Appendices

Appendix A

Contaminant of Concern Chemical Properties

TABLE A-1

CONSTITUENT OF CONCERN CHEMICAL PROPERTY DATA

Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummrich Facility, Sauget, Illinois

Constituent	CAS #	Solubility	Soil-Water Partition Coefficient	Soil Organic Carbon-Water Partition Coefficient	Diffusivity in Water
		(mg/L)	(Kd) (L/kg)	(Koc) (L/kg)	(cm^2/s)
Chlorobenzene	108-90-7	4.72E+02 (b)	1.31E+00 (a)	2.19E+02 (b)	8.70E-06 (b)
1,2-Dichlorobenzene	95-50-1	1.56E+02 (b)	3.70E+00 (a)	6.17E+02 (b)	7.90E-06 (b)
1,3-Dichlorobenzene	541-73-1	1.25E+02 (d)	2.59E+00 (a)	4.32E+02 (d)	8.85E-06 (d)
1,4-Dichlorobenzene	106-46-7	7.38E+01 (b)	3.70E+00 (a)	6.17E+02 (b)	7.90E-06 (b)
Benzene	71-43-2	1.75E+03 (b)	3.53E-01 (a)	5.89E+01 (b)	9.80E-06 (b)
1,2,4-Trichlorobenzene	120-82-1	3.00E+02 (b)	1.07E+01 (a)	1.78E+03 (b)	8.23E-06 (b)

foc - fraction organic carbon.
L - liters
mg - milligrams
Kg - Kilograms
cm - centimeters

Note:
1. Table Source: URS Corporation, Former Chlorobenzene Process Area Characterization Report, February 2010.

Appendix B

Summary of EABR Field Testing Results

MEMORANDUM

STRATEGIC. ENVIRONMENTAL. SOLUTIONS.

To: Jerry Rinaldi, Solutia
Brett Shank, Solutia

Date: June 24, 2011

cc: Scott Crawford (XDD)
file (11003.03)

From: Jaydeep Parikh
Dennis Keane
Kyle Boretsky

Re: **Summary of EABR Field Testing Results**
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility
Sauget, Illinois

This memorandum summarizes the results of the Enhanced Aerobic Bioremediation (EABR) field testing conducted at the above-mentioned site (Site). The memorandum also provides a discussion of the data collected to evaluate the field testing objectives, and provides recommendations for the full-scale EABR design and implementation approach.

The EABR field testing was conducted per the "Outline of Proposed Field Testing for EABR" dated April 21, 2011 and subsequent discussions with Solutia. Wells for the EABR field testing were installed between May 12 and 20, 2011. Subsequently, the EABR field testing was conducted between June 13 and 17, 2011. The primary objectives of the EABR field testing were: a) to determine if alternative well installation methods and/or wider well spacing can be effective and result in cost savings; and b) to collect EABR design data including injection flow and pressure, and oxygen distribution data.

During the field testing, pulses of oxygen were injected in two test areas (Test Areas A and B) at varying flow rates, and monitoring was performed to assess oxygen distribution and related parameters. The following bullet points summarize the data/assessment for key design parameters/considerations for EABR based on the field testing at the Site.

KEY OBSERVATIONS:

The key test data and observations from the oxygen injection tests are summarized below:

A. Well Installation Method: EABR field testing wells were installed by the direct-push technology (DPT) method using 3¼ inch diameter rods and 1 inch diameter stainless steel screen and casings. All wells that were tested for oxygen injection performed as intended indicating

that this drilling method is appropriate for the EABR well installation. One limitation observed during this drilling method was refusal due to subsurface obstructions in certain areas of the Site. For cost savings, XDD recommends that all EABR wells should be attempted to be installed by the DPT method. Where refusal is encountered for the DPT method, a sonic drilling method (a costlier well installation method, but proven to work at the Site) would be used to complete the well installation.

