance with the schedule and mini-SAP overview in Appendix A. Results from these data will be used for Decision Point #1 to determine if the Treatability Study should proceed to the full-scale test.

The schedule includes contingent sampling from well TAV-INJ1 during the first week after injection if the ORP drops rapidly. On the morning after injection is completed, check the ORP value in well TAV-INJ1 and if it has dropped more than 50 mV from the value measured right after the injection was completed, then retrieve Sonde 1, install the groundwater sampling pump and collect samples on the first, second, and fourth, day after injection is completed. The groundwater pump may be left in the well during these first three sampling events. After the third sampling day, remove the pump, reinstall Sonde 1, and resume logging until the first weekly groundwater sample is to be collected.

Sampling frequency for wells TAV-INJ1, TAV-MW6, and TAV-MW7 will then be weekly for the first eight weeks after injection is complete followed by two monthly sampling events for a total of thirteen sampling events over the four-month performance monitoring period (or as few as ten events if first, second, and fourth day sampling in TAV-INJ1 is not necessary).

Prior to each sampling event at each well, retrieve the sonde from the well and place it on clean plastic sheeting. Deploy a decontaminated portable piston pump system into the well and follow FOP 05-01 for sampling.

Submit samples for laboratory analyses as listed in the min-SAPs in Appendix A and in accordance with SNL/NM procedures.

# 8.0 PHASE I: FULL-SCALE TEST AT INJECTION WELL TAV-INJ1

A full-scale test is planned for three locations as shown in Figures 1-1 and 1-2:

- Injection well TAV-INJ1.
- Injection well TAV-INJ2.
- Injection well TAV-INJ3.

The full-scale test at injection well TAV-INJ1 is part of Phase I of the Treatability Study and is predicated on successful results from the pilot test at that location as determined under Decision Point #1 described in the Revised Work Plan with concurrence from NMED HWB.

The full-scale test at each location plans for gravity injecting approximately 530,000 gal of potable water mixed with substrate solution components and co-injected with KB-1® Dechlorinator to replace one pore volume of the aquifer within a delivery radius of 60 ft of the injection well over a vertical horizon of 25 ft as shown in Figure 1-2. Approximately 5,000 gal per day is expected to be injected and the total injection timeframe for each full-scale test is estimated to take approximately 6 months. An additional 100 gal of unamended potable chase water will also be injected each day.

Groundwater monitoring at each location will be conducted throughout the injection period and for 24 months after each injection has been completed to assess ISB performance.

Data collected during the first six months of post-injection performance monitoring from wells TAV-INJ1, TAV-MW6, and TAV-MW7 are to be used for Decision Point #2 as described in the Revised Work Plan. If the test data at Decision Point #2 indicate successful performance, injection wells TAV-INJ2 and TAV-INJ3 will be installed and followed by full-scale test as Phase II of the Treatability Study.

For a full-scale test, the Aboveground Injection System will be expanded to facilitate daily injection of deoxygenated substrate solution of at least 5,000 gal per day. System setup for full-scale test is presented in Section 8.2.

Procedures for the full-scale test are presented in Section 8.3. These procedures may be revised at any stage of the Treatability Study based on specific conditions encountered during well installation, data collected during the pilot test and subsequent full-scale test, and field implementation lessons learned.

## 8.1 Equipment Cleaning and Inspection

Prior to initiating the full-scale test, all new equipment must be cleaned in accordance with Table 7.1. Equipment used during the pilot test should have been cleaned and stored properly prior to the post-injection monitoring period. Perform a visual inspection to ensure that this equipment remains clean and in good working order.

If downhole sondes are still deployed, retrieve and clean them, recalibrate the sensors, and replace the batteries. Check the condition of sensors that may require replacement solution and replace as necessary. Redeploy Sondes 1, 2, and 3 in wells TAV-INJ1, TAV-MW6, and TAV-MW7, respectively, as in the pilot test.

## 8.2 Expand the Aboveground Injection System

Figure 4-2 shows the additional equipment necessary for implementing the full-scale test. The added equipment is listed in Table 5-2. The primary added components are:

- Two more 5,000-gal deoxygenation tanks (Tanks C and D),
- Connection to a potable water supply and associated backflow preventer, and
- Chase Water Tank.

Additionally, a custom-made larger capacity or multi-chamber KD may be employed.

Figure 8-1 shows the site plan for the full-scale test at injection well TAV-INJ1 and incorporates the additional equipment discussed above.

<u>Deoxygenation Tanks</u>

To facilitate an optimal injection schedule, two more 5,000-gal tanks (Tanks C and D), are added to the system to give a total capacity of 20,000 gal. Tanks C and D should be in clean condition before they are brought on site. Install Tanks C and D in close proximity to and in the same manner as Tanks A and B. Inspect, leak check, and set up these tanks in the same fashion as Tanks A and B. Cleaning Tanks A and B after pilot test is not necessary.

For the full-scale test, the four deoxygenation tanks will alternate in pairs between one pair storing substrate solution for deoxygenation, and the other pair being partially gravity drained once deoxygenation is achieved.

Initially, the four deoxygenation tanks will each receive 2,500 gal of potable water including 100 gal mixed with KB-1® Primer in the Premix Tank. Once the 2,500 gal mixture is deoxygenation (within a few hours), another 2,500 gal of potable water will be added to each deoxygenation tank including 100 gal mixed with substrate solution components in the Premix Tank. When the full 5,000 gal of substrate solution is deoxygenated in Tanks A and B, half their content will be gravity drained into the injection well. When the substrate solution in Tanks C and D has been deoxygenated, half of their content will be gravity injected while Tanks A and B are refilled with potable water and substrate solution components. Tanks will be drained half-way each time leaving 2,500 gal of deoxygenated substrate solution in the tank. This process will be alternated throughout the injection period. The remaining 2,500 gal solution can accelerate the deoxygenation of refilled substrate solution without relying on using KB-1® Primer or sparging large volumes of water with argon gas.

<u>Potable Water Supply Connection</u>

Potable water will be supplied from a fire hydrant located approximately 60 ft southwest of well TAV-INJ1 (Figure 8-1). A backflow preventer will be supplied by the Facilities Engineering. A water hose to lead from the fire hydrant to the mixing area will be supplied by the System Operation Team (the Aboveground Injection System contractor).

1. Coordinate with Facilities Engineering to install the required backflow preventer to the water supply fire hydrant. Record the beginning flow meter totalizer reading for the back-flow preventer.
2. Clean and attach a flexible potable water hose to the backflow preventer that can reach to the inside bottom of each of the six tanks (deoxygenation tanks A, B, C, D, Premix Tank, and Chase Water Tank)

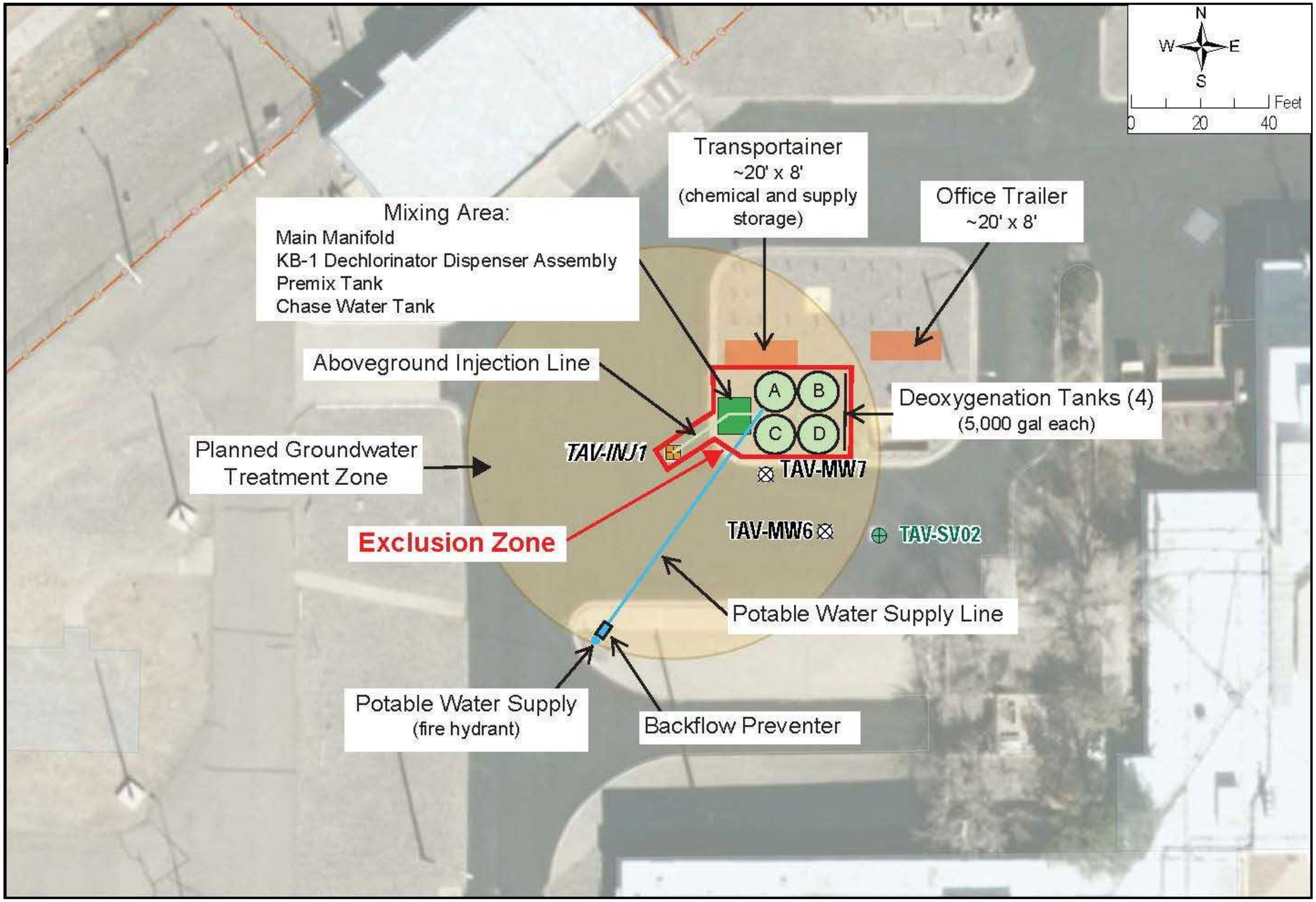



Figure 8-1.
Site Layout Plan – Full-scale Test at Injection Well TAV-INJ1

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3. Install a hose ramp/cover over the length of hose that is potentially subject to vehicular traffic.

Chase Water Tank

The Chase Water Tank is to have a 100-200 gal capacity and be easily filled from ground level but also be configured to gravity-drain its entire content. A cone-bottom tank on a stand is shown to meet this need, but this may be substituted for a functional equivalent such as an elevated tote provided it can be completely gravity drained.

1. Inspect, leak check, and set up Chase Water Tank in the mixing area near the Premix Tank and the Bioaugmentaion Assembly. It will be used for unamended potable water that will be deoxygenated by sparging with argon gas and then gravity injected into the Aboveground Injection Line at the end of each daily injection. Ensure access for an argon cylinder to be brought in close proximity for sparging the tank.
2. Connect the 1.5-in ID discharge line from Chase Water Tank to the Main Manifold assembly as shown in Figure 4-2 and in Detail B of Figure 4-3.

Larger KB-1® Dechlorinator Injection Dispenser

The 500 mL capacity KD used in the pilot test may be replaced with a custom-made one with larger capacity to allow co-injection of KB-1® Dechlorinator in one aliquot per day. The larger KD should have a capacity of at least 1,100 mL to accommodate daily substrate solution injections of 5,000 gal. This may be accomplished with either one larger chamber or a series of smaller chambers. The specifications for this KD will be determined based on results from the pilot test.

**Important Note on System Operation Temperature:**

Storage of KB-1® Dechlorinator must be at a temperature between 32-86 °F. No more than two stainless steel six-liter cylinders will be in storage at one time during the full-scale tests.
If injection occurs during winter months, the integrity of the aboveground injection system and the deoxygenation tanks, as well as the bacteria activity will be evaluated. Injection procedures may be modified or injection may be suspended if below freezing temperatures prevent safe operation or bacteria survival.

## 8.3 Full-scale Injection

Initiate data logging from the Sondes 1, 2, and 3 prior to starting substrate solution preparation for the full-scale test. Set the data logging frequency for the sondes at hourly.

As shown in Table 5-1, the target daily injection volume is approximately 5,000 gallon referred to as a “batch.” Before starting to fill the deoxygenation tanks, inspect and calibrate the field parameter sensors on Sonde 6 to be used with the flow cell in accordance with FOP 05-02. Water depth and turbidity measurements are not needed.

Appendix A includes the analytical sampling schedule and mini-SAP overview including suites of analyses to be performed by the analytical laboratories.

Appendix B includes the following forms for collecting field data and recoding sample collection:

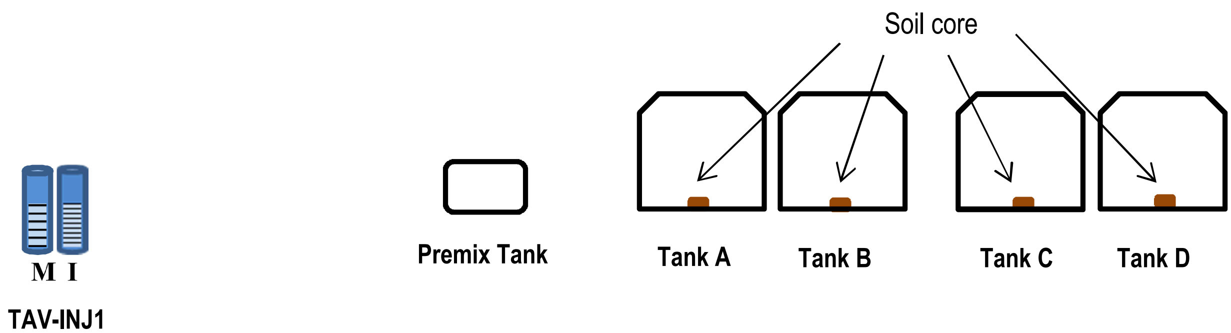
- LTS GW-2012-001 - Field Measurement Log for Groundwater Sample Collection
- LTS GW-2012-002 - Groundwater Sample Collection Field Equipment Check Log
- Analysis Request and Chain of Custody Form (ARCOC) - Sample Management Office
- Treatability Study Substrate Solution Preparation Log

- Treatability Study Tank Deoxygenation Log
- Treatability Study Daily Injection Log
- SiREM Chain of Custody Form

Appendix C presents more detailed graphical instructions for co-injection of the KB-1® Dechlorinator.

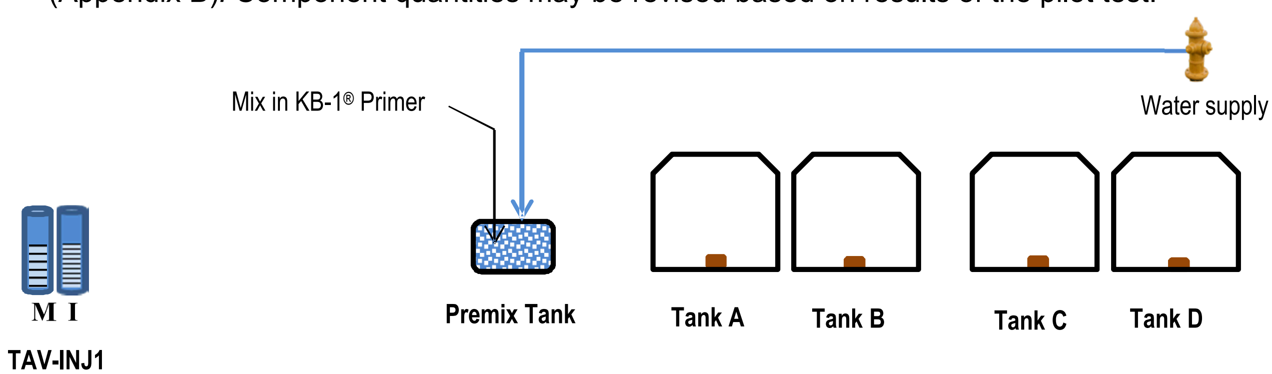
<u>Step 1: Place Soil Core into Tanks A, B, C, and D</u>

1. Immediately prior to filling the deoxygenation tanks, place approximately 15 lbs of soil core each directly into Tanks A, B, C, and D. This core should be from the screened interval of well TAV-INJ1 collected during borehole drilling and sealed in an acetate sleeve. Reseal remaining core. Core from above or below the screened interval may be used if there is not enough screened-interval core.



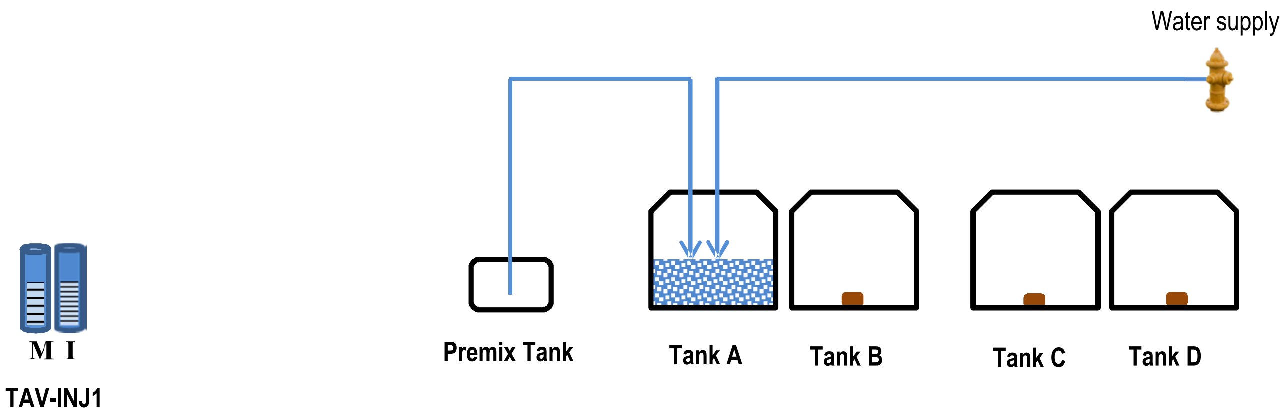

<u>Step 2: Fill the Premix Tank and Mix In KB-1® Primer</u>

1. Collect a grab sample of potable water from the water supply (fire hydrant) and submit it to the analytical laboratory to be analyzed for VOCs, NPN, and dissolved arsenic, iron, and manganese. This may be collected from the entry point to the Premix Tank before mixing in substrate solution components.
2. Fill the Premix Tank with 100 gal of potable water from the water supply (fire hydrant) while mixing in ten (10) 800-gram pouches of KB-1® Primer into the Premix Tank (as shown in Table 5-1). Record mixing data on the *Substrate Solution Preparation Log* (Appendix B). Component quantities may be revised based on results of the pilot test.

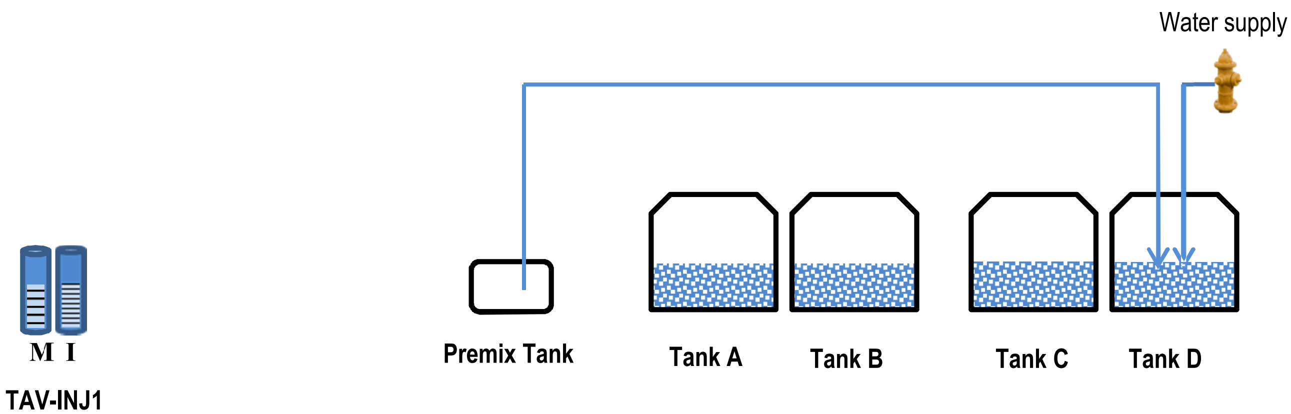


Step 3: Fill Tanks A, B, C, and D to half-full and Start Deoxygenation

1. Fill Tank A with 2,400 gal of potable water while transfer pumping in the 100-gal KB-1® Primer solution from the Premix Tank for a total of 2,500 gal. Keep the discharge ends of these lines submerged to mitigate oxygenation during pumping. Use a clean sump pump to transfer the Premix Tank content.
   The hose from the hydrant may be connected to the drain outlet bulkhead fitting of the tank or lowered into the tank from the top manway. Any connection to the tank needs to be secured to prevent the hose from pulling off of or falling out of the tank.




2. When the 2,500-gal total is reached in Tank A, repeat Steps 2 and 3 for Tanks B, C, and D. Avoid spillage when moving hoses from one tank to another.

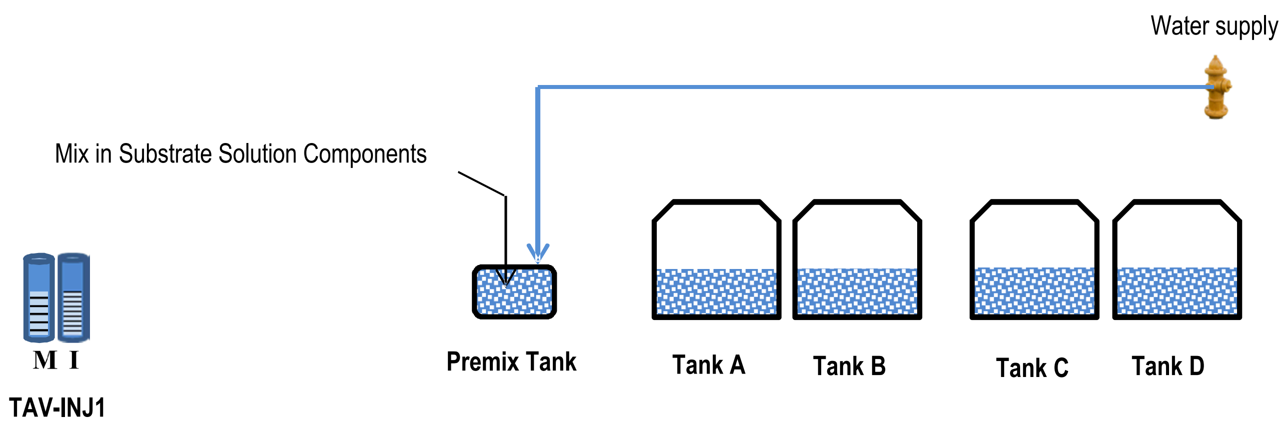



3. When the four tanks each have 2,500 gal in them, start monitoring field parameters in each tank by collecting grab samples from sampling ports SPA, SPB, SPC, and SPD as described in Section 7.3.1 and Table 7-3. Record the data on *Tank Deoxygenation Log* (Appendix B) forms for each tank.
4. If DO does not decline to less than 0.5 mg/L in any of the deoxygenation tanks within four hours of being filled, discuss field conditions with the Project Lead. Adding more KB-1® Primer or implementing sparging with argon gas may be necessary.

Step 4: Fill the Premix Tank and Mix In Substrate Solution Components

1. Fill the Premix Tank with 100 gal of potable water from the water supply while mixing in substrate solution components in the quantities specified in Table 5-1 and record the data on the *Substrate Preparation Log* (Appendix B).

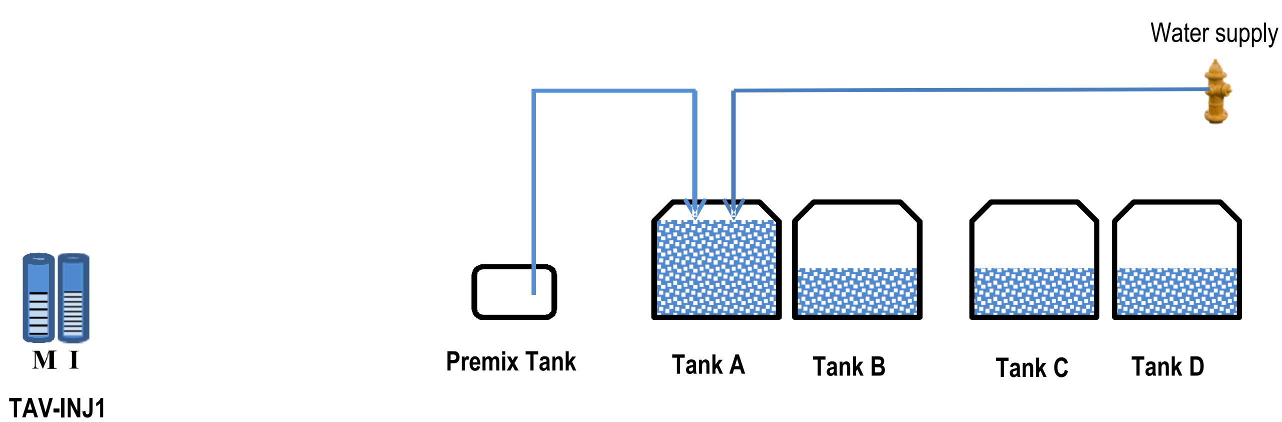
   Note: Quantities in Table 5-1 are subject to revision based on analytical results from the Pilot Test.



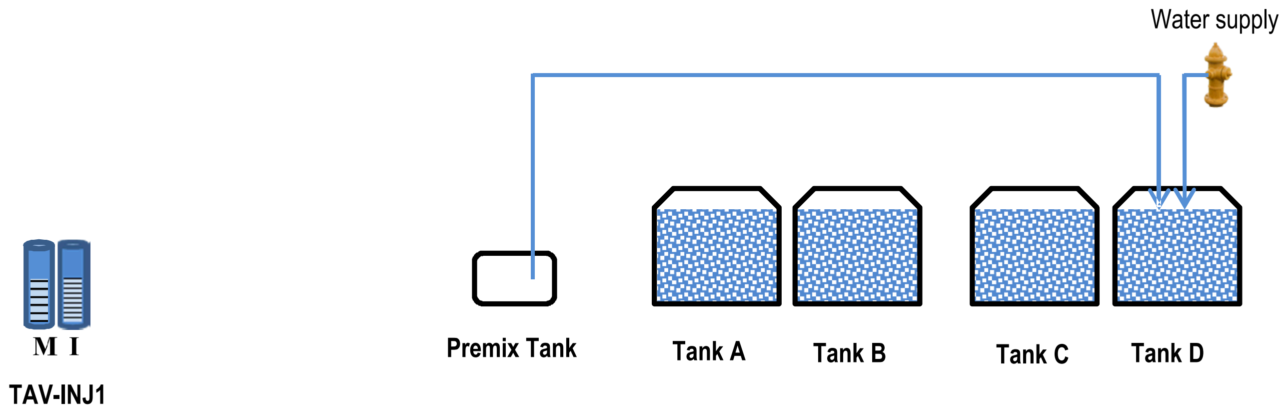

Step 5: Fill Tanks A, B, C, D to Full-Tank and Monitor Deoxygenation

1. After DO has dropped below 0.5 mg/L in Tank A, transfer the content of the Premix Tank into Tank A and add in 2,400 gal potable water from the water supply. Tank A will then contain approximately 5,000 gal of substrate solution. Record mixing data on the *Substrate Solution Preparation Log* (Appendix B).
2. Continue monitoring DO and ORP in Tank A and record measurements on the *Tank Deoxygenation Log*. DO and ORP will likely rise initially as the potable water is added but should then decline again within 24-48 hours. Results from the pilot test will give an indication as to how long deoxygenation takes and if additional actions such as adding KB-1 Primer are necessary.

   Suspend measuring field parameters from the deoxygenation tanks outside of normal working hours and resume them upon return to the site.



3. When the 5,000-gal total is filled in Tank A, repeat Steps 4 and 5 for Tanks B, C, and D and monitor DO and ORP in each tank. Avoid spillage when moving hoses from one tank to another.



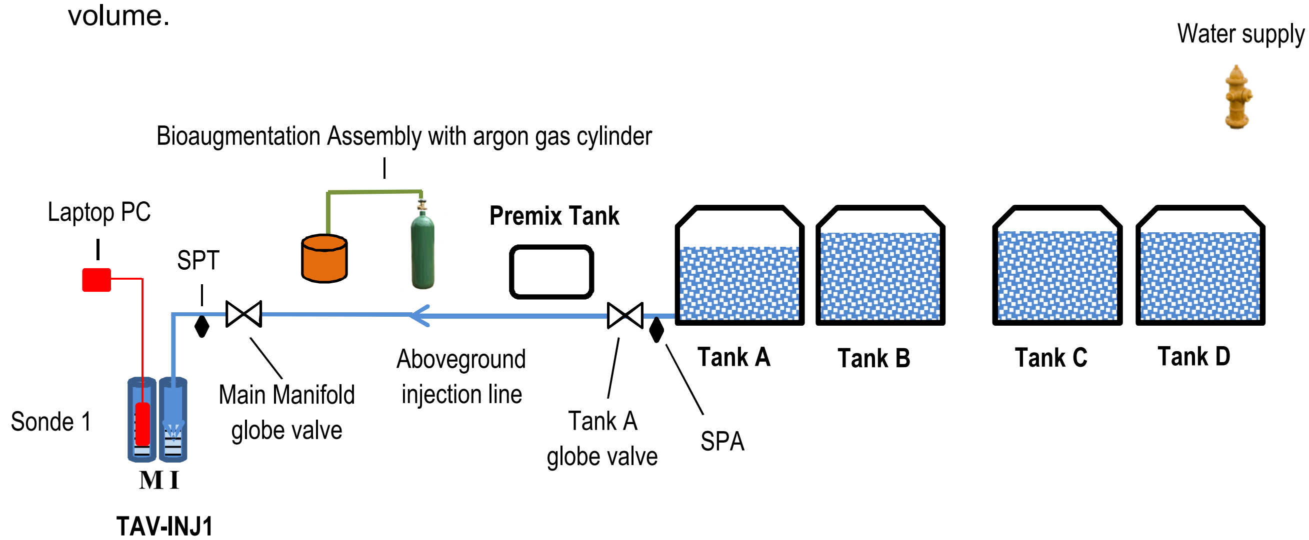

Step 6: Prepare Equipment for Substrate Solution and KB-1® Dechlorinator Injection

1. Take a manual depth to water measurement in the well TAV-INJ1 monitoring casing and, if possible, in the adjacent injection casing.
2. Replace the batteries, calibrate, and redeploy Sonde 1 into the well TAV-INJ1 monitoring casing. Check to see if the manual depth measurement in TAV-INJ1 reconciles with the depth of submergence measured by Sonde 1.
3. Check that Sondes 1, 2, and 3 are working properly and continuing to log data at hourly intervals.
4. When DO and ORP in Tank A and Tank B return to below 0.5 mg/L **and** the ORP drops below negative 75mV, the first 5,000-gal batch of substrate solution is ready for gravity injection. Continue recording data on the corresponding *Tank Deoxygenation Log* forms.
5. Set up and connect the Bioaugmentation Assembly and the argon gas cylinder.
6. Set up the Aboveground Injection Line to the TAV-INJ1 wellhead and extend the Exclusion Zone delineation out around the well as shown in Figure 8-1. Connect it to the Main Manifold and in turn, to the Tank A connection assembly.

Step 7: Displace Water Column with Substrate Solution in Well TAV-INJ1

Use a *Daily Injection Log* (Appendix B) to record measurements (field parameters, total flow volumes, and flow rates, etc.).

1. Record the time (24 hr), and the Sonde 1 readings with special attention to DO, ORP and water depth. Calculate the saturated casing volume (per FOP 05-01). Volume will be approximately 60 gal.
2. Record the initial total gallons reading on the totalizing flow meter. This should be the same as the last reading from the pilot test injection.
3. **Skip this step if DO in well TAV-INJ1 is below 0.5 mg/L and proceed to Step 8.** Open the Main Manifold globe valve part way, then gradually open the Tank A globe valve. Inject three times the saturated casing volume (total of approximately 180 gal) of substrate solution into the TAV-INJ1 injection casing via the Aboveground Injection Line. Adjust the flow rate to approximately 20 gpm (or as revised based on Pilot Test results) with the Main Manifold globe valve. **Do not** co-inject KB-1® Dechlorinator with this volume.




4. Monitor DO from Sonde 1 until it has dropped to less than 0.5 mg/L. If DO has not dropped significantly within 30 minutes, inject another saturated casing volume (~60 gal) checking DO at SPT and downhole again. Contact the Project Lead if 0.5 mg/L is not reached downhole within an hour of injection.

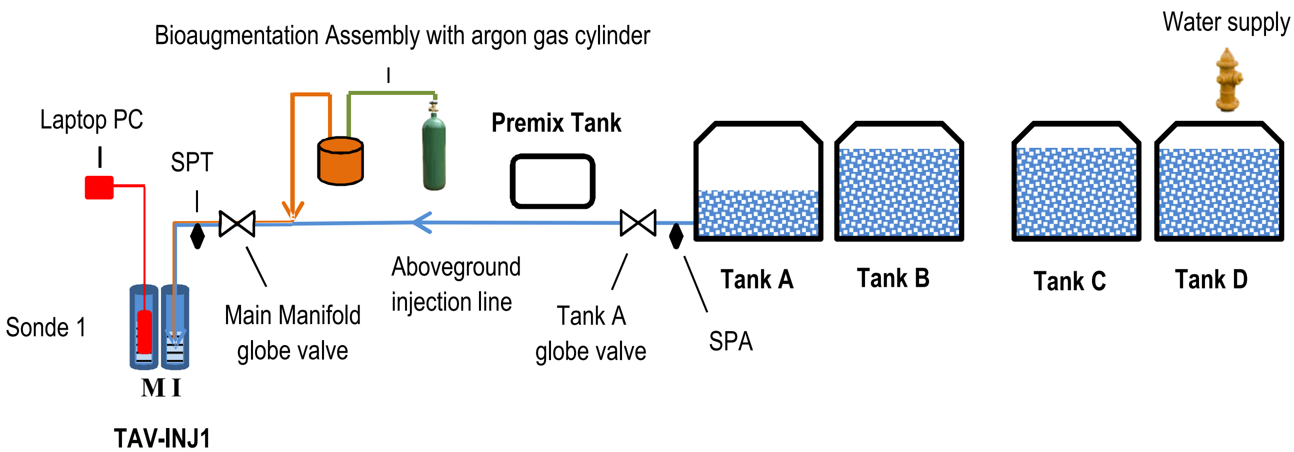
Step 8: Inject Substrate Solution and KB-1® Dechlorinator into Well TAV-INJ1

The KB 1® Dechlorinator co-injection process is the same as described under the pilot test (Section 7.5 and Appendix C) with the following exceptions:

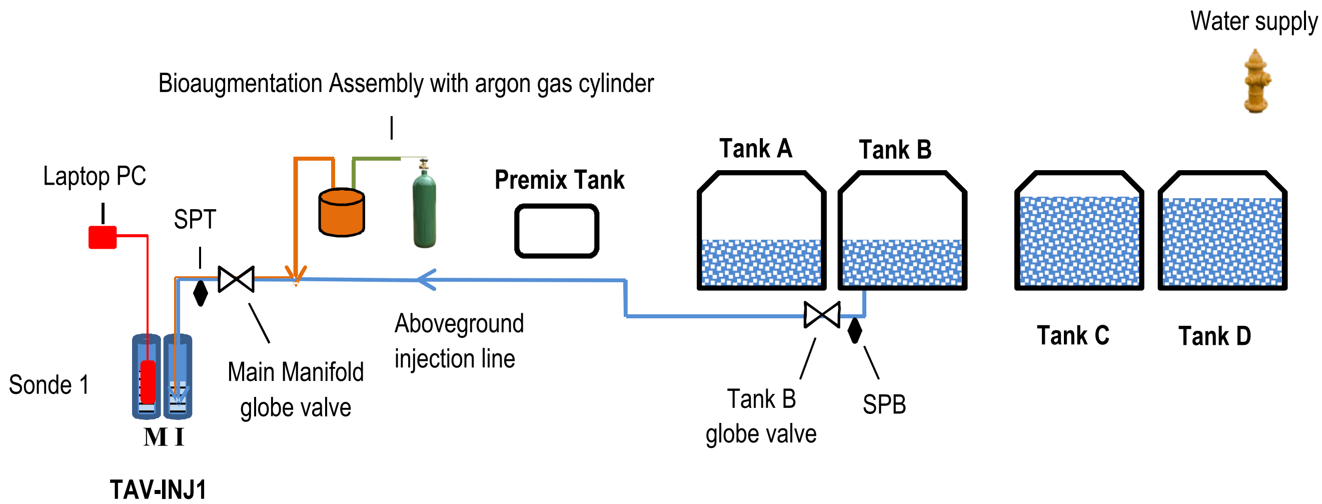
- A larger volume or multi-chamber KD may be used so that it can be filled just once at the beginning of each injection day.
- Approximately 100 gal of potable chase water will be injected at the end of each daily batch injection.
- Aboveground Injection Line valves will be left closed between injection events and the line will not be drained until the final batch of the full-scale test is injected.