B. Dual-Level Wells: EABR field testing results confirm that shallow and deep well screens will be necessary in the areas where lower permeability (e.g., clay) layers are observed within the treatment interval of 15 to 30 feet below ground surface (bgs) to influence the relatively sandy zones above and below the clay layers (based on the Test Area A results). Results from Test Area B indicate that the entire 15 to 30 feet bgs treatment interval, where no clay layers are present can be influenced by injecting in the deep injection well. Therefore, the dual-level wells may not be necessary for oxygen distribution in areas where the clay layers are absent[1]. Installing only deep wells in the areas without the clay layer will reduce the well count by 59 wells (a 25% reduction in the number of wells from 240 to 181). The cost savings would include eliminating the 59 shallow wells and reduce pipe runs, associated equipment and instruments. As indicated in the below footnote, using a single deep well will potentially reduce the ability to optimize the system and may result in other operational limitations (e.g., if the deeper interval achieve target cleanup, but the shallow interval does not, we would still need to inject oxygen through the deep zone to continue to supply oxygen to the shallow zone). The pros/cons of reducing the well count is recommended to be discussed further.

C. Well Spacing: EABR field testing results indicate that the well spacing included in the 30% and 60% EABR design is appropriate (30 foot spacing between wells within rows, and 40 foot spacing between rows). During the testing, the following radii of influence (ROI) were observed:

- greater than 20 feet and 15 feet in the deep zones of Test Areas A and B (influence observed to the farthest monitoring locations); and
- greater than 10[2] feet and 15 feet in the shallow zone of Test Areas A and B.

It was noted that oxygen distribution may not be homogeneous due to subsurface heterogeneity; however, the overall design of well spacing is appropriate given the flexibility in injection flow

[1] Please note that oxygen utilization due to bacterial activity was not evaluated during the field testing, and therefore it is unknown if injections in deep well alone can keep up with the oxygen utilization in the entire treatment interval. Additionally, some areas may still need nested wells due to geological heterogeneity that may not be detected in the available data. These wells may need to be installed at a later date based on monitoring data and integrated in the system.

2 In Test Area A, the shallow and deep piezometers located at 15 foot distance did not show any influence while injecting at the shallow and deep injection wells likely due to a geological anomaly. Additionally, the shallow piezometer at a distance 20 feet had anomalously high dissolved oxygen during baseline sampling, and therefore, that data point could not be used in determining oxygen influence.

rates available from the system design.

D. Injection Flow Rate and Pressures: EABR field testing results indicate that an injection rate of approximately 5 standard cubic feet per minute (SCFM) is appropriate for the full-scale EABR. Flow rates greater than 15 SCFM were achievable without exceeding the maximum injection pressures specified in the design, however, groundwater mounding was observed at several monitoring locations at these higher flow rates. XDD recommends using an initially lower injection rate (e.g., 1 SCFM per well) at the startup, and increase up to 5 SCFM based on field observations and actual oxygen distribution. Additional adjustments in the flow rates will be made as a part of system operation optimization.

E. Well Construction: EABR field testing results indicate that the well screen placement is appropriate (e.g., screened interval of 29 to 31.5 feet bgs for a treatment interval extending down to 30 feet bgs). During injections in the shallow well in Test Area A, significant silting was observed in the shallow piezometers located at 5 and 10 foot distances. Due to soil types and the pulsing cycles, injection wells could potentially have significant silting issues during long term operation. XDD recommends the following to address the silting issue:

- increase the length of the blind sump at the bottom of the wells from 1 foot to 2 feet;
- specify and follow a more aggressive well development protocol for the EABR wells; and
- include monitoring of the wells for silting and restoration (by well re-development, as necessary) as a part of quarterly/annual monitoring.

F. Injection Influence on NAPL: During injections into the shallow well in Test Area B, non-aqueous phase liquid (NAPL) was accumulated in the purge water from the shallow piezometer located at a distance 15 feet. This observation indicates that there could be potential migration of NAPL due to pulsing of oxygen in the treatment area.

The remainder of the memorandum summarizes the test data and specific observations for the oxygen injection tests along with data tables and summary figures. The observations are organized according to the injection location at the time of the observation. Injection commenced on June 14, 2011 after completion of system setup and baseline groundwater monitoring.