1. When DO has dropped below 0.5 mg/L, resume injecting the content of Tank A until approximately 2,500 gal are left in the tank (half-full) while co-injecting 550 mL of KB-1® Dechlorinator as summarized in Section 7.5 and presented in detail in Appendix C. Adjust the rate of KB-1® Dechlorinator co-injection to ensure even mixing with the substrate solution (approximately 110 mL / 500 gal). Record measurements and injection volumes on a *Daily Substrate Injection Log* (Appendix B).

   Observe the water level rise measurements indicated by Sonde 1. Prevent a water level rise above 335 ft by reducing the injection flow rate as necessary.




2. Collect a laboratory sample and duplicate of the Tank A combined injection stream at SPT while the KB-1® Dechlorinator is being injected. Follow the sample collection procedure presented in Table 7-3. Analytical parameters for the injection stream are the same as those listed for background groundwater sampling presented in Section 6.3.
3. When one half of Tank A content has been injected, interrupt KB-1® Dechlorinator injection and close the Tank A globe valve. Leave the Main Manifold globe valve open and unadjusted to retain the position that had established the injection flow rate. Record the totalizer reading and switch the Aboveground Injection Line connection to the Tank B Connection Assembly.
4. Open the Tank B glove valve and inject half the content of Tank B (2,500 gal) while co-injecting 550 mL of KB-1® Dechlorinator as summarized in Table 5-1 and presented in detail in Appendix C. Adjust the rate of KB-1® Dechlorinator co-injection to ensure even mixing with the substrate solution (approximately 110 mL per 500 gal).




The total injected volume from Tank A plus Tank B will equal 5,000 gal, constituting "Batch 1."

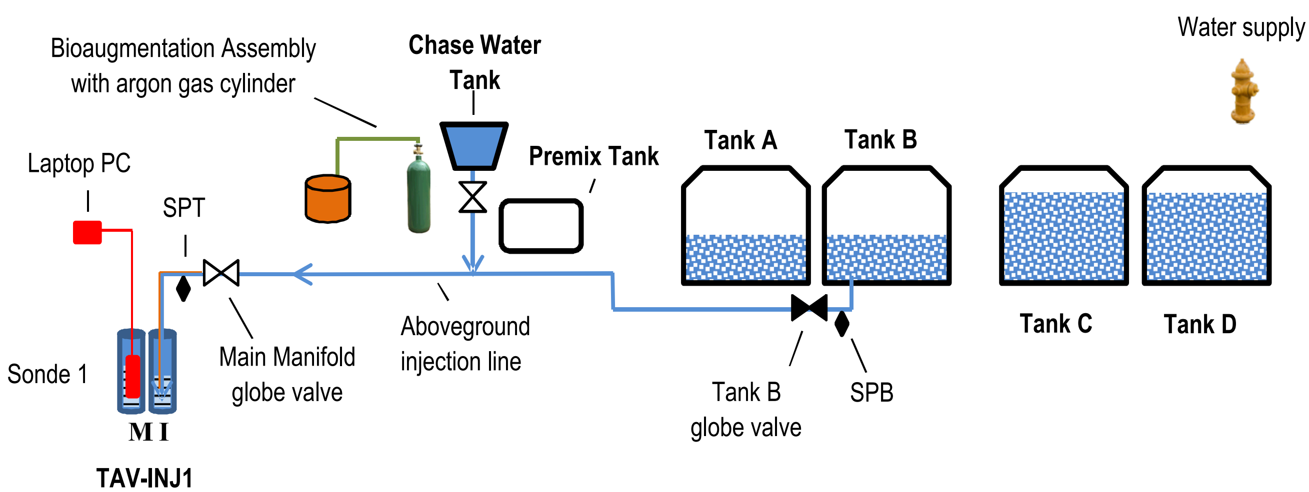
5. Continue to monitor and record downhole parameters, injection times, totalizer readings, system pressure readings, and volume of KB-1® Dechlorinator injected on the *Daily Injection Log* (Appendix B).
6. Collect a set of laboratory samples and duplicates of the Tank B combined injection stream at SPT while the KB-1® Dechlorinator is being injected. Follow the sample collection procedure presented in Table 7-3. Analytical parameters for the injection stream are the same as those listed for background groundwater sampling presented in Section 6.3.
7. Add accumulated SPT sampling and deoxygenation tank parameter measurement purge water into Tank A. This will be only a few liters and will not noticeably impact the overall DO or ORP of the tank content.
8. Submit injection stream samples from SPT to the analytical laboratories.

Step 9: Prepare and Inject Chase Water

**Skip this step if injection well groundwater sampling is to be conducted on the following business day.**

1. During injection from Tank B, fill the Chase Water Tank with 100 gal of potable water. **Do not add any amendments to this water or mix it with KB-1® Dechlorinator.**
2. As the injection of 2,500 gal from Tank B nears completion, sparge the potable water in the Chase Water Tank with argon gas and measure the drop in DO by lowering Sonde 6 into the tank. Note how long it takes to reach 0.5 mg/L for future reference and adjust the argon gas regulator to get sparging completed in less than 15 minutes. This setting will be used for subsequent chase water sparging steps.
3. Once Tank B injection is complete, close the Tank B valve. Monitor the subsequent drop in water level back to the static water level then open the Chase Water Tank valve and gravity drain the deoxygenated potable water into the injection well. After the chase water has been injected, close the valve. Record the chase water DO, volume injected, time injection was completed, and downhole sonde measurements on the Daily Injection Log.

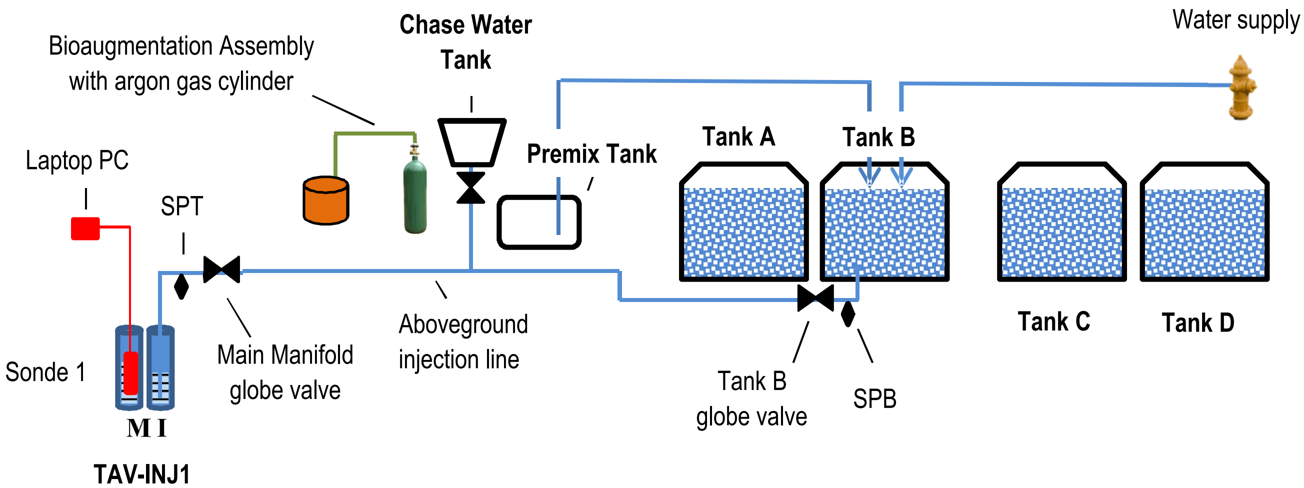
   Note: Observation of the time needed for the water level to return to a static level during the pilot test and the full-scale test operational schedule may determine that the planned frequency and volume of chase water injection need to be revised.




4. After the chase water has been injected, close the valve. Record the chase water DO, volume injected, time injection was completed, and downhole sonde measurements on the *Daily Injection Log*.

Step 10: Refill Tanks A and B with 2,500 Gallons of Substrate Solution.

1. Repeat Steps 5 and 6 for Tanks A and B. Record the substrate solution component mix on a *Substrate Solution Preparation Log*.




2. Resume monitoring DO and ORP drop in Tanks A and B and continue monitoring in Tanks C and D. Record values on tank-specific *Tank Deoxygenation Log* forms.

**Steps 7 through 10 are anticipated to take one work day to perform.**

**At the end of each day or operation, check that the system status is as follows:**

- The cumulative injected volume should be approximately 5,000 gal (2,500 from Tank A and 2,500 from Tank B) plus the chase water volume.
- All system valves and ports are closed.
- The Aboveground Injection Line remains connected to the injection casing.
- Tanks A and B should each be holding 5,000 gal of substrate solution and restarting the process of deoxygenating.
- Tanks C and D should each be holding 5,000 gal of substrate solution that has sufficiently deoxygenated so that it will be ready for injection by the following morning.
- Tank manways are closed, all other equipment is properly secured, and supplies are stored appropriately.
- Exclusion zone is properly delineated.
- Downhole sondes in all wells and associated data logging are performing normally.

**The following business day morning:**

- Inspect and maintain the Exclusion Zone, and status of equipment.
- Check that data is continuing to be logged from all three downhole sondes (TAV-INJ1, TAV-MW6, and TAV-MW7). Gently move sondes up and down a few feet in the well to counter potential DO measurement drift. Make sure the sonde is returned to its same depth. Note parameter measurements as “pre-injection” values on a new *Daily Injection Log*.
- Check field parameters in Tanks A, B, C, and D and record readings on separate *Tank Deoxygenation Log* forms for each tank. Tanks C and D should be sufficiently deoxygenated to perform gravity injection of the next batch (DO and ORP below 0.5 mg/L and negative 75 mV, respectively). If not, contact the Project Lead for instruction.
- Set up equipment and supplies and perform Steps 7 through 10 substituting Tanks C and D for Tanks A and B as **Injection Day #2** on the *Daily Field Injection Log*.
- Complete daily log forms, and perform the end of the day system checks listed above.

**After injection of Batch #2, the cumulative volume injected should be approximately 10,000 gal (plus approximately 200 gal of chase water).**

Repeat these daily steps for the duration of the full-scale test optimizing the process throughout as necessary to accommodate the rate of substrate solution deoxygenation in conjunction with injection rate and field logistics.

Based on a total substrate solution volume of 530,000 gal injected in daily increments of 5,000 gal batches, a total of 106 injection days (injected on normal business days within a six-month period) will be needed.

Injection of the Final Batch

After the final injection from each deoxygenation tank, there will be some residual substrate solution in each tank that will not gravity drain because it sits below the drain valve. Transfer this residual volume (approximately 100–300 gal per tank) into the final deoxygenation tank using the sump pump and drain it while co-injecting the final aliquot of KB-1® Dechlorinator. **Do not follow this with chase water.**

Pump the residual substrate solution out of the final deoxygenation tanks into the Premix Tank and gravity drain it into the Aboveground Injection Line via the Chase Water Tank connection.

Disconnect the Aboveground Injection Line from the last tank and allow it to completely drain the content inside into the well. Then disconnect the injection line from the injection casing and recording the final totalizer reading. Replace the compression coupling on the top of the injection casing with a removable but water-tight cap.

Note the downhole field parameters on the *Daily Injection Log* for Sondes 1, 2, and 3 and ensure that wellheads are secured while protecting the deployed sonde cables.

## 8.4 Monitoring During the Injection Period

Monitoring during the injection period of the full-scale test includes both field parameter measurements and collection of samples for laboratory analysis.

Aboveground Sampling

The System Operations Team is responsible for collecting samples and measuring field parameters taken from the Aboveground Injection System.

Sonde 6 will be connected to a flow cell to measure field parameters from components of the Aboveground Injection System during the injection period in the same manner as performed during the pilot test. Measurements will be noted on the *Substrate Solution Preparation Log* (Appendix B) and collected as described in Section 7.3.1.

Samples of the injection stream are to be collected from SPT for laboratory analysis using the flow-cell assembly during active injection to compare results with groundwater samples and to comply with NMED GWQB Discharge Permit requirements. Table 8.1 below presents the SPT sampling schedule. Analytical parameters will be the same as those analyzed for baseline groundwater sampling presented in Section 6.3.

Table 8-1. Injection Stream Sampling Frequency During Full-Scale Test

| Timeframe | Frequency | Notes |
|---|---|---|
| Week 1, Days 1 through 4 | Twice per day | Once for each tank drained (assuming Tanks A and B on Days 1 and 3, and Tanks C and D on Days 2 and 4). |
| Weeks 2 through 13 | Weekly | Sample collection timed to rotate through tanks being drained (Week 2 = Tank A, Week 3 = Tank B, Week 4 = Tank C, Week 5 = Tank D, etc.) |
| Weeks 14 until injection complete | Monthly | Sample collection to rotate through tanks being drained. |

<u>Downhole Sonde Measurements</u>

The System Operation Team is responsible for downhole sonde measurements. The electronically logged measurements in wells TAV-INJ1, TAV-MW6, and TAV-MW7 are to be set at an hourly frequency. These data will be downloaded each business day to a laptop computer using supplier software. Refer to the equipment supplier software instructions for details on programming and retrieving logged sonde measurements.

Additionally, during active injection, downhole conditions in well TAV-INJ1 will be viewed in real time and manually recorded on the *Daily Injection Log* at least once for approximately every 500 gal of substrate volume injected. Real-time monitoring may be performed using the software dashboard on the laptop computer or the handheld instrument used for Sonde 6.

These data will be used to determine if DO and ORP conditions are suitable for survivability of the KB-1® Dechlorinator (targeting less than 0.5 mg/L and less than negative 75 mV ORP). If these conditions are not being maintained during injection, consult with the Project Lead as the mix of substrate solution components may need to be revised.

A pH range of 6.9 – 7.5 is optimal but must remain between 6.0 – 8.5. Consult with the Project Lead if pH is outside the optimal range.

Water depth reading is actually feet of submergence indicating how high the top of the water column is above the water depth sensor. The injection rate needs to be set to ensure that the water column does not rise more than 335 ft in the well. The sonde submergence reading must be kept less than 335 ft plus the depth of the sonde below the static water.

1. Place the downhole sondes so the water depth sensor is set at the midpoint of the static submerged well screen for each well in the same fashion as describe for the pilot test.
2. Confirm the data loggers are still operating at all three well locations. Maintain an hourly logging interval for all three wells unless otherwise specified by the Project Lead. Data logging is to be conducted throughout the injection period and during at least the first six months of the post-injection performance monitoring period.
3. Check the downhole sondes and perform data downloads daily.
4. Each week, briefly and gently move the sondes up and down a few feet in the water column to ensure the sensors are monitoring representative water conditions and to remove potential accumulation of bubbles on the sensors. This helps to mitigate unrepresentative drift in DO readings.
5. Suspend data logging when groundwater samples are to be collected. The Groundwater Sampling Team will retrieve the sonde, take a manual depth to water measurement, deploy the groundwater sampling pump assembly, collect the sample, retrieve the pump assembly, and redeploy the sonde.
6. Each time the sonde is removed from the well, field check the components in accordance with FOP-05-02 and recalibrate the sensors in accordance with manufacturer's instructions. Record the calibration on the *Groundwater Sample Collection Field Equipment Check Log (LTS GW-2012-002)*. Inspect the sonde assembly to ensure the field cable and safety cable connections are secure and clean the sensors of any residue buildup. Replace sensor fluids if necessary. Replace the batteries in the sonde at least monthly (the EXO1 takes two D-cell batteries).
7. When the Groundwater Sampling Team has redeployed the sonde, resume data logging.

Groundwater Sampling

The Groundwater Sampling Team is responsible for the following tasks.

1. Collect monthly groundwater samples from wells TAV-INJ1, TAV-MW6, and TAV-MW7 during the full-scale injection period. This sampling schedule is incorporated into the overall groundwater sampling schedule shown in Appendix A.
2. Prior to each sampling event at each well, retrieve the multi-parameter sonde from the well and place it on clean plastic sheeting. The System Operation Team will inspect, maintain, and calibrate the sonde assembly as described in Task 4 above. Deploy a freshly decontaminated portable piston pump system into the well and follow FOP 05-01 for sampling. Purge the wells by purging a minimum of one saturated casing volume and reaching stabilized field monitoring parameters. Record purging data on the *Field Measurement Log for Groundwater Sample Collection (LTS GW-2012-001)* included in Appendix B.

Purge Water

The Groundwater Sampling Team collects purge water from wells TAV-INJ1, TAV-MW6, and TAV-MW7 in 55-gal drums during sampling. After all three wells have been sampled; the System Operation Team transfers the purge water into a deoxygenation tank. Indicate the addition of this purge water on the applicable *Substrate Solution Preparation Log* (Appendix B).

## 8.5 Post-Injection Performance Monitoring

Post-injection performance monitoring will begin after the entire full-scale test volume has been injected. The Groundwater Sampling Team assumes responsibility for operation of the downhole sondes, associated data logging, and continues groundwater sampling from the three wells for 24 months. As shown in Appendix A, groundwater sampling frequency remains monthly for three months following injection and will then be reduced to quarterly for the remainder of the 24-month period.

Downhole Sonde Measurements

Field parameters including water level, DO, ORP, pH, SC, and temperature will continue to be electronically logged with downhole multi-parameter Sondes 1, 2, and 3 for at least the first six months after full-scale injection is complete. Results from the first six months will be used for Decision Point #2 to determine if Phase II of the Treatability Study will be implemented by installing injection wells TAV-INJ2 and TAV-INJ3 and conducting full-scale tests at those locations. Procedures are the same as described for downhole sonde measurement during injection in Section 8.4.

After six months, consult with the Project Lead to determine if downhole data logging is to continue or if field parameter measurements taken during planned groundwater sampling events will be sufficient for the remainder of the 24-month post-injection performance monitoring period.

Groundwater Sampling

The Groundwater Sampling Team will collect groundwater samples from wells TAV-INJ1, TAV-MW6, and TAV-MW7 in the same manner as during the injection period in accordance with applicable SNL/NM FOPs.

Store, characterize, and dispose of sampling purge water and associated decontamination water in accordance with the WMP.

Continue to remove and redeploy the downhole multi-parameter sondes in these three wells until the 24-month post-injection monitoring period is complete unless some of them have been redeployed for subsequent full-scale tests at other TAVG locations.

Completion of Post-Injection Performance Monitoring

After completing 24 months of post-injection performance monitoring, the Groundwater Sampling Team will continue to groundwater sampling from monitoring wells TAV-MW6 and TAV-MW7 in conjunction with the ongoing TAVG LTS monitoring program. Discontinue sampling from injection well TAV-INJ1, but continue regular inspection and maintenance of the wells until long-term plans for TAVG AOC are determined.

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# 9.0 PHASE II: WELL INSTALLATION AND BASELINE SAMPLING

Phase II of the Treatability Study will be implemented if results of the first six months of post-injection performance monitoring at injection well TAV-INJ1 are deemed successful through the evaluation under Decision Point #2 in the Revised Work Plan.

Under Phase II, injection wells TAV-INJ2 and TAV-INJ3 will be installed near monitoring wells TAV-MW10 and LWDS-MW1, respectively, as shown in Figure 1-2. These wells are expected to be installed, developed, and slug tested in the same manner as described for TAV-INJ1 unless lessons learned from installation and subsequent tests at well TAV-INJ1 support modification to procedures. Table 6-3 presents the anticipated construction details for these two additional injection wells.

Because full-scale test injection at well TAV-INJ2 is scheduled to start within approximately one month of well installation, well development, slug testing, and any follow up geophysical logging will need to be performed shortly after the well installation.

To establish baseline conditions, collect baseline groundwater samples and follow the same procedure as in Section 6.3 for establishing baseline purge volume, field parameter measurements, and analytical constituents.

To confirm that there are sufficient VOC and nitrate concentrations present to justify performing full-scale tests in wells TAV-INJ2 and TAV-INJ3, analyze VOCs, NPN, and sulfate on rush turnaround. Compare the VOCs, NPN, and sulfate concentrations to those assumed in the Revised Work Plan electron donor mass calculation (Appendix A of the Revised Work Plan) to determine if the amount and mixture of substrate solution components need to be revised.

Provided these results indicate that the full-scale tests are to proceed at these locations, proceed to full-scale test at well TAV-INJ2 and subsequently at well TAV-INJ3.

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# 10.0 PHASE II: FULL-SCALE TESTS AT INJECTION WELLS TAV-INJ2 AND TAV-INJ3

Full-scale tests at injection wells TAV-INJ2 and TAV-INJ3 are expected to follow the same procedures and use the same equipment as the full-scale test at well TAV-INJ1 as described in Section 8.0 unless revised as a result of lessons learned during implementation of the first test.

## 10.1 Equipment Cleaning and Inspection

Equipment used during the prior full-scale test will have been cleaned and stored properly during the transition into the post-injection monitoring period. Before the system equipment is set up at the test site, perform a visual inspection to ensure that each piece of equipment is clean and in good working order. Any new or replacement equipment must be cleaned in accordance with Table 7.1.

Two downhole multi-parameter sondes will be used for each of the full-scale tests at wells TAV-INJ2 and TAV-INJ3; one placed in the injection well and one in the nearest monitoring well. It is assumed that Sondes 1, 2, and 3 will still be deployed for post-injection performance monitoring associated with the full-scale test at well TAV-INJ1 when the full-scale test at well TAV-INJ2 is ready to be started. Therefore, two additional sondes will be used for the full-scale test at well TAV-INJ2. These additional two sondes will be numbered and deployed as follows:

- Sonde 4: Injection well TAV-INJ2.
- Sonde 5: Monitoring well TAV-MW10.

Before installing them, clean the sondes, sensors, and cables, install new batteries, and calibrate the sensors.

For the full-scale test at well TAV-INJ3, it is assumed that at least two of the three sondes used for the TAV-INJ1 test will be removed and made available for redeployment as follows:

- Sonde 2: Injection well TAV-INJ3.
- Sonde 3: Monitoring well LWDS-MW1.

Before installing them, clean the sondes, sensors, and cables, install new batteries, and calibrate the sensors.

Sonde 1 will remain in well TAV-INJ1 to monitor for potential rebound of field parameters and Sonde 6 will continue to be used for measuring field parameters of the aboveground substrate solution, injection stream, and chase water for each test. If downhole field parameters in well TAV-INJ1 appear more stable than in well TAV-MW6, then Sonde 1 may be used in well TAV-INJ3 instead of Sonde 2.

Refer to Section 7.2.6 for instructions on deploying the sondes and initiating data logging.

## 10.2 Site Preparation and Equipment Set Up

The Aboveground Injection System equipment will be moved to the vicinity of the new injection well provided drilling and development equipment has been demobilized from the area and Facilities Engineering has been notified.

Figures 10-1 and 10-2 show the site plans for full-scale tests at wells TAV-INJ2 and TAV-INJ3, respectively.

Site Staging

An Exclusion Zone must be delineated in the field using caution tape or other visible barrier system acceptable to Facilities Engineering to keep non-project workers out of the work area. Stage each site as described in Section 7.2 and as shown in Figures 10-1 and 10-2. The project area may be modified based on site conditions.

For the full-scale test at well TAV-INJ2, the potable water source is the fire hydrant located approximately 150 ft to the northeast of the TAV-INJ2 wellhead. The potable water source for the full-scale test at well TAV-INJ3 is pending decision by Facilities Engineering, but has been assumed to be located southwest of the TAV-INJ3 wellhead and outside the TA-V security fencing.

Install additional hose guards as necessary to protect the potable water source line from vehicular traffic. Set up portable bollards around monitoring well LWDS-MW1. Bollards are not necessary for delineating the TAV-MW10 wellhead as it will be within the test Exclusion Zone.

Stormwater Pollution Prevention

Implement stormwater pollution prevention controls for each test location as discussed in Section 7.2.5 along with any modifications specific to each site.

## 10.3 Full-scale Injection

The process for performing the full-scale injections at well TAV-INJ2 and subsequently at well TAV-INJ3 will essentially be the same as described in Section 8.3, although modifications to the procedures may be implemented based on lessons learned from prior tests.

Similarly, the quantities and mixing ratios of substrate solution components may be adjusted based on the baseline conditions observed at each location and on lessons learned from prior tests.

Primary location-specific differences in procedures are listed below:

- Soil core used for inoculating the initial batches of substrate solution shall come from the screened interval of the injection well borehole at the specific test location.
- The performance monitoring well for the full-scale test at well TAV-INJ2 is well TAV-MW10 and the performance monitoring well for the full-scale test at well TAV-INJ3 is well LWDS-MW1.
- Hydraulic conductivity in the vicinity of well TAV-INJ3 is anticipated to be two orders of magnitude lower than at wells TAV-INJ1 and TAV-INJ2 which would cause the substrate solution to rise higher in the injection well casing and may limit the daily injection rate. Consequently, the injection period may be longer than six months.
- Wells TAV-INJ3 and LWDS-MW1 are located outside the TA-V security fence thereby limiting the need for additional security escorts provided the potable water supply is also outside this fencing. However, longer injection period may initiate extra efforts to reduce inconvenience to pedestrian and vehicle traffic.
- After injection is complete at TAV-INJ3 (the third of three full-scale tests), the Aboveground Injection System components will be demobilized for long-term storage and possibly repurposing. The storage container and office trailer will also be removed.

## 10.4 Monitoring During the Injection Period

Follow the same procedures as outlined in Section 8.4 substituting in the associated wells for each test:

- Injection well TAV-INJ2: Monitoring well TAV-MW10
- Injection well TAV-INJ3: Monitoring well LWDS-MW1

Sondes 4 and 5 will be added to the equipment list. The Project Lead will determine which downhole sondes can be removed from post-injection performance monitoring and to deploy for these full-scale tests or if additional sondes will be necessary.

## 10.5 Post-injection Performance Monitoring

Follow the same procedures as outlined in Section 8.5 substituting in the associated wells for each test.

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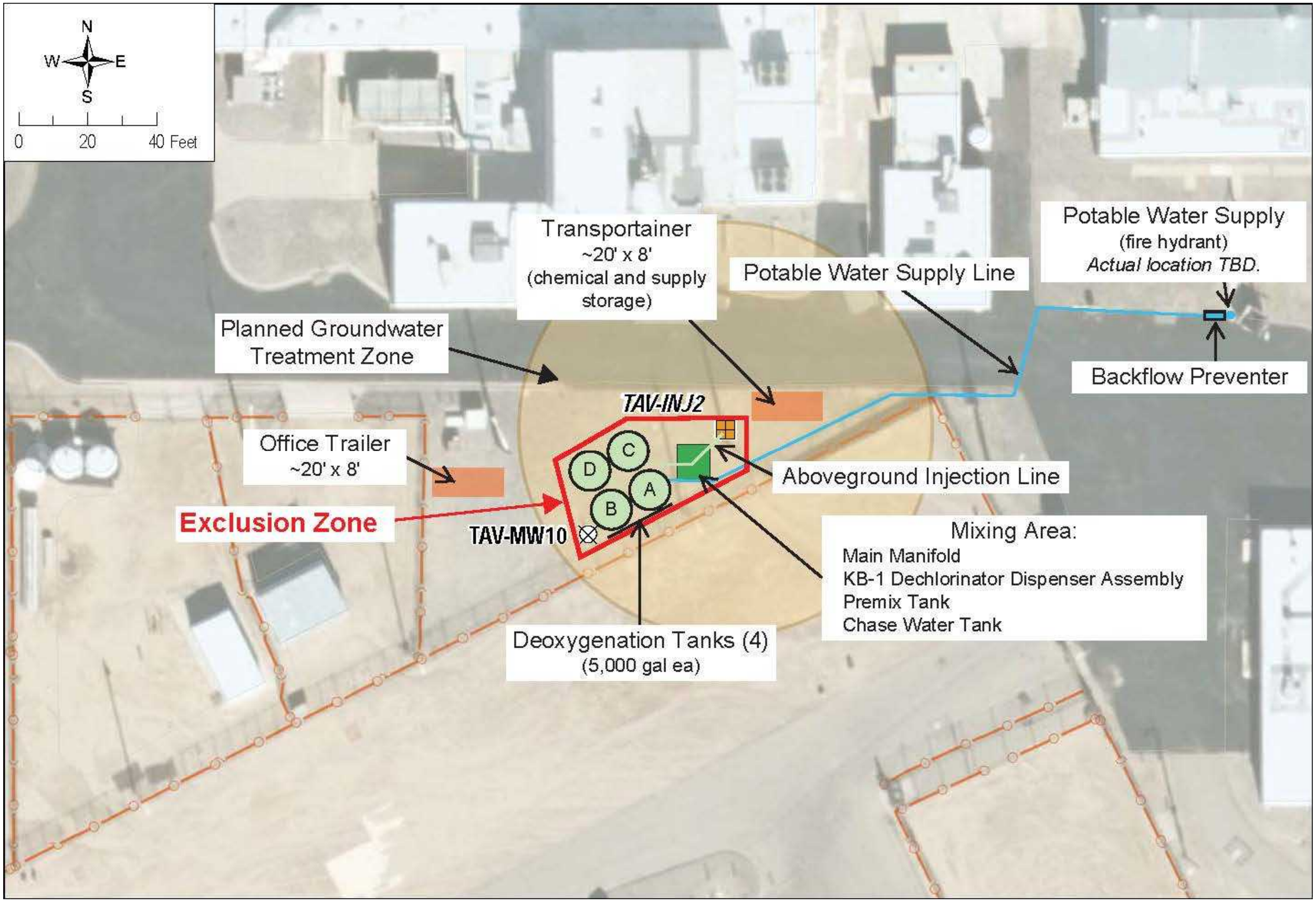


Figure 10-1
Site Layout Plan – Full-scale Test at Injection Well TAV-INJ2

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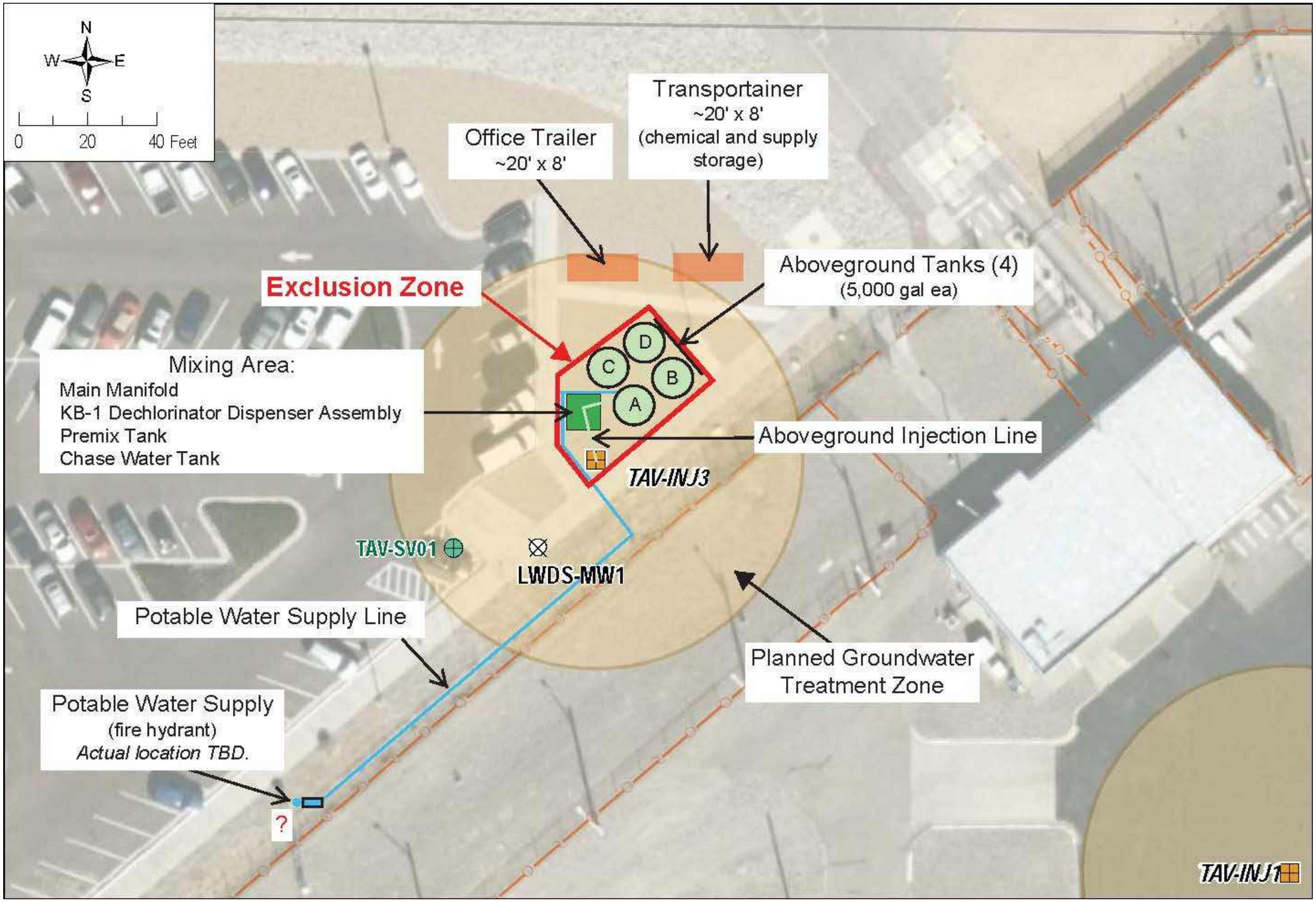


Figure 10-2
Site Layout Plan – Full-scale Test at TAV-INJ3

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# APPENDIX A

## Groundwater Sampling Plan

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# TA-V Groundwater Monitoring
# Overview for Mini-Sampling and Analysis Plans to be Implemented During the In-Situ Bioremediation Treatability Study

## Second Quarter, Fiscal Year 2017 — Fourth Quarter, Fiscal Year 2022

### Summary

The Groundwater Sampling Team will perform groundwater sampling from injection wells and groundwater monitoring wells at Technical Area-V (TA-V) in support of the In-Situ Bioremediation (ISB) Treatability Study. Sampling activities will be performed in advance, during, and subsequent to injections of ISB substrate solution into up to three injection wells; TAV-INJ1, TAV-INJ2, and TAV-INJ3. This will be integrated with the ongoing Long-Term Stewardship (LTS) groundwater monitoring being conducted at the site.

The Treatability Study will be conducted at three different locations at TA-V, each centered around a different injection well. There are four categories of sampling objectives that may apply to a given well at a given time:

- Long-Term Stewardship (LTS),
- Waste water profiling (WW),
- Treatability Study performance (TSP), and
- New Mexico Environment Department (NMED) Ground Water Quality Bureau (GWQB) discharge permit compliance.

At least one of these sampling objectives will be applicable to each groundwater monitoring well at any given time. Which sampling objectives are applicable will change over time depending on the status of the Treatability Study. A brief description of each of these objectives follows.

Table A-1 lists the analytical parameters for each objective and Table A-2 presents the sampling frequency for each well in the groundwater monitoring network at TA-V during each of the Treatability Study phases. Table A-3 presents the planned groundwater sampling schedule for the duration of the Treatability Study and indicates which suite of parameters are to be analyzed based on the categories described below and presented in Tables A-1 and A-2. The schedule is subject to change based on receipt of the NMED GWQB discharge permit and other required approvals, funding, and procurement.

### Long-Term Stewardship (LTS) Analysis

Groundwater at TA-V is monitored through Sandia's LTS Program. LTS monitoring consists of analyzing for the TA-V constituents of concern (COCs); nitrate and TCE. LTS monitoring is the default when wells are not included in monitoring for the Treatability Study or have additional sampling requirements imposed to comply with the associated discharge permit from GWQB. Four quarters' monitoring of perchlorate is required for wells TAV-MW15 and TAV-MW16.

Sampling frequency is well-specific with some wells sampled quarterly, some semiannually, and some annually. Injection wells are included in the sampling schedule for baseline conditions and during the Treatability Study period, but are not planned to be included in the LTS groundwater monitoring program after the Treatability Study.

**Waste Water (WW) Profiling**

Waste water generated during groundwater sampling (purging and decontamination water) is typically disposed of via the sanitary sewer under a permit issued by the Albuquerque Bernalillo County Water Utility Authority. Annual sampling for a number of parameters is required for each sampled well to verify that parameters are within the limits of the sanitary sewer discharge permit. In addition to all the active groundwater monitoring wells at TA-V, this sampling objective also applies to the injection wells where sampling is conducted during the Treatability Study.

For newly installed wells (injection or monitoring), waste water profiling is to be performed during the first sampling event for that well. It is then performed annually along with other previously profiled wells, typically during the fiscal year third quarter (April, May, June). Currently, TA-V Groundwater annual waste water profiling is conducted in May.

**Treatability Study Performance (TSP)**

Groundwater samples collected from injection wells and paired, nearby monitoring wells will be analyzed for a number of parameters to evaluate the effectiveness of the Treatability Study to:

- Deliver the ISB injection solution.
- Create conditions favorable to facilitating denitrification of nitrate and dechlorination of TCE and its daughter products.
- Reduce COC concentrations.
- Minimize COC concentration rebound.

Sample frequency changes throughout the Treatability Study and is presented in Table 1. There are three primary stages of sampling for this suite of parameters referred to as TSP in Table A-3:

- Baseline sampling conducted prior to injection at a given location.
- Sampling during each six-month full-scale injection (the pilot test will not include sampling during the short injection period).
- Post-injection sampling for 24 months after each full-scale injection is complete (4 months for the pilot test).

**NMED GWQB Discharge Permit (DP) Compliance (within and adjacent to the injection Treatment Area)**

The GWQB discharge permit requires analyzing samples for a number of parameters at the injections wells and paired monitoring wells. These analyses are included with the suite of analytical parameters monitored under ISB performance but shown separately on Table 1 under the heading “Within the Treatment Area” (DP1). This suite of parameters will be analyzed in conjunction with TSP analyses to the degree required by the discharge permit including during baseline sampling. Additionally, several wells located outside the planned Treatment Area for each full-scale test will be monitored for select dissolved metals to support discharge permit compliance as indicated under the heading “Adjacent to the Treatment Area (DP2).”