List of Tables

List of Figures

TEST AREA A OBSERVATIONS

For a layout of the test well network please refer to Figure 1. Oxygen distribution in Test Area A was influenced by general soil heterogeneity and the confining clay layer observed at 22.0 to 23.5 feet bgs. Injections into the deep injection well (IW-1AD) showed direct influence at deep monitoring locations at PZ-A5D, PZ-A10D and PZ-A20D. In addition, elevated pressure and significant groundwater mounding were observed at both PZ-A5I and PZ-A10S indicating oxygen injection influence.

Direct influence was not observed at monitoring points PZ-A15S (above the clay layer) or PZ-A15D. PZ-A15S was likely not influenced due to the presence of the clays layer. However, PZ-A15D may have either been hydrogeologically isolated from the injection wells, or, there was an anisotropic oxygen distribution at the test injection well, etc. Well construction of PZ-A15S and PZ-A15D were eliminated as a possible explanation for lack of influence (injection testing in both of these piezometers showed that oxygen was able to be injected into both shallow and deep well at rates of 10.9 SCFM and 17.8 SCFM, respectively).

Injections into the shallow injection well (IW-1AS) showed direct influence at PZ-A5S, PZ-A5I (pressure) and PZ-A10S. Again, no direct influence was observed at PZ-A15S (or PZ-A15D) due to reasons noted in the previous paragraph.

The baseline dissolved oxygen (DO) value at PZ-A20S was anomalous (greater than 10 mg/L values obtained using two separate field instruments during baseline sampling compared to all other wells with DO values less than 2 mg/L), and therefore, it could not be used for monitoring oxygen influence during the field testing.

MEMORANDUM

Additional details of the testing in Area A are provided below:

Testing at IW-1AD

- Oxygen distribution in the subsurface was heterogeneous, with the farthest influence observed at 20 feet from the injection location.
- Observations at different radii were:
    - 5 feet: Increasing DO concentrations at PZ-A5D and bubbling/steady pressure was observed at PZ-A5I.
    - 10 feet: Elevated DO concentrations were observed at PZ-A10S. In addition, an elevated then a steady decline of DO concentrations as a result of an injection pulse was observed at PZ-A10D.
    - 15 feet: No influence was observed at this well cluster.
    - 20 feet: Elevated DO concentrations as well as groundwater surfacing were observed at well location PZ-A20D.
- During the afternoon of 6/14/2011, injection pulsing operated at a cycle of fifteen minutes on, forty-five minutes off at a flow rate of 3.8 SCFM. During this time the following observations were made:
    - Bubbling that eventually led to a steady, pulsed groundwater surfacing from PZ-A5I. At the same location, mounding was observed at the grout seal and small bubbles were observed within the grout.
    - Due to continuous surfacing at PZ-A5I, a well head was placed on the well. Regular pressure readings were recorded and ranged from 5.0 to 7.0 psi for the remainder of the field testing.
    - A continuous rise in DO concentration was observed in PZ-A5D over the course of twenty-five minutes to a maximum concentration of 3.07 mg/L.
    - Influence was observed at PZ-A20D as surfacing of out of the riser started at 15:52 and was capped around 16:30. A measurement of DO at 16:23 indicated a concentration of 46.0 mg/L.
- On 6/15/11 continuous groundwater measurements at PZ-A10D indicated a pulse of DO from 15:55 to 16:10. This observation most likely originated from the tenth pulse, which was operating on a fifteen minute on, fifteen minute off cycle and operated at a flow rate of 5.5 SCFM. The maximum DO concentration was recorded at 15:55 with a concentration of 95.89 mg/L and fifteen minutes later that concentration had gradually declined to 13.91 mg/L.
- Influence was not observed at two monitoring wells, PZ-A15S and PZ-A15D, at the fifteen foot distance. It is speculated that there is a subsurface heterogeneity or secondary porosity that prevented oxygen from reaching the monitoring cluster. This is further emphasized by the fact that three refusals were encountered just west of PZ-A5I and PZ-A5D during well installation in May 2011. A foundation wall or other obstruction may be blocking influence

at the fifteen-foot well cluster, directing flow towards the twenty-foot well cluster, as evident by the surfacing at PZ-A20D on the first day of injections.