GWQB discharge permit sampling frequency is incorporated into the Treatability Study performance sampling schedule. Additional sampling may be required if detected concentrations exceed permit limits.

Table A-1. Analytical Parameters for Each Sampling Objective

| Analytical parameter | | Long-Term Stewardship (LTS) | Waste water profiling (WW) | Treatability Study Performance (TSP) | GWQB Discharge Permit Compliance | |
|---|---|---|---|---|---|---|
| | | | | | Within the Treatment Area (DP1) *To be determined* | Adjacent to the Treatment Area (DP2) |
| Alkalinity [a] | | -- | X | X | | -- |
| Ammonia (as nitrogen) | | -- | -- | X | | -- |
| Anions (bromide, chloride, fluoride, nitrite, and sulfate) | | -- | X [b] | X | | -- |
| Dhc, and if present, vcrA | | -- | -- | X | | -- |
| Dissolved metals | arsenic, iron, manganese | -- | -- | -- | | X |
| | arsenic, calcium, iron, magnesium, manganese, potassium, and sodium | -- | -- | X | | -- |
| Methane, ethene, ethane | | -- | -- | X | | -- |
| NPN | | X | -- | X | | -- |
| Orthophosphate (as phosphorus) | | -- | -- | X | | -- |
| Perchlorate [c] | | X | -- | -- | | -- |
| Sulfide | | -- | -- | X | | -- |
| Total metals plus uranium [d] | | -- | X | -- | | -- |
| TOC | | -- | -- | X | | -- |
| VOCs (TCL) | | X | -- | X | | -- |
| Radiological Screening Parameters: gamma spectroscopy (short-list), gross alpha and beta, and tritium | | -- | X | -- | | -- |

Notes on following page.

## Table A-1. Analytical Parameters for Each Sampling Objective (concluded)

Notes:

[a] Alkalinity measured as (1) $CaCO_3$, (2) $CO_3^{2-}$ as $CaCO_3$, and (3) $HCO_3^-$ as $CaCO_3$.

[b] Nitrite is not required for waste water profiling.

[c] Four quarters after installation of wells TAV-MW15 and TV-MW16 only.

[d] Total metals are not filtered and include the 23 metals listed in the TAL.

Dhc = Dehalococcoides

DP1 = GWQB discharge permit compliance (within the treatment area)

DP2 = GWQB discharge permit compliance (adjacent to the treatment area)

LTS = Long-Term Stewardship

NPN = nitrate plus nitrite

TCL = Target Compound List

TOC = total organic carbon

TSP = Treatability Study performance

vcrA = vinyl chloride reductase

VOCs = volatile organic compounds

WW = waste water profiling

Table A-2. Well-specific Sampling Frequencies

<table>
<tr><th>Injection Wells</th><th>Pre-Treatability Study</th><th>Phase I<br>(TAV-INJ1)</th><th>Phase II<br>(TAV-INJ2)</th><th>Phase II<br>(TAV-INJ3)</th></tr>
<tr><td>TAV-INJ1</td><td>Not yet installed</td><td>TSP & DP1<br>Pilot Study (TAV-INJ1)<br>Baseline (1 event) & post-injection:<br>• Weekly (8 events)<br>• Monthly (4 events)<br>Full-scale Test (TAV-INJ1)<br>During injection:<br>• Monthly (6 events)<br>Post-injection:<br>• Monthly (3 events)<br>• Quarterly (7 events)</td><td colspan="2">Sampling suspended after completing TSP & DP1.</td></tr>
<tr><td>TAV-INJ2</td><td colspan="2">Not yet installed</td><td>TSP & DP1<br>Full-scale Test (TAV-INJ2)<br>During injection:<br>• Monthly (6 events)<br>Post-injection:<br>• Monthly (3 events)<br>• Quarterly (7 events)</td><td>Sampling suspended after completing TSP & DP1.</td></tr>
<tr><td>TAV-INJ3</td><td colspan="3">Not yet installed.</td><td>TSP & DP1<br>Full-scale Test (TAV-INJ3)<br>During injection:<br>• Monthly (6 events)<br>Post-injection:<br>• Monthly (3 events)<br>• Quarterly (7 events)</td></tr>
</table>

Table A-2. Well-specific Sampling Frequencies (continued)

| Monitoring Wells | Pre-Treatability Study | Phase I (TAV-INJ1) | Phase II (TAV-INJ2) | Phase II (TAV-INJ3) |
|---|---|---|---|---|
| AVN-1 | LTS - Annually | | | |
| LWDS-MW1 | LTS - Quarterly | LTS - Quarterly<br>DP2 - Quarterly | LTS - Quarterly<br>DP2 - Quarterly | TSP & DP1<br>**Full-scale Test (TAV-INJ3)**<br>*During injection:*<br>• Monthly (6 events)<br>*Post-injection:*<br>• Monthly (3 events)<br>• Quarterly (7 events) |
| LWDW-MW2 | LTS - Annually | | | |
| TAV-MW2 | LTS - Quarterly | LTS - Quarterly, DP2 - Quarterly | | |
| TAV-MW3 | LTS - Annually | | | |
| TAV-MW4 | LTS - Quarterly | LTS – Quarterly, DP2 - Quarterly | | |
| TAV-MW5 | LTS - Annually | | | |
| TAV-MW6 | LTS - Quarterly | TSP & DP1<br>**Pilot Study (TAV-INJ1)**<br>*Baseline (1 event) & post-injection:*<br>• Weekly (8 events)<br>• Monthly (4 events)<br>**Full-scale Test (TAV-INJ1)**<br>*During injection:*<br>• Monthly (6 events)<br>*Post-injection:*<br>• Monthly (3 events)<br>• Quarterly (7 events) | LTS – Quarterly after TSP & DP1 | |

Table A-2. Well-specific Sampling Frequencies (continued)

<table>
<tr><th>Monitoring Wells</th><th>Pre-Treatability Study</th><th>Phase I<br>(TAV-INJ1)</th><th>Phase II<br>(TAV-INJ2)</th><th>Phase II<br>(TAV-INJ3)</th></tr>
<tr><td>TAV-MW7</td><td>LTS - Semiannually</td><td>TSP & DP1<br>Pilot Study (TAV-INJ1)<br>Baseline (1 event) & post-injection:<br>• Weekly (8 events)<br>• Monthly (4 events)<br>Full-scale Test (TAV-INJ1)<br>During injection:<br>• Monthly (6 events)<br>Post-injection:<br>• Monthly (3 events)<br>• Quarterly (7 events)</td><td colspan="2">LTS – Semiannually after TSP & DP1</td></tr>
<tr><td>TAV-MW8</td><td>LTS - Quarterly</td><td colspan="3">LTS – Quarterly, DP2 - Quarterly</td></tr>
<tr><td>TAV-MW9</td><td colspan="4">LTS - Annually</td></tr>
<tr><td>TAV-MW10</td><td>LTS - Quarterly</td><td>LTS - Quarterly<br>DP2 - Quarterly</td><td>TSP & DP1<br>Full-scale Test (TAV-INJ2)<br>During injection:<br>• Monthly (6 events)<br>Post-injection:<br>• Monthly (3 events)<br>• Quarterly (7 events)</td><td>LTS – Quarterly<br>after TSP & DP1</td></tr>
<tr><td>TAV-MW11</td><td>LTS - Quarterly</td><td colspan="3">LTS – Quarterly, DP2 - Quarterly</td></tr>
<tr><td>TAV-MW12</td><td>LTS - Quarterly</td><td colspan="3">LTS – Quarterly, DP2 – Quarterly</td></tr>
<tr><td>TAV-MW13</td><td colspan="4">LTS - Annually</td></tr>
</table>

Table A-2. Well-specific Sampling Frequencies(concluded)

| Monitoring Wells | Pre-Treatability Study | Phase I (TAV-INJ1) | Phase II (TAV-INJ2) | Phase II (TAV-INJ3) |
|---|---|---|---|---|
| TAV-MW14 | LTS - Quarterly | LTS – Quarterly, DP2 – Quarterly | | |
| TAV-MW15 | LTS - Quarterly | | | |
| TAV-MW16 | LTS - Quarterly | | | |

Notes:

Waste water profiling is performed for each sampled well on an annual basis.

DP1 = GWQB discharge permit compliance (within the treatment area)

DP2 = GWQB discharge permit compliance (adjacent to the treatment area)

LTS = Long-Term Stewardship

TSP = Treatability Study performance

## Table A-3. Treatability Study Groundwater Sampling Schedule

| | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 | FY2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 | Q4 |
| | Oct | Nov | Dec | JAN | FEB | MAR | APR | MAY | JUN | Jul | Jul | Jul | AUG | SEP | SEP | SEP | SEP | SEP | SEP | SEP | SEP |
| TAV-INJ1<br>Pilot Test (blue)<br>Full-scale test (purple) | | Pre-TS LTS | | | Revised LTS | | | Revised LTS | | TAV-INJ1 baseline | | | MW 6&7 baseline | Injection (Mon) | Post-Inj D1 (Tues) | Post-Inj D2 (Wed) | Post-Inj D4 (Fri) | Post-Inj W1 (Mon) | Post-Inj W2 | Post-Inj W3 | Post-Inj W4 |
| TAV-INJ2<br>Full-scale Test | | | | | | | | | | | | | | | | | | | | | |
| TAV-INJ3<br>Full-scale Test | | | | | | | | | | | | | | | | | | | | | |
| AVN-1 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| **TAV-INJ3** | | | | | | | | | | | | | | | | | | | | | |
| LWDS-MW1 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| LWDS-MW2 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| TAV-MW2 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW3 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| TAV-MW4 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW5 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| **TAV-INJ1** | | | | | | | | | Install | TSP, DP1 | | | TSP | | TSP | TSP | TSP | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW6 | | LTS | | | LTS | | | LTS, WW | | | | | TSP, DP1 | | | | | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW7 | | LTS | | | | | | LTS, WW | | | | | TSP, DP1 | | | | | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW8 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW9 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| **TAV-INJ2** | | | | | | | | | | | | | | | | | | | | | |
| TAV-MW10 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW11 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW12 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW13 | | LTS | | | | | | LTS, WW | | | | | | | | | | | | | |
| TAV-MW14 | | LTS | | | LTS | | | LTS, WW | | | | | LTS, DP2 | | | | | | | | |
| TAV-MW15 | Install | LTS, p, WW | | | LTS, p | | | LTS, p | | | | | LTS, p | | | | | | | | |
| TAV-MW16 | Install | LTS, p, WW | | | LTS, p | | | LTS, p | | | | | LTS, p | | | | | | | | |
| **Total wells sampled per event** | 0 | 18 | 0 | 0 | 11 | 0 | 0 | 18 | 0 | 1 | 0 | 0 | 13 | | 1 | 1 | 1 | 3 | 3 | 3 | 3 |
| **Total wells sampled per quarter** | | 18 | | | 11 | | | 18 | | | | | | | 29 | | | | | | |

Table A-3. Treatability Study Groundwater Sampling Schedule (continued)

| | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 | FY 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q1 | Q1 | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 |
| | OCT | OCT | OCT | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
| TAV-INJ1<br>Pilot Test (blue)<br>Full-scale test (purple) | Post-Inj W5 | Post-Inj W6 | Post-Inj W7 | Post-Inj W8 | Post-Inj W12 | Post-Inj W16 | DECISION POINT #1 Expand system. Start Inj. | Inj M1 | Inj M2 | Inj M3 | Inj M4 | Inj M5 | Inj M6<br>End inj. | Post-Inj M1 | Post-Inj M2 |
| TAV-INJ2<br>Full-scale Test | | | | | | | | | | | | | | | |
| TAV-INJ3<br>Full-scale Test | | | | | | | | | | | | | | | |
| AVN-1 | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ3** | | | | | | | | | | | | | | | |
| LWDS-MW1 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| LWDS-MW2 | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW2 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW3 | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW4 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW5 | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ1** | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW6 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW7 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| TAV-MW8 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW9 | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ2** | | | | | | | | | | | | | | | |
| TAV-MW10 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW11 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW12 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW13 | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW14 | | | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW15 | | | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| TAV-MW16 | | | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| **Total wells sampled per event** | 3 | 3 | 3 | 3 | 13 | 3 | | 13 | 3 | 3 | 19 | 3 | 3 | 13 | 3 |
| **Total wells sampled per quarter** | 28 | | | | | | 16 | | | 25 | | | 19 | | |

Table A-3. Treatability Study Groundwater Sampling Schedule (continued)

| | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2019 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 | FY 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 |
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
| **TAV-INJ1** Pilot Test (blue) Full-scale test (purple) | Post-Inj M3 | | | Post-Inj M6 | DECISION POINT #2 | | | Post-Inj M10 | | | Post-Inj M13 | | | Post-Inj M16 | | | Post-Inj M19 | | | Post-Inj M22 | | | Post-Inj M25 | |
| **TAV-INJ2 Full-scale Test** | | | | | | | | MW10 baseline | TAV-INJ2 Baseline | System set up. Start Inj. | Inj M1 | Inj M2 | Inj M3 | Inj M4 | Inj M5 | Inj M6 End Inj. | Post-Inj M1 | Post-Inj M2 | Post-Inj M3 | | | | Post-Inj M7 | |
| **TAV-INJ3 Full-scale Test** | | | | | | | | | | TAV-INJ3 Baseline | LWDS-MW1 Baseline | | | | | System set up | Start inj. | Inj M1 | Inj M2 | Inj M3 | Inj M4 | Inj M5 | Inj M6 Stop injection. | Post-inj M1 |
| AVN-1 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ3** | | | | | | | | | Install | TSP, DP1 | | | | TSP | | | | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| LWDS-MW1 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | TSP | | | TSP | | | TSP, DP1 | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 |
| LWDS-MW2 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW2 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW3 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW4 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW5 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ1** | TSP, DP1 | | | TSP, DP1 | | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | |
| TAV-MW6 | TSP, DP1 | | | TSP, DP1 | | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | |
| TAV-MW7 | TSP, DP1 | | | TSP, DP1 | | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | |
| TAV-MW8 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW9 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ2** | | | | | | | | Install | TSP, DP1 | | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1, WW | | | | TSP, DP1 | |
| TAV-MW10 | | LTS, DP2 | | | LTS, DP2 | | | TSP, DP1 | | | TSP, DP1, WW | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1 | TSP, DP1, WW | | | | TSP, DP1 | |
| TAV-MW11 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW12 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW13 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW14 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | |
| TAV-MW15 | | LTS | | | LTS | | | LTS, WW | | | LTS | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| TAV-MW16 | | LTS | | | LTS | | | LTS, WW | | | LTS | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| **Total wells sampled per event** | 3 | 10 | 0 | 3 | 10 | 0 | 0 | 19 | 1 | 1 | 14 | 2 | 2 | 15 | 2 | 2 | 14 | 4 | 4 | 19 | 2 | 2 | 15 | 2 |
| **Total wells sampled per quarter** | | 13 | | | 13 | | | 20 | | | 17 | | | 19 | | | 20 | | | 25 | | | 19 | |

Table A-3. Treatability Study Groundwater Sampling Schedule (continued)

| | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2021 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 | FY 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 | Q1 | Q1 | Q1 | Q2 | Q2 | Q2 | Q3 | Q3 | Q3 | Q4 | Q4 | Q4 |
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
| **TAV-INJ1**<br>Pilot Test (blue)<br>Full-scale test (purple) | | | | | | | | | | | | | | | | | | | | | | | | |
| **TAV-INJ2 Full-scale Test** | | Post-Inj M10 | | | Post-Inj M13 | | | Post-Inj M16 | | | Post-Inj M19 | | | Post-Inj M22 | | | Post-Inj M25 | | | | | | | |
| **TAV-INJ3 Full-scale Test** | Post-inn M2 | Post-Inj M3 | | | Post-Inj M6 | | | Post-Inj M9 | | | Post-Inj M12 | | | Post-Inj M15 | | | Post-Inj M18 | | | Post-Inj M21 | | | Post-Inj M24 | |
| AVN-1 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ3** | TSP, DP1 | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | |
| LWDS-MW1 | TSP, DP1 | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | |
| LWDS-MW2 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW2 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW3 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW4 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW5 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ1** | | | | | | | | | | | | | | | | | | | | | | | | |
| TAV-MW6 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW7 | | LTS | | | | | | LTS, WW | | | | | | LTS | | | | | | LTS, WW | | | | |
| TAV-MW8 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW9 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| **TAV-INJ2** | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | | | | | | | | |
| TAV-MW10 | | TSP, DP1 | | | TSP, DP1 | | | TSP, DP1, WW | | | TSP, DP1 | | | TSP, DP1 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW11 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW12 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW13 | | | | | | | | LTS, WW | | | | | | | | | | | | LTS, WW | | | | |
| TAV-MW14 | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2, WW | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | | | LTS, DP2 | |
| TAV-MW15 | | LTS | | | LTS | | | LTS, WW | | | LTS | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| TAV-MW16 | | LTS | | | LTS | | | LTS, WW | | | LTS | | | LTS | | | LTS | | | LTS, WW | | | LTS | |
| **Total wells sampled per event** | 2 | 14 | 0 | 0 | 13 | 0 | 0 | 20 | 0 | 0 | 13 | 0 | 0 | 14 | 0 | 0 | 12 | 0 | 0 | 19 | 0 | 0 | 12 | 0 |
| **Total wells sampled per quarter** | | 16 | | | 13 | | | 20 | | | 13 | | | 14 | | | 12 | | | 19 | | | 12 | |

Table A-3. Treatability Study Groundwater Sampling Schedule (concluded)

Notes:

| | | |
|---|---|---|
| (light gray shading) | = | Well not yet installed |
| (gray shading) | = | Discontinue monitoring |
| (tan shading) | = | DP compliance monitoring well |
| **Red font** | = | Injection in progress |
| **DP1** | = | NMED discharge permit compliance (within the treatment area) |
| **DP2** | = | NMED discharge permit compliance (adjacent to the treatment area) |
| **LTS** | = | Long-Term Stewardship |
| **p** | = | perchlorate analysis |
| **TSP** | = | Treatability Study performance |
| **WW** | = | waste water profiling |

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# APPENDIX B

## Field Data Collection Forms

- LTS GW-2012-001 - Field Measurement Log for Groundwater Sample Collection
- LTS GW-2012-002 - Groundwater Sample Collection Field Equipment Check Log
- Analysis Request and Chain of Custody Form (ARCOC) - Sample Management Office
- Treatability Study Substrate Solution Preparation Log
- Treatability Study Tank Deoxygenation Log
- Treatability Study Daily Injection Log
- SiREM Chain of Custody Form

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**Insert (existing form)**

**LTS GW-2012-001 - Field Measurement Log for Groundwater Sample Collection**

**Insert (existing form)**

**LTS GW-2012-002 - Groundwater Sample Collection Field Equipment Check Log**

## Insert (existing form)

## ARCOC – Sample Management Office – Analysis Request and Chain of Custody Form

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# Treatability Study Substrate Solution Preparation Log