- Groundwater elevations were measured to track groundwater mounding. During injections into IW-1AD, a rise in groundwater elevation was observed between 0.24 feet and 6.10 feet depending on the monitoring location. For a complete summary of groundwater elevation rise and associated pulsing information for IW-1AD, refer to Table 3 and Table 6.
- For a complete summary of observations in Area A refer to Table 1.

Testing at IW-1AS

- Oxygen distribution in the subsurface was heterogeneous, with the farthest influence observed at 10 feet from the injection location. Due to the anomalous baseline DO data at PZ-A20S, distribution was unable to be evaluated at the twenty foot interval.
- Observations at different radii were:
    - 5 feet: Oxygen concentration was detected above 25.0% from within the well casing at PZ-A5S. Pressure continued to remain between 5.0 psi and 7.0 psi at PZ-A5I.
    - 10 feet: Oxygen concentrations were detected above 25.0% from within the well casings at PZ-A10S, PZ-10I and PZ-10D.
    - 15 feet: No influence was observed at this well cluster.
    - 20 feet: Due to the anomalous baseline DO data at PZ-A20S, influence/distribution was not able to be evaluated or effectively measured at this location.
- Silt build-up within the piezometer from the pulsed oxygen injections prevented further groundwater monitoring on PZ-A5S and PZ-A10S.
- Silt build up in PZ-A10S was observed during the second pulse in IW-1AS that operated at a pulse cycle of fifteen minutes on, thirty minutes off, at a flow rate of 1.6 SCFM. Due to the silt build up in this well, a Four Gas Meter was used to track oxygen influence for the remainder of the day.
- Elevated oxygen concentrations above 25.0% were recorded by a Four-Gas Meter for PZ-A5S, PZ-A10S, PZ-A10D and PZ-A10I inside the well casings.
- Influence was not observed at PZ-A15S due to the reasons listed above under IW-1AD.
- Groundwater elevations were measured to track groundwater mounding. During injections into IW-1AS, a rise in groundwater elevation was observed between 0.07 feet and 3.74 feet depending on the monitoring location. For a complete summary of groundwater elevation rise and associated pulsing information for IW-1AS, refer to Table 3 and Table 6.
- For a complete summary of observations in Area A refer to Table 1.

MEMORANDUM

TEST AREA B OBSERVATIONS

Oxygen distribution in Test Area B was relatively homogeneous. Injections into the shallow well (IW-1BS) resulted in direct influence at monitoring locations PZ-B7.5S and PZ-B15S. Injections into the deep injection well (IW-1BD) showed influence at all monitoring locations including the nearby shallow injection well.

The results indicate that the deep injection well set at the bottom of the treatment interval can influence the entire treatment interval with a ROI of greater than fifteen feet. Therefore, dual-level injection wells may not be needed in areas with similar geology to Area B (i.e., clay layer absent).

Additional details of the testing in Area B are provided below:

Testing at IW-1BD

- Oxygen distribution in the subsurface was relatively homogeneous, with distribution observed at each of the monitoring wells and the shallow injection well (IW-1BS). The farthest influence was observed at 15 feet from the injection location.
- Observations at different radii were:
    - 7.5 feet: Elevated DO concentrations were observed at PZ-A7.5D. Elevated concentration as well as bubbling was observed at PZ-7.5I
    - 15 feet: Elevated DO concentrations were observed at both PZ-A15S and PZ-15D.
- During the afternoon of 6/14/2011, injection pulsing in IW-1BD was held fairly constant at a flow rate of 8.9 SCFM that operated on a pulsing cycle of fifteen minutes on, forty-five minutes off. During this time the following observations were made:
    - NAPL observed in purge water at PZ-7.5D. The DO concentration was observed to be 7.48 mg/L.
    - Influence was observed in all wells in Area B during the afternoon of the first day of injections in IW-1BD. DO concentrations ranged from 4.25 mg/L in PZ-B15S to 77.22 mg/L in PZ-B7.5I.
    - In addition to the elevated concentration in PZ-B15S, bubbling was also observed in the purge water.
- Before the start of work on 6/15/11, staining on the ground surface near IW-1BS was observed. A strong chlorobenzene odor was observed and PID screening indicated a maximum concentration of 1,556 ppm at ground surface. The staining appeared to extend from the injection well, northwest towards D Street (see Figure 1) aided by the heavy rains in the previous overnight hours. Staining was the result of minor amounts of NAPL (10-20 mL) located in the bentonite grout seal surfacing during injections. A minor NAPL sheen on top of the grout seal was observed at this location over the remainder of the week.
- Groundwater elevations were measured to track groundwater mounding. During injections into IW-1BD, a rise in groundwater elevation was observed between 0.06 feet and 2.21 feet

depending on the monitoring location. For a complete summary of groundwater elevation rise and associated pulsing information for IW-1BD, refer to Table 4 and Table 8.

- For a complete summary of observations in Area A refer to Table 2.

IW-1BS

- Oxygen distribution in the subsurface was homogeneous, with the farthest influence observed at 15 feet from the injection location.
- Observations at different radii were:
    - 7.5 feet: Groundwater monitoring was not performed on this cluster as influence had already been established on previous days during the injection into IW-1BD
    - 15 feet: Elevated DO concentrations were observed at PZ-A15S and PZ-15D.
- Oxygen injection may have mobilized NAPL near PZ-15S as a large amount was removed during groundwater measurements/purging.
- Pulsing in IW-1BS consisted of a series of three pulses that operated on a cycle of fifteen minutes on, thirty minutes off with a flow rate of 1.5 SCFM on the morning of 6/16/2011.
- Influence was observed in PZ-B15S as evident by DO concentrations ranging from 7.65 mg/L to 9.28 mg/L during pulsing.
- Groundwater monitoring at PZ-B15S was terminated due to significant amount of NAPL observed in flow through cell. While monitoring ceased, purging of the well continued for approximately an hour and half. NAPL accumulation equaled approximately 0.75 inches in five gallons of purge water and approximately 0.5 inches in an additional 2.5 gallons of purge water.
- In addition small droplets of NAPL were also observed on the surface of the purge water.
- Groundwater elevations were measured to track groundwater mounding. During injections into IW-1BD, a rise in groundwater elevation was observed between 0.14 feet and 1.19 feet depending on the monitoring location. For a complete summary of groundwater elevation rise and associated pulsing information for IW-1BS, refer to Table 4 and Table 9.
- For a complete summary of observations in Area A refer to Table 2.