**Project Name:** Technical Area-V Treatability Study

**Technician Names:** ______________________________________________

**Injection Well I.D.:** _______________ **Date (MM/DD/YYYY):** __________________

**Deoxygenation Tank (A, B, C, D):** _______

| **Deoxygenation accelerator added in Premix Tank** | |
|---|---|
| Approximate volume of water (gal) | |
| KB-1 Primer (grams) | |

| **Substrate components added in Premix Tank** | |
|---|---|
| Approximate volume of water (gal) | |
| Ethyl lactate (gal) | |
| Diammonium phosphate (lbs) | |
| Yeast extract (lbs) | |
| Sodium bromide (lbs) | |

| **Deoxygenation Tank _____** | **Volume in tank (gal)** | **Fill Time (24 hr)** |
|---|---|---|
| Volume from Premix Tank | | **Start:** _________ |
| After fill with groundwater or potable water | | **Finish:** ________ |
| **Net volume added (gal)** | | Total time: |

Notes: ________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

# Treatability Study Tank Deoxygenation Log

**Project Name:** Technical Area-V Treatability Study

**Technician Names:** ____________________________________________

**Deoxygenation Tank (A, B, C, D):** ____________ **Date (MM/DD/YYYY):** ___________________

| Time (24 hr) | Volume in tank (gal) | DO (mg/L) | ORP (mV) | pH | SC (µS/cm) | Temp ($^oC$) |
|---|---|---|---|---|---|---|
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| | | | | | | |
| Ready to inject | | < 0.5 | < negative 75 | 6.0-8.5 | | |

Notes: Fill includes groundwater sampling purge water (Y/N) If Yes, well names and volumes (gal): ________

_______________________________________________________________________________

_______________________________________________________________________________

# Treatability Study Daily Injection Log

**Project Name:** Technical Area-V Treatability Study

**Lead Technician Name:** ______________________________ **Injection Well I.D.:** ______________

**Date (MM/DD/YYYY):** ______________ **Batch Number:** __________ **Deoxygenation Tank (A, B, C, D):** __________

| Time (24 hr) | Injection stage [a] | Totalizer (gal) | Cumulative volume of KB-1® Dechlorinator injected (mL) | Pressure/vacuum (psi) | | | | Water depth (ft submerged) | Downhole Field Parameters (injection well) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | G1 | G2 | G3 | G4 | | DO (mg/L) | ORP (mV) | pH | SC (µS/cm) | Temp (°C) |
| | | | | | | | | | | | | | |
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[a] = Injection stages include **pre-injection (PI)** = Initial readings prior to injection for the day, **displacement (D)** = initial injection of substrate solution without KB-1® Dechlorinator to displace injection well water column and reduce downhole DO and ORP to below 0.5 mg/L and negative 75 mV, respectively, **co-injection (CI)** = combined injection of substrate solution and KB-1® Dechlorinator, **chase (Ch)** = injection of sparged potable water with no amendments. Use other brief descriptors as appropriate.

# Treatability Study Daily Injection Log (continued)

**Project Name:** Technical Area-V Treatability Study

**Technician Names:** ______________________________ **Injection Well I.D.:** ______________

**Date (MM/DD/YYYY):** ________________

## Daily summary:

Volume of substrate solution injection (gal): from Tank ___ ____________ from Tank ___ ______________

Volume of KB-1 Dechlorinator injected (mL): with Tank ___ ____________ with Tank ___ ______________

Volume of chase water injected (gal): ________________

Totalizer Start (gal): __________________ Finish: _________________

Volume (gal) remaining in: Tank A ______________ Tank B ______________ Tank C ______________ Tank D ______________

Injection stream sample collected (Yes or No): _________ Tank being drained: __________

Totalizer reading (gal) when sample collected: ________________ Sample ID: ______________________________

Notes: ______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

SiREM

130 Research Lane, Ste 2
Guelph ON, Canada N1G 5G3
(519) 822-2265

# Chain-of-Custody Form

siremlab.com

Lab #

| Project Name | Project # |
|---|---|
| Project Manager | |
| Email | |
| Company | |
| Address | |
| | |
| Phone # | Fax # |
| Sampler's Signature | Sampler's Printed Name |

**Analysis**

Preservative

**Preservative Key**

0. None
1. HCL
2. Other ____________
3. Other ____________
4. Other ____________
5. Other ____________
6. Other ____________

| Client Sample ID | Lab ID | Sampling | | Matrix | # of Containers | | | | | | | | | | | | Other Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Date | Time | | | | | | | | | | | | | | |
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| Sample Receipt | Invoice Information | For Lab Use Only |
|---|---|---|
| Cooler Condition: | P.O. # | |
| Cooler Temperature: | Bill To: | |
| Custody Seals: Yes ☐ No ☐ | | |

| Relinquished By: | Received By: | Relinquished By: | Received By: | Relinquished By: | Received By: |
|---|---|---|---|---|---|
| Signature | Signature | Signature | Signature | Signature | Signature |
| Printed Name | Printed Name | Printed Name | Printed Name | Printed Name | Printed Name |
| Firm | Firm | Firm | Firm | Firm | Firm |
| Date/Time | Date/Time | Date/Time | Date/Time | Date/Time | Date/Time |

*Distribution: White - Return to Originator. Yellow - Lab Copy. Pink - Retained by Client*

*In the absence of an executed agreement, submission of samples to SiREM implies consent for performance of analyses specified on this Chain-of-Custody form and agreement with the terms and conditions of the SiREM Laboratory Services Agreement. The entity submitting samples shall be responsible for payment in full for said analyses.*

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# APPENDIX C

## Detailed Injection Procedures

**Figure C-1. Injection System Components.**

- An argon gas cylinder.
- The KB-1® Dechlorinator cylinder containing the liquid KB-1® Dechlorinator bioaugmentation bacteria.

  A 6L-capacity cylinder will be used. Only 800 mL are calculated to be required for the pilot test injection. The supplier, SiREM, requires a minimum 3 liter (L) order. It has a **shelf life of only two weeks, therefore delivery must be coordinated for arrival as close to its use as possible**. Excess KB-1® Dechlorinator will be shipped back to the supplier for appropriate disposal. For subsequent full-scale tests, schedule delivery of full 6 L cylinders to arrive with overlapping shelf lives to ensure a continuous supply during the multi-month injection period. Storage of KB-1® Dechlorinator must be at a temperature between 32-86 $^{o}$F.
- A KB-1® Dechlorinator injection dispenser (KD) consisting of a separate transparent graduated cylinder that is connected in line between the KB-1 cylinder and the Aboveground Injection Line. This is used to measure incremental aliquots of KB-1® Dechlorinator between 50 mL to 500 mL prior to injection. A digital scale (not shown in the figure) will also be used to measure the change in weight of the KB-1 cylinder as it is emptied which corresponds to dispensed volume, but the KD provides more accuracy when dispensing smaller amounts as is planned for this Treatability Study.

Perform the following checks on the system prior to initiating injection:

1. Make sure all system valves and sampling ports are properly closed. Check the initial totalizer reading.
2. Check latest downhole parameter measurements on data logger. It may be necessary to briefly raise and lower the sonde (by 1 foot) to minimize DO readings drift and accumulation of bubbles on the sensors.

Make sure the Exclusion Zone is in place and that all equipment is set up neatly and is readily accessible.

**Figure C-1.** Injection System Components.

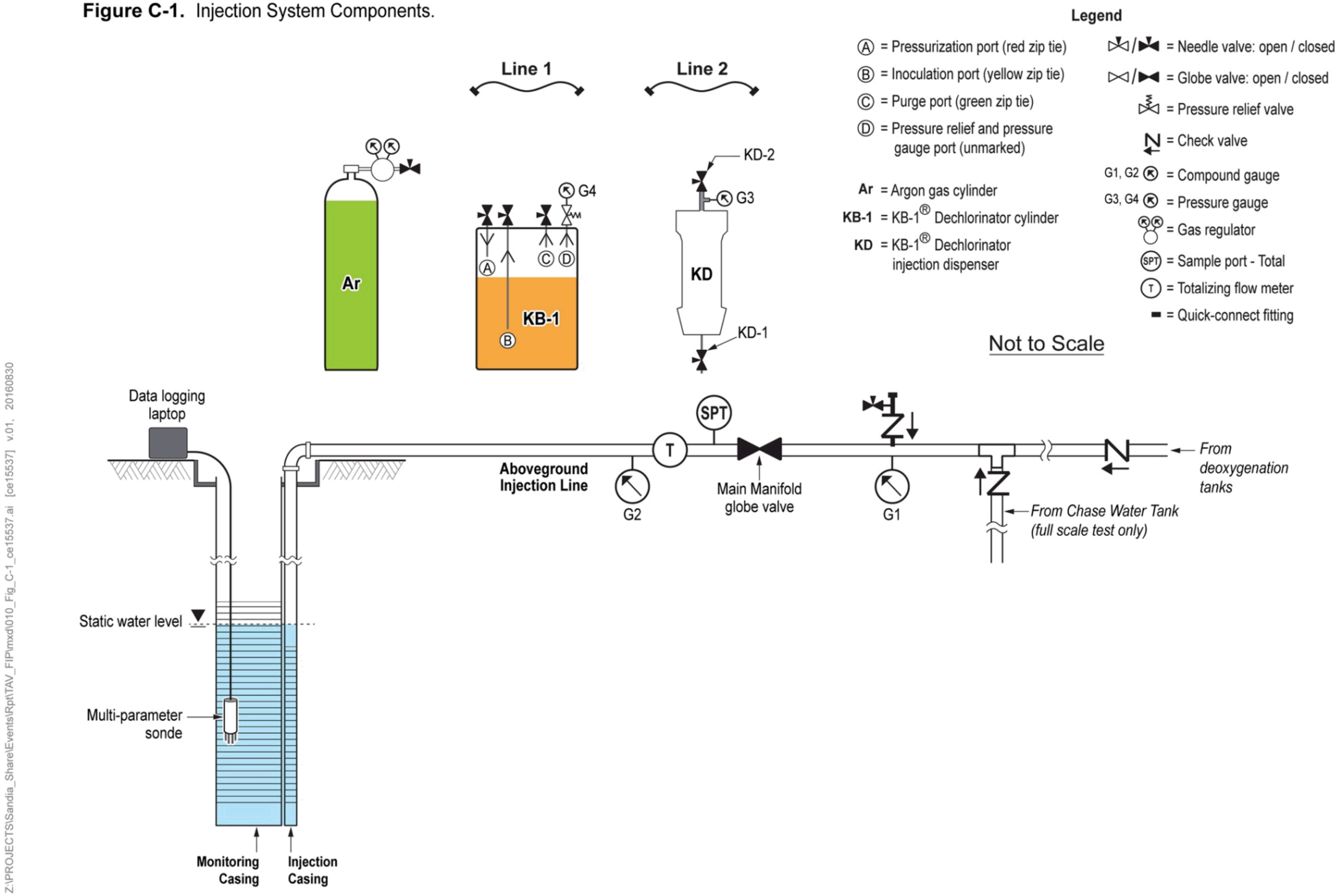


**Figure C-2. Bleed Pressure from the KB-1® Dechlorinator Injection Dispenser.**

1. Check all four KB-1 cylinder port valves to make sure they are closed.

   Ⓐ Pressurization port (marked with a red zip tie)

   Ⓑ Inoculation port (marked with a yellow zip tie).

   Ⓒ Purge port (marked with a green zip tie).

   Ⓓ Pressure relief and pressure gauge port (unmarked - has a pressure gauge).

2. Leaving the bottom valve of the KB-1® Dechlorinator injection dispenser (KD-1) closed, slightly open the top valve (KD-2) to release pressure. When pressure reaches 1 psi, close KD-1.

Note: If pressure in the KD is ≤1 psi upon receipt from the supplier, skip this step.

**Figure C-2.** Bleed Pressure from the KB-1® Dechlorinator Injection Dispenser.

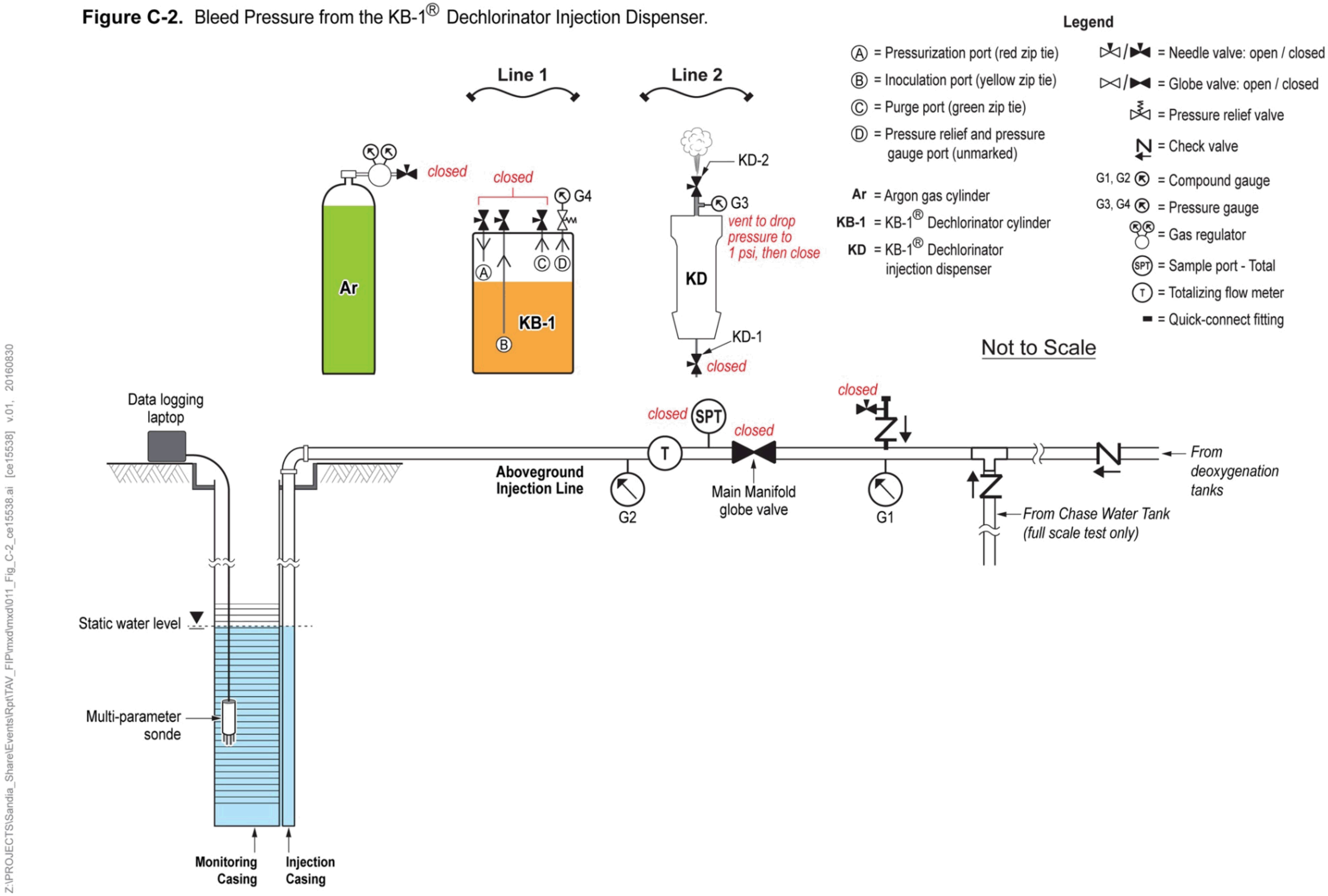


**Figure C-3. Purge KB-1® Dechlorinator Lines and Injection Dispenser with Argon Gas.**

1. Make sure the Main Manifold globe valve and the globe valve at the deoxygenation tank are closed.
2. Connect one end of Line 1 to the argon gas regulator valve and the other end to KD valve KD-1.
3. Connect one end of Line 2 to KD valve KD-2 and the other end to the needle valve at the connection to the Aboveground Injection Line.
4. Open the gas regulator valve to allow argon gas to pressurize Line 1 up to 10 psi.
5. Open valve KD-1 to then pressurize the KD up to 10 psi as measured on compound gauge G3.
6. Close the gas regulator valve.
7. Open the needle valve located at the connection to the Aboveground Injection Line.
8. Gradually open valve KD-2 to continue the argon purge through Line 2 and vent through the needle valve.
9. Close the needle valve when pressure measured at pressure gauge G3 drops back to 1 psi. The needle valve and gas regulator valve should now be closed and valves KD-1 and KD-2 should be open.
10. Repressurize Line 1, the KD, and Line 2 to 10 psi (measured on G3) by gradually opening and then closing the gas regulator valve.
11. Vent the Line 1, the KD, and Line 2 through the needle valve again closing it when the pressure measured at G3 drops back to 1 psi again.

Repeat steps 10 and 11 (resulting in a total of three purge cycles). At the end of this process, Line 1, the KD, and Line 2 will be purged with argon gas and remain under slight pressure (~1 psi).