Table 1 Summary of Observations - Area A
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Pulse Duration (# of Pulses)	Injection Well					Observation Well	Time of Observance	DO (mg/l)	Notes
		Day 1 (Monday 6-13-11)							
Baseline						PZ-A5S	17:11	0.85	
						PZ-A5I	16:53	0.82	
						PZ-A5D	15:21	1.13	
						PZ-A10S	16:20	0.63	
						PZ-A10I	17:10	1.34	
						PZ-A10D	16:45	0.62	
						PZ-A15S	17:40	0.61	
						PZ-A15D	11:53	0.64	
						PZ-A20S	16:42	16.17	Anomalous reading (using two separate YSIs)
						PZ-A20D	16:40	0.80	
		Day 2 (Tuesday 6-14-11)							
	Injection Well	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Observation Well	Time of Observance	DO (mg/l)	Notes
Pulse 15 min, 45 min off (6)	IW-1AD	15:05	15.5	3.0	6.0	PZ-A5I	15:05	NA	Bubbling and continuous overflow out of casing, dropped flow to 3.0 acfm
		15:05	15.5	3.0	6.0	PZ-A10S	15:05	NA	Mounding observed at grout seal, small bubbles observed within grout
		15:10	14.5	2.5	4.9	PZ-A15D	15:23	0.90	
		15:47	16.3	3.0	6.2	PZ-A5D	15:47	3.07	Continuous rise from 1.63 to 3.07 over the course of 25 mins
		15:58	14.0	2.0	3.8	PZ-A10D	16:08	0.44	
		15:58	14.0	2.0	3.8	PZ-A20D	16:23	46.00	
									Surfacing from within well observed starting at 15:52, measurement taken at 16:23. Pressure at PZ-A5I = 7.0 psi
		Day 3 (Wednesday 6-15-11)							
	Injection Well	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Observation Well	Time of Observance	DO (mg/l)	Notes
Pulse 15 min, 30 min off (4)	IW-1AD	8:58	14.5	1.5	2.9	PZ-A20D	9:00	32.13	
		9:43	13.5	1.5	2.8	IW-1AS	9:46		>25.0% Oxygen observed on Four Gas Meter*
Pulse 15 min, 15 off (8)		15:17	13.0	3.0	5.5	PZ-A10D	15:45	1.32	Air bubbles observed at 15:55, DTW = 8.98, Total Well Depth = 30.2 ft. Pressure at PZ-A5I = 6.5 psi
		15:44	12.0	3.0	5.3	PZ-A10D	15:55	95.89	
		16:07	18.0	3.0	6.5	PZ-A10D	16:06	13.91	
		16:07	18.0	3.0	6.5	PZ-A15D	16:10	0.11	
		16:39	14.5	3.0	5.8	PZ-A15S	16:39	0.24	
		16:39	14.5	3.0	5.8	PZ-A10S	16:51	0.48	
		Day 4 (Thursday 6-16-11)							
Pulse 15 min, 30 min off (8)	IW-1AS	9:57	10.0	1.0	1.6	PZ-A10S	10:24	3.32	Approximately 1.0" of silt build up observed in flow-through cell
		10:47	10.0	1.0	1.6	PZ-A10S	11:13	2.45	
		11:17	10.0	1.0	1.6	PZ-A5S	11:31		>25.0% Oxygen observed on Four Gas Meter*
						PZ-A10S	11:31		23.0 % Oxygen observed on Four Gas Meter*
						PZ-A10D	11:31		>25.0% Oxygen observed on Four Gas Meter*
		14:51	14.5	9.5	18.5	PZ-A5S	15:00		>25.0% Oxygen observed on Four Gas Meter*
						PZ-A10S	15:00		>25.0% Oxygen observed on Four Gas Meter*
						PZ-A10D	15:00		22.8% Oxygen observed on Four Gas Meter*
						PZ-A10I	15:00		>25.0% Oxygen observed on Four Gas Meter*
									Could not perform GW monitoring on PZ-A5S, PZ-A10S due to large amounts of silt in purge water

* Oxygen concentration measured from within well casing
psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute
mg/l = milligrams per liter

Table 2 Summary of Observations - Area B
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Pulse Duration (# of Pulses)	Injection Well					Observation Well	Time of Observance	DO (mg/l)	Notes
		Day 1 (Monday 6-13-11)							
Baseline						PZ-7.5S	17:11	0.85	
						PZ-7.5I	11:55	0.89	
						PZ-7.5D	15:30	1.48	
						PZ-15S	15:00	1.95	
						PZ-15D	14:27	1.82	
		Day 2 (Tuesday 6-14-11)							
		Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Observation Well	Time of Observance	DO (mg/l)	Notes
Pulse 15 min, 45 min off (6)	IW-1BD	15:26	12.0	5.0	8.9	PZ-7.5D	15:30	7.48	NAPL observed in purge water
		15:26	12.0	5.0	8.9	PZ-7.5S	15:55	15.80	
		16:14	12.0	5.0	8.9	PZ-15D	16:20	5.80	
		16:14	12.0	5.0	8.9	PZ-15S	16:40	4.25	
		17:01	12.0	5.0	8.9	PZ-7.5I	17:02	77.22	Bubbling observed in purge water
		Day 3 (Wednesday 6-15-11)							
Pulse 15 min, 30 min off (10)		Overnight							Observed staining on groundsurface around well IW-1BS that continued to migrate due to heavy rain overnight toward D Street (Northwest), brownish color with strong cholorbenzene odor. PID=1556 ppm
		Prior to Injection				PZ-B15D	8:43	1.23	
		8:52	11.0	2.5	4.3	PZ-B15D	9:03	3.02	
		9:31	11.5	2.5	4.4	PZ-B7.5I	9:32		>25.0% Oxygen observed on Four Gas Meter*
						IW-1BS	9:34		>25.0% Oxygen observed on Four Gas Meter*
		11:06	11.0	2.5	4.3	PZ-B15D	11:20	3.62	
		13:52	11.5	2.5	4.4	PZ-B15D	13:52	4.34	
		14:30	11.0	2.5	4.3	PZ-15S	14:37	6.06	
		Day 4 (Thursday 6-16-11)							
Pulse 15 min, 30 min off (3)	IW-1BS	Prior to Injection				PZ-B15S	8:06	4.31	Small air bubbles observed in initial purge as well as NAPL Blobs.
		9:33	8.5	1.0	1.5	PZ-B15S	9:35	9.28	
						PZ-B15S	10:03		Stopped monitoring due to significant amount of LNAPL and DNAPL observed in flow through cell. Continued to pump until 1130. DNAPL accumulation = ~.75" in 5 gals and ~0.5" in 2.5 gals.
		10:28	8.0	1.0	1.5	PZ-B7.5S	11:25	0.43	