**Figure C-3.** Purge KB-1® Dechlorinator Lines and Injection Dispenser with Argon Gas.

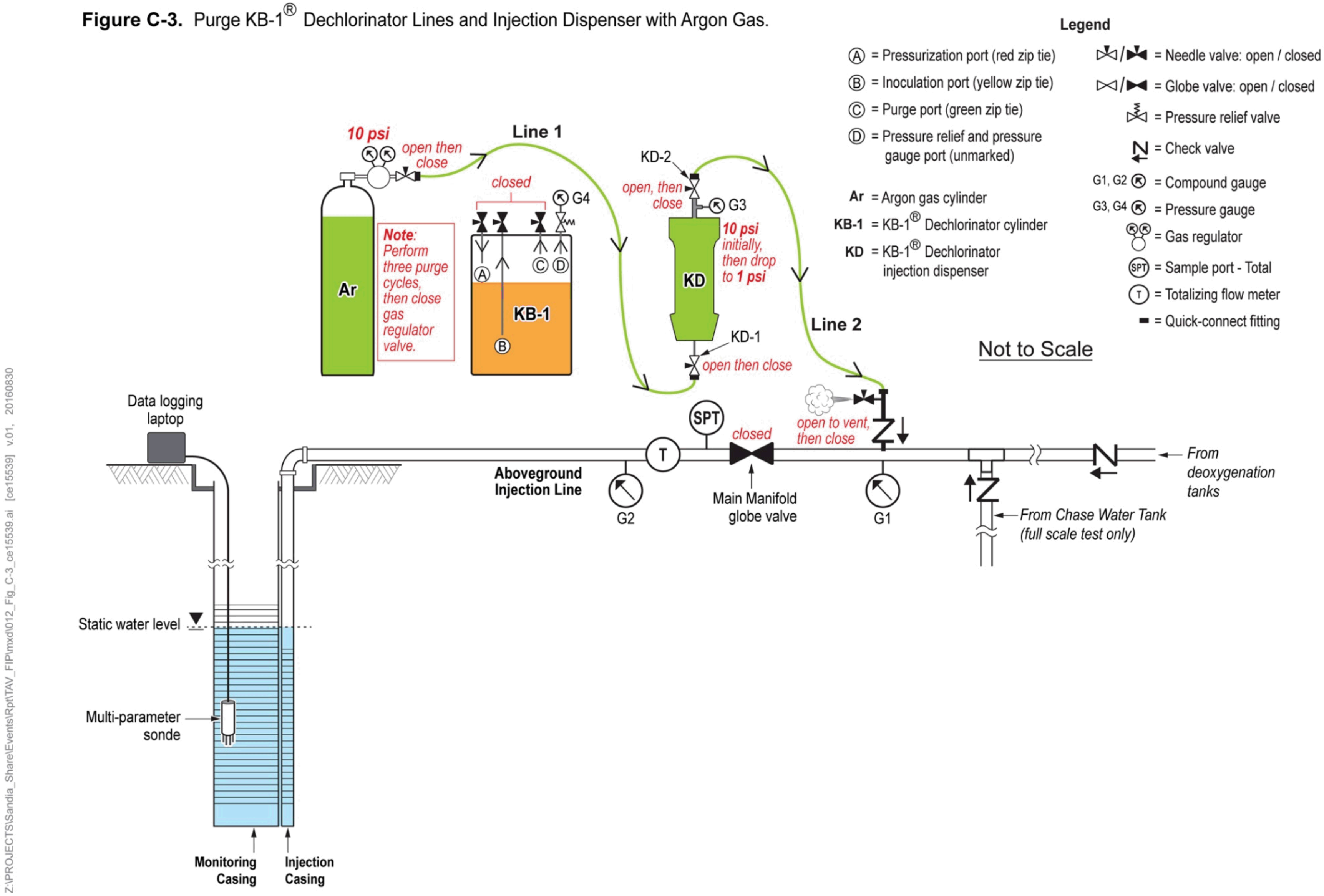


**Figure C-4. Fill the KB-1® Dechlorinator Injection Dispenser with the First Aliquot of KB-1® Dechlorinator.**

1. Disconnect Line 1 from valve KD-1 and reconnect it to the pressurization port Ⓐ. The other end of Line 1 remains connected to the gas regulator.
2. Disconnect both ends of Line 2 and reconnect one end to the inoculation port Ⓑ and the other end to valve KD-1.
3. Fill the KD with a 500 ml aliquot of KB-1® Dechlorinator by opening valves in the following order:
   a. Gas regulator.
   b. Pressurization port Ⓐ.
   c. Inoculation port Ⓑ.
   d. KD-1.

   Note: The KD for the pilot test has a capacity of 500 ml. A larger KD or one with multiple chambers may be fabricated for used in full-scale tests.
4. Vent the KD through valve KD-2 as necessary. **Do not to exceed 15 psi**.
5. After the KD is filled (500 ml), close valves in reverse order:
   a. KD-2.
   b. KD-1.
   c. Inoculation port Ⓑ.
   d. Pressurization port Ⓐ.
   e. Gas regulator.

Note: The volume of KB-1® Dechlorinator remaining within Line 2 after the KD has been filled will be injected as part of this aliquot. Volume within the 0.25-in ID line is approximately 10 ml/linear foot of tubing. If Line 2 is 5 ft long, it will contain approximately 50 ml and total injected with first aliquot will be 550 mL.

**Figure C-4.** Fill the Injection Dispenser with the First Aliquot of KB-1® Dechlorinator.

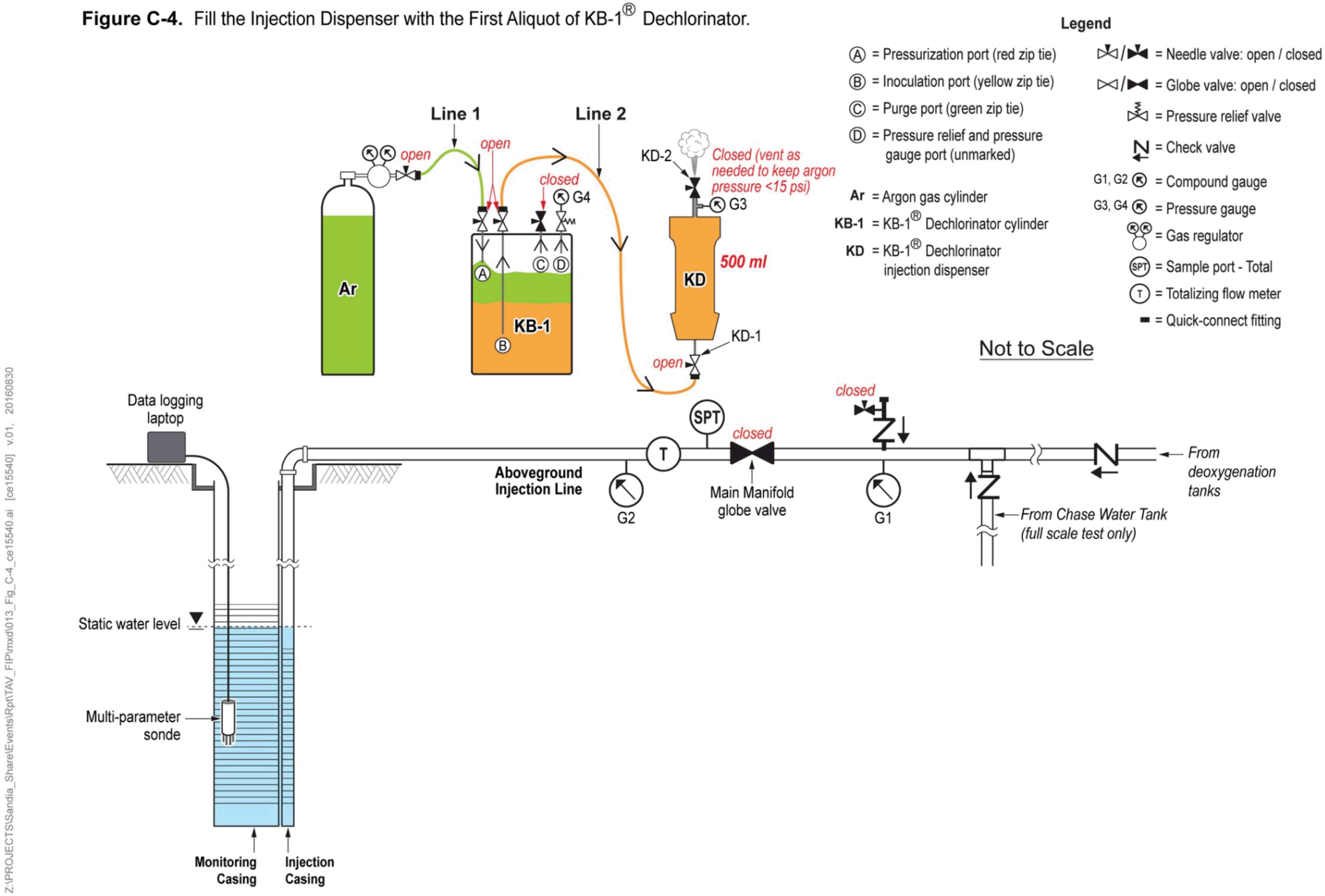


**Figure C-5 Displace the Injection Well Water Column with Substrate Solution.**

1. Calculate three (3) saturated casing volumes (~180 gal total).
2. Gradually open the deoxygenation tank globe valve and then the Main Manifold globe valve to gravity drain the substrate solution. Monitor totalizer readings and depth to water in the injection well. Close the Main Manifold globe valve after injecting the above-referenced volume and record the totalizer reading. Leave the deoxygenation tank globe valve open.
3. Observe the real-time field parameter readings from the injection well down-hole sonde using the laptop computer (or a handheld unit). Look for DO to drop below 0.5 mg/L before co-injecting KB-1® Dechlorinator. Depth of water submergence measured from the downhole water level sensor should increase indicating discharged substrate solution has reached the water column (and filled the injection line) but may return rapidly to static level.

Record pressure or vacuum readings on compound gauges G1 and G2. G1 should display a positive pressure from the head of water in the upstream deoxygenation tank. G2 should display a vacuum as the substrate solution downstream of the closed Main Manifold globe valve in the Aboveground Injection Line and injection casing equilibrates with atmospheric pressure.

**Figure C-5.** Displace the Injection Well Water Column with Substrate Solution.

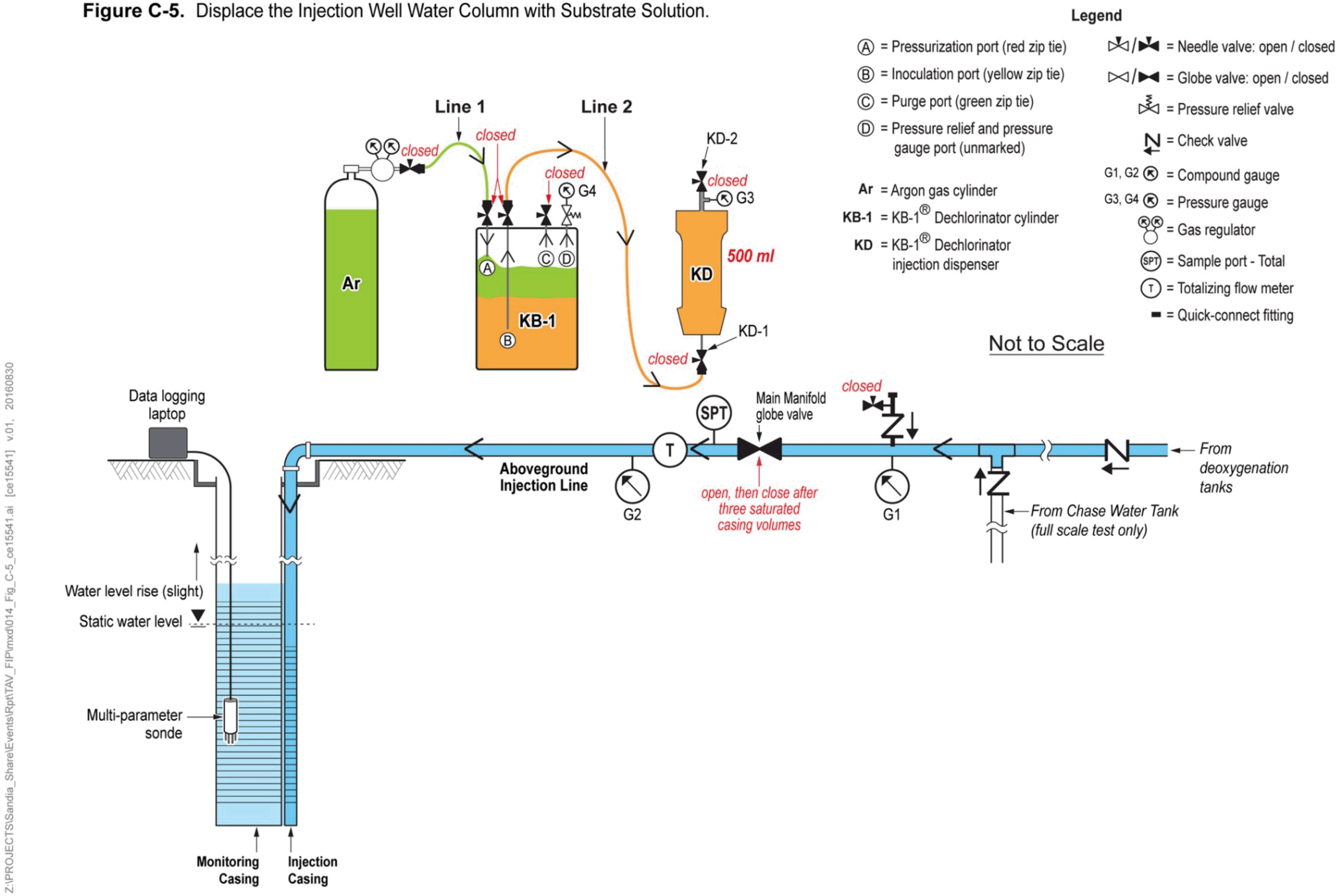


**Figure C-6. Inject Remaining Substrate Solution and KB-1® Dechlorinator - First Aliquot.**

1. Disconnect Line 1 from the pressurization port Ⓐ and reconnect it to valve KD-2.
2. Disconnect Line 2 from the inoculation port Ⓑ and reconnect it to the needle valve at the connection to the Aboveground Injection Line check valve. Line 2 should already be connected to valve KD-1 (at the bottom of the KD). Line 2 should still contain KB-1® Dechlorinator. The quick-connect fittings should prevent it leaking out.
3. Resume substrate solution injection from Tank A.
   a. Gradually open the Main Manifold globe valve and adjust the flow rate to 20 gpm (unless a revised rate has been determined by slug test and well development). Measure the flow rate over time using the totalizing flow meter. Record the Aboveground Injection Line pressure shown on compound gauge G1.
4. Open the valves for injecting KB-1® Dechlorinator in the following order:
   b. Gas regulator. Pressurize approximately 10 psi more than the Aboveground Injection Line pressure measured at G1. **Do not exceed 15 psi.**
   c. KD-2.
   d. KD-1. Adjust the KB-1® Dechlorinator injection rate to be evenly mixed with the substrate solution as it is injected targeting approximately 110 mL of KB-1 Dechlorinator injected per 500 gal of substrate solution.
   e. Inject the 500 mL of KB-1® Dechlorinator plus the volume in Line 2 (approximately 10 mL per linear foot of tubing).
5. During injection, continue to the monitor the water level in the monitoring casing to ensure the water column does not rise more than 335 ft above the static water level and adjust the injection flow rate if necessary.

After the KD is emptied, continue purging for a few minutes to ensure content inside Line 2 are injected. Make sure KB-1® Dechlorinator injection bas been completed before the last substrate solution is drained from the deoxygenation tank.

**Figure C-6.** Inject Remaining Substrate Solution and KB-1® Dechlorinator - **First Aliquot**.

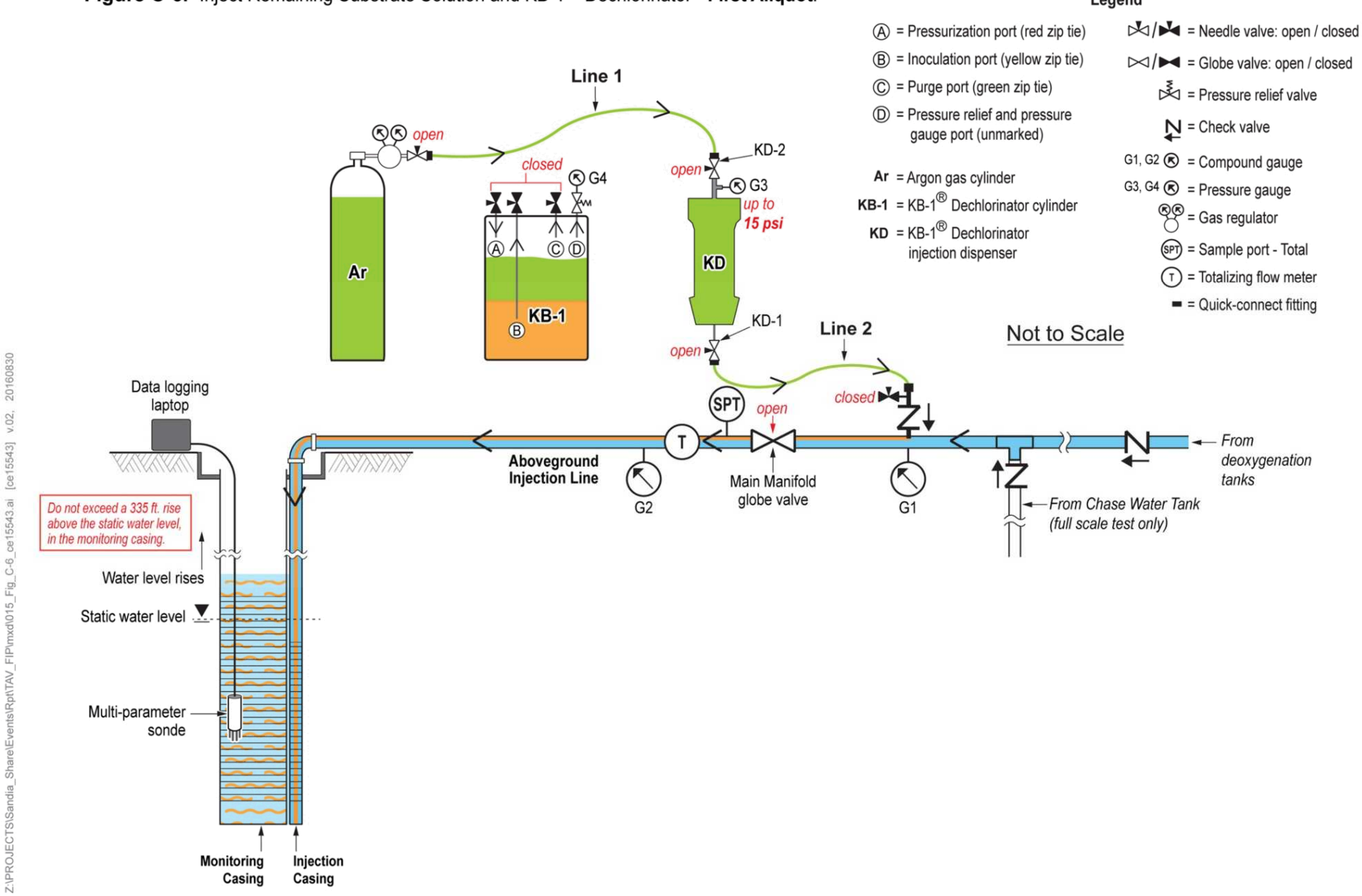


**Figure C-7. Interrupt Injection.**

1. After the first aliquot of KB-1® Dechlorinator (500 ml + volume of Line 2) has been injected, interrupt substrate solution injection by closing valves in following order:
   a. Main Manifold globe valve.
   b. KD-1.
   c. KD-2.
   d. Gas regulator.
   e. Globe valve at the deoxygenation tank.
2. Monitor the injection well water level. Should see water level drop as injected solution moves into the formation.

Record pressure or vacuum readings from compound gauges G1 and G2.