* Oxygen concentration measured from within well casing
psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute
mg/l = milligrams per liter

Table 3 Summary of Groundwater Elevations - Area A
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A5S	6/13/2011	9:55	6.87	N/A					
	6/14/2011	12:10	6.81	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/14/2011	12:28	5.96	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/15/2011	13:37	6.22	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:49	6.16	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:42	6.63	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:51	6.02	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A5I	6/13/2011	9:55	7.00	N/A					
	6/14/2011	12:11	7.10	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/14/2011	12:30	1.00	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/17/2011	9:42	8.54	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:51	4.80	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A5D	6/13/2011	9:55	9.25	N/A					
	6/14/2011	12:10	9.49	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/14/2011	12:29	1.55	IW-1AD	12:11	12:26	17.0	5.0	10.6
	6/15/2011	13:34	8.67	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:52	6.02	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:40	10.00	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:50	8.57	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A10S	6/13/2011	9:55	12.17	N/A					
	6/15/2011	13:35	11.58	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:50	10.18	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:40	11.72	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:52	11.72	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A10I	6/13/2011	9:55	11.18	N/A					
	6/15/2011	13:36	10.37	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:51	8.38	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:41	11.84	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:51	10.46	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A10D	6/13/2011	9:55	9.05	N/A					
	6/15/2011	13:36	8.81	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:50	8.66	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:41	9.04	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:52	8.97	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A15S	6/13/2011	9:55	10.34	N/A					
	6/15/2011	13:34	9.89	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:50	8.68	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:39	10.50	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:50	10.06	IW-1AS	9:44	9:59	10.0	2.5	4.1

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A15D	6/13/2011	9:55	8.72	N/A					
	6/15/2011	13:33	8.07	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:50	7.60	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:39	8.55	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:49	8.35	IW-1AS	9:44	9:59	10.0	2.5	4.1

Table 3 Summary of Groundwater Elevations - Area A
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-A20S	6/13/2011	10:30	9.40	N/A					
	6/15/2011	13:34	8.76	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:50	8.52	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:40	9.38	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:50	9.22	IW-1AS	9:44	9:59	10.0	2.5	4.1
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
PZ-A20D	6/13/2011	9:55	12.22	N/A					
	6/15/2011	13:35	11.24	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:51	7.70	IW-1AD	13:37	13:52	13.5	1.5	2.8
	6/17/2011	9:41	12.85	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:51	11.75	IW-1AS	9:44	9:59	10.0	2.5	4.1
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
IW-1AS	6/13/2011	9:55	11.91	N/A					
	6/15/2011	13:35	10.85	IW-1AD	13:37	13:52	15.0	1.5	3
	6/15/2011	13:51	9.21	IW-1AD	13:37	13:52	13.5	1.5	2.8
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
IW-1AD	6/13/2011	9:55	7.25	N/A					
	6/17/2011	9:42	7.15	IW-1AS	9:14	9:27	10.5	2.5	4.2
	6/17/2011	9:51	7.08	IW-1AS	9:44	9:59	10.0	2.5	4.1