**Figure C-7.** Interrupt Injection.

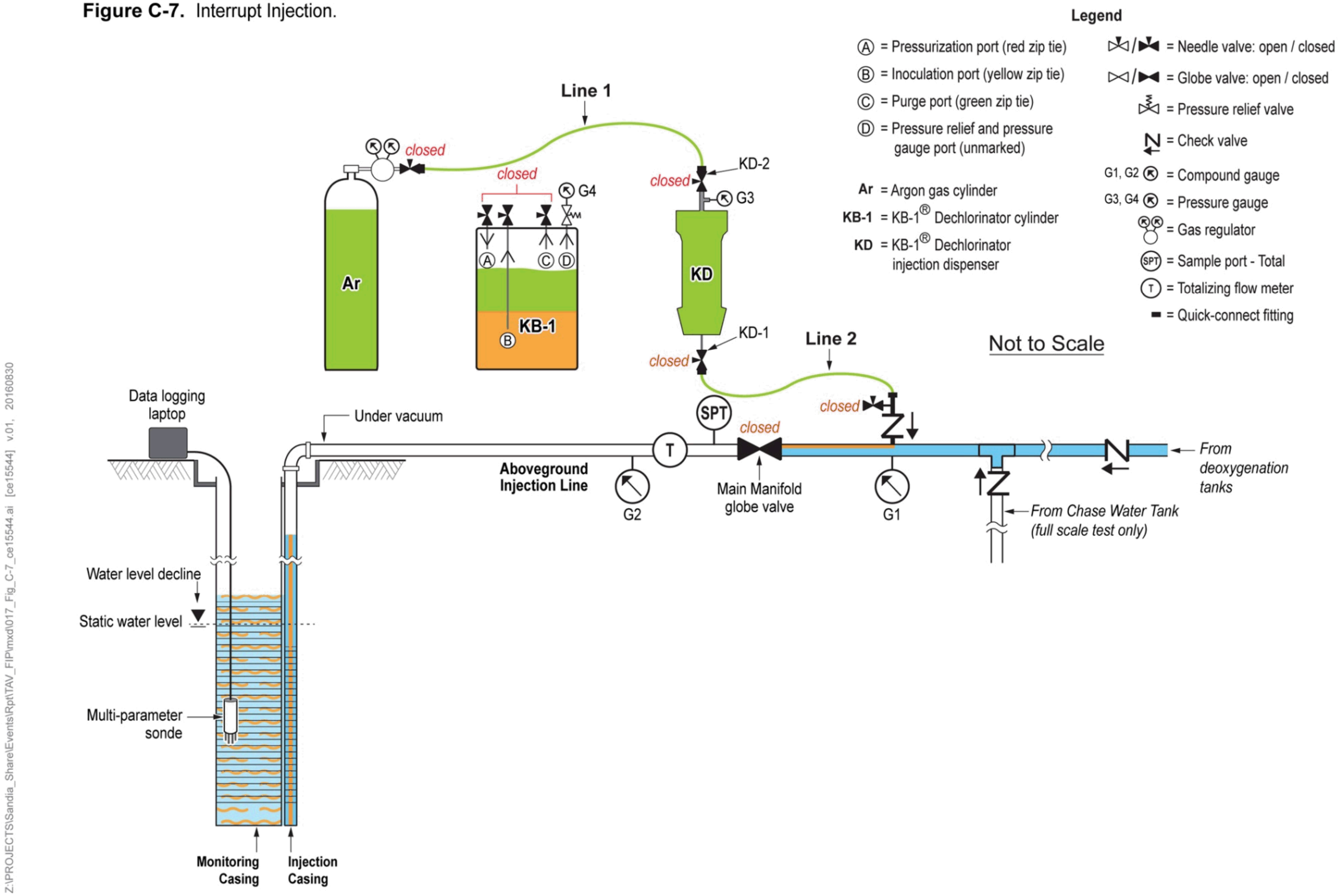


**Figure C-8: Refill KB-1® Dechlorinator Injection Dispenser with the Remainder of KB-1® Dechlorinator - Second Aliquot.**

1. Disconnect Line 1 from valve KD-2 and reconnect it to the pressurization port Ⓐ. The other end of Line 1 remains connected to the gas regulator valve.
2. Disconnect Line 2 from the needle valve and reconnect it to the inoculation port Ⓑ. The other end of Line 2 remains connected to valve KD-1.
3. Fill the KD with the second (and final) aliquot volume of KB-1® Dechlorinator to be injected for the pilot test (Total injection volume minus the first aliquot volume) by opening the valves in the following order:
   a. Gas regulator.
   b. Pressurization port Ⓐ.
   c. Inoculation port Ⓑ.
   d. KD-1.
   Note: Line 2 will still be filled with KB-1® Dechlorinator after this step.
4. Vent the KD through valve KD-2 as necessary. **Do not exceed 15 psi**.
5. Once the second aliquot volume of KB-1® Dechlorinator has been loaded into the KD, close valves in the reverse order from the above step:
   a. KD-1.
   b. Inoculation port Ⓑ.
   c. Pressurization port Ⓐ.
   d. Gas regulator.

<u>Note</u>: The volume of KB-1® Dechlorinator in this second aliquot volume is to include the volume remaining within Line 2. The volume within a 0.25-in ID line is approximately 10 ml/linear foot of tubing (e.g., If Line 2 is 5 ft long, it will contain approximately 50 ml and therefore the KD would be filled to 250 ml for a second aliquot of 300 ml to be injected.)

<u>Note</u>: Because the minimum volume of KB-1® Dechlorinator supplied by SiREM is 3 L, there will be approximately 2.2 L remaining in the KB-1 cylinder at the end of the pilot test. This is to be shipped back to SiREM in accordance with the Waste Management Plan.

**Figure C-8.** Refill the Injection Dispenser with the Remainder of KB-1® Dechlorinator Injection Volume - **Second Aliquot**.

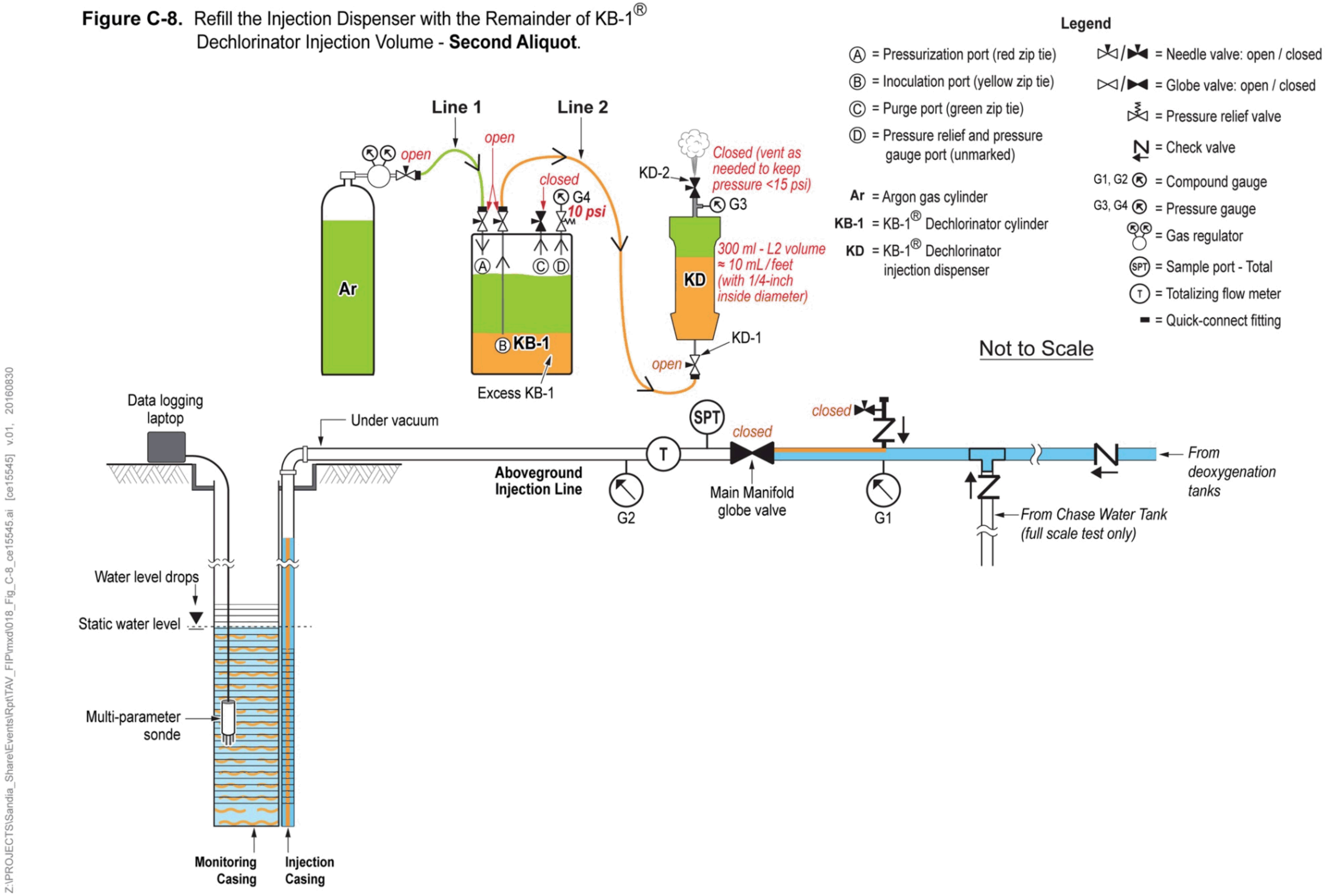


**Figure C-9: Inject Remaining Substrate Solution and KB-1® Dechlorinator - Second Aliquot.**

1. Disconnect Line 1 from the pressurization port Ⓐ and reconnect it to valve KD-2.
2. Disconnect Line 2 from the inoculation port Ⓑ and reconnect it to the Aboveground Injection Line check valve. L2-B should remain connected to valve KD-1. Note that Line 2 should still contain KB-1® Dechlorinator.
3. Restart injection of substrate solution injection from the deoxygenation tank.
   a. Gradually open Main Manifold globe valve and adjust flow rate to the same flow rate as before (see Figure C-6). Check the flow rate over time using totalizing flow meter. Record the Aboveground Injection Line pressure at G1.
4. Open valves for injecting KB-1® Dechlorinator in the following order:
   a. Gas regulator. Pressurize approximately 10 psi more than Aboveground Injection Line pressure measured at G1. **Do not exceed 15 psi.**
   b. KD-2.
   c. KD-1. Open gradually to inject the KB-1® Dechlorinator into the Aboveground Injection Line proportionately with the volume of remaining Tank A substrate solution being injected at the same time.
5. During injection, continue to the monitor the water level in the monitoring casing to ensure the water column does not rise more than 335 ft above the static water level and adjust the injection flow rate if necessary.

After the KD is emptied, continue purging for a few minutes to ensure content inside Line 2 are injected. Make sure KB-1® Dechlorinator injection bas been completed before the last substrate solution is drained from the deoxygenation tank.

**Figure C-9.** Inject Remaining Substrate Solution and KB-1® Dechlorinator - **Second Aliquot**.

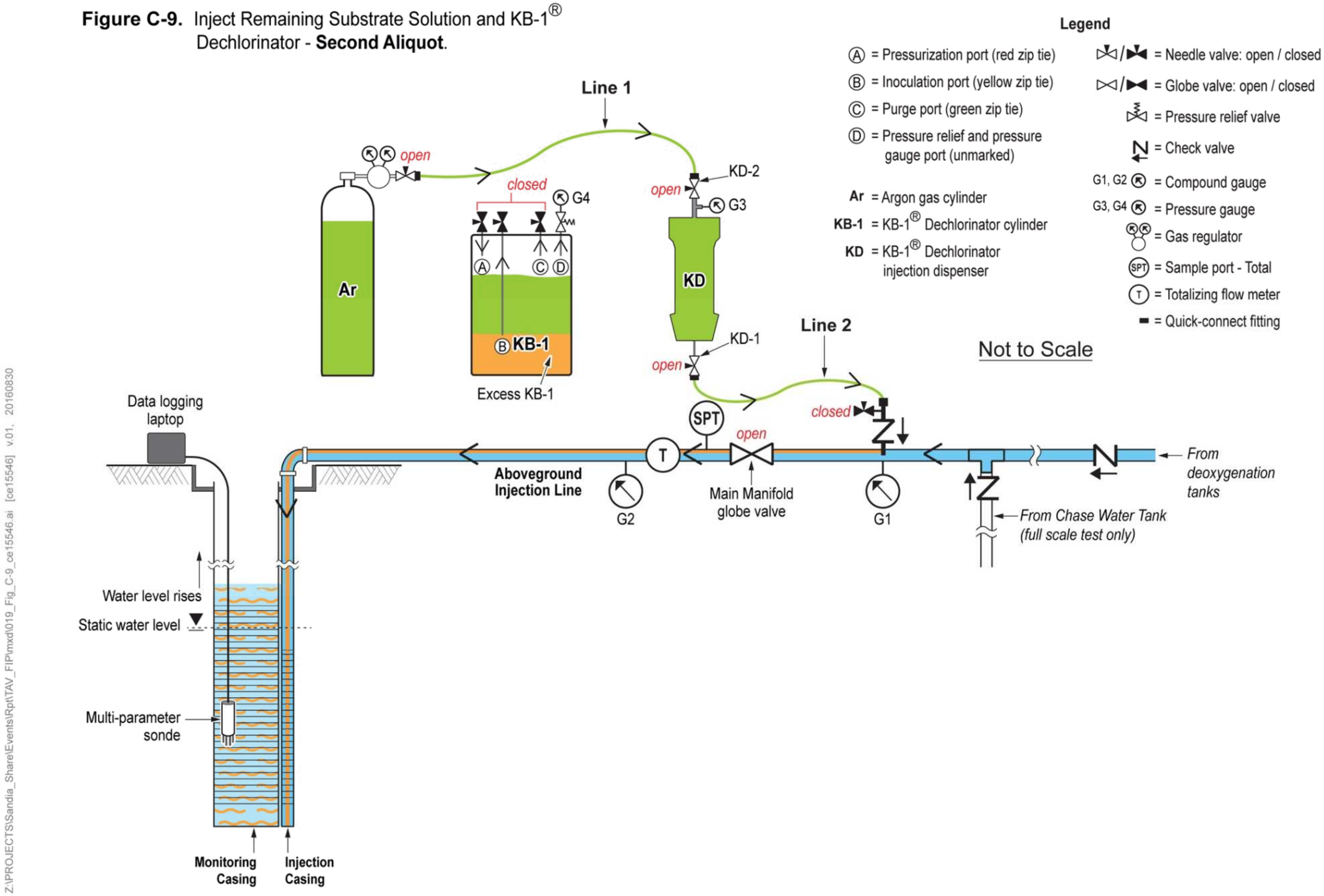


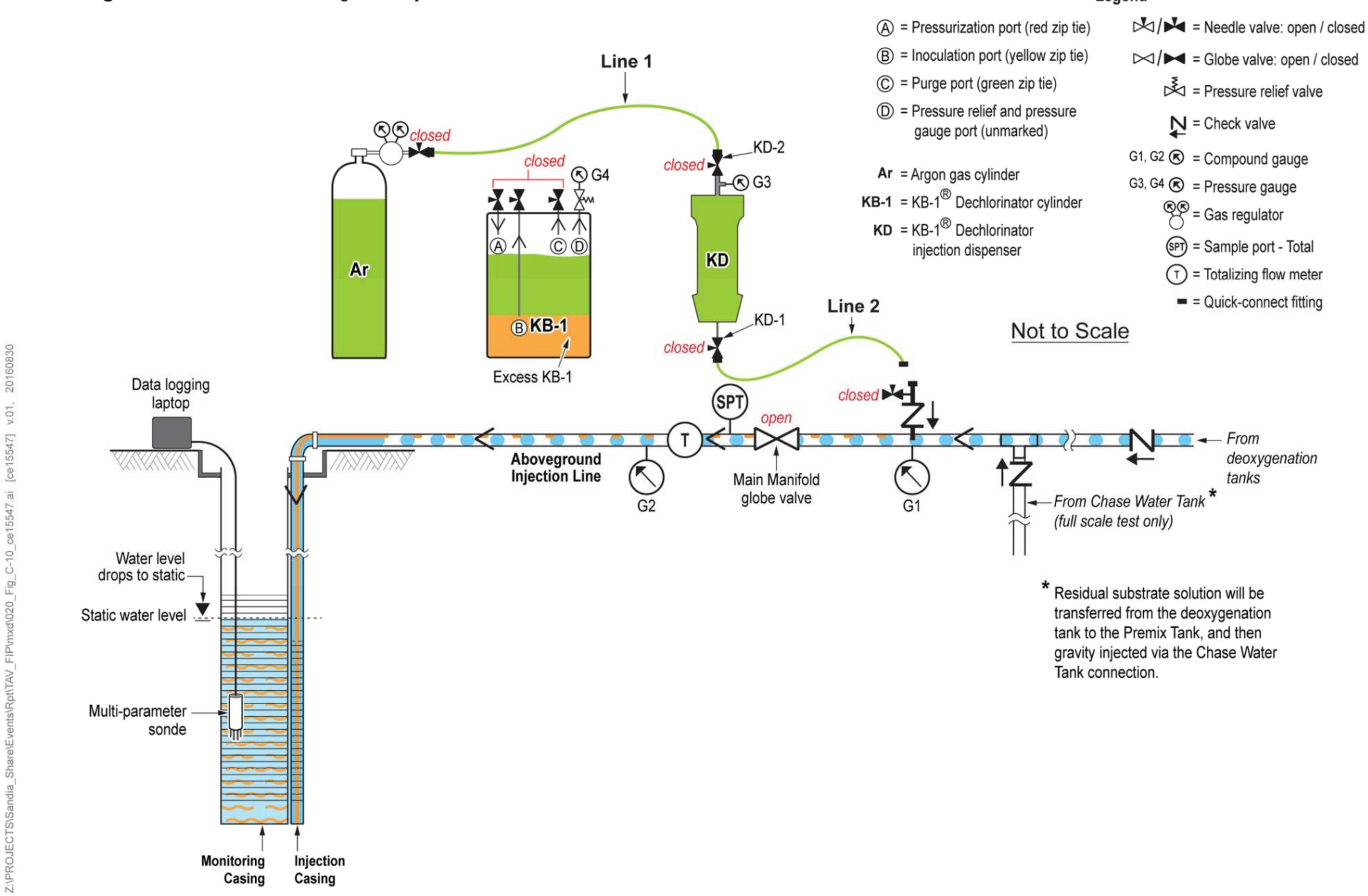
**Figure C-10. Drain the Aboveground Injection Line.**

The following steps describe the process for the end of the pilot test. The full-scale tests include a step of injecting deoxygenated potable (chase) water at the end of each day of injection. The following steps are applicable to the final injection batch for full-scale tests after any residual substrate solution from the deoxygenation tanks has been consolidated and gravity injected.

1. After the KB-1® Dechlorinator is injected and Tank A is drained, leave the Main Manifold globe valve open to facilitate final draining of Aboveground Injection Line. Record the final totalizer reading and time, then close valves in the following order:
   a. Main Manifold globe valve.
   b. KD-1.
   c. KD-2. Line L2 should no longer contain any KB-1® Dechlorinator.
   d. Gas regulator.
2. Disconnect the Bioaugmentation Assembly, clean components in accordance with supplier instructions. Handle decontamination waste in accordance with the WMP. Excess KB-1® Dechlorinator is to be shipped in its cylinder back to the supplier.

Disassemble/store the gravity injection system components as appropriate and secure the injection wellhead.

**Figure C-10.** Drain the Aboveground Injection Line.



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