DTW = depth to water
ft. TOC = feet from top of casing
psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 4 Summary of Groundwater Elevations - Area B
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Well Designation	Date	Time	DTW (ft. TOC)	Injection Well	Pulsing Start	Pulsing Finish	Pressure (psi)	Flow (cfm)	Flow (scfm)
PZ-B7.5S	6/13/2011	10:19	10.70	N/A	N/A				
	6/14/2011	8:52	11.66	IW-1BD	N/A				
	6/14/2011	14:11	10.38	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/14/2011	14:33	10.25	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/15/2011	10:05	10.26	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/15/2011	10:28	10.20	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/16/2011	10:14	10.47	IW-1BS	10:17	10:32	9.0	1.0	1.6
	6/16/2011	10:29	9.69	IW-1BS	10:17	10:32	8.0	1.0	1.5
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
PZ-B7.5I	6/13/2011	10:23	10.06	N/A	N/A				
	6/14/2011	11:35	9.51	IW-1BD	11:25	11:40	10.3	1.0	1.7
	6/14/2011	14:11	9.61	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/14/2011	14:34	7.40	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/15/2011	10:06	9.45	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/15/2011	10:28	8.95	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/16/2011	10:15	10.03	IW-1BS	10:17	10:32	9.0	1.0	1.6
	6/16/2011	10:30	9.81	IW-1BS	10:17	10:32	8.0	1.0	1.5
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
PZ-B7.5D	6/13/2011	10:25	8.45	N/A	N/A				
	6/14/2011	11:34	7.90	IW-1BD	11:25	11:40	10.3	1.0	1.7
	6/14/2011	14:11	7.97	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/14/2011	14:34	5.55	IW-1BD	14:20	14:28	15.0	3.5	6.9
	6/15/2011	10:06	7.95	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/15/2011	10:28	7.64	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/16/2011	10:14	8.36	IW-1BD	10:17	10:32	9.0	1.0	1.6
	6/16/2011	10:28	8.22	IW-1BS	10:17	10:32	8.0	1.0	1.5
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
PZ-A15S	6/13/2011	10:00	8.27	N/A	N/A				
	6/14/2011	11:38	8.14	IW-1BD	11:25	11:40	10.3	1.0	1.7
	6/15/2011	10:07	6.40	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/15/2011	10:29	6.10	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/16/2011	N/A - NAPL		IW-1BS					
	6/16/2011	N/A - NAPL		IW-1BS					
Well Designation	**Date**	**Time**	**DTW (ft. TOC)**	**Injection Well**	**Pulsing Start**	**Pulsing Finish**	**Pressure (psi)**	**Flow (cfm)**	**Flow (scfm)**
PZ-A15D	6/13/2011	10:07	6.95	N/A	N/A				
	6/14/2011	11:39	6.46	IW-1BD	11:25	11:40	10.3	1.0	1.7
*	6/15/2011	10:07	6.40	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/15/2011	10:29	6.10	IW-1BD	10:10	10:25	11.0	2.5	4.3
	6/16/2011	10:13	7.89	IW-1BS	10:17	10:32	9.0	1.0	1.6
**	6/16/2011	10:29	6.70	IW-1BS	10:17	10:32	8.0	1.0	1.5

*Pumping for DO Measurements
**NAPL Observed
DTW = depth to water
ft. TOC = feet from top of casing
psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 5 Additional Oxygen Injection Testing Results
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Well Location	Date	Breakout Pressure (psi)	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
IW-1BS	6/16/2011	2.5	9.0	1.5	2.4	
			8.3	0.5	0.8	
			9.8	4.8	7.8	
			10.0	8.5	15.5	
PZ-B7.5I	6/16/2011	1.0	7.3	0.5	0.7	
			8.3	2.5	3.8	
			9.0	5.0	7.9	
			9.8	11.0	18.0	
PZ-B7.5D	6/16/2011	2.5	7.5	0.5	0.7	
			12.0	1.5	2.7	
			13.8	5.0	9.5	
PZ-B15D	6/16/2011	1.0	9.0	0.5	0.8	
			10.0	2.5	4.1	
			11.5	9.0	15.7	
PZ-B7.5S	6/16/2011	1.0	6.0	0.5	0.7	
			7.5	1.5	2.2	
			9.5	5.0	8.1	
			10.0	9.5	15.7	
PZ-A15D	6/17/2011	7.0	10.0	2.0	3.3	
			10.5	4.0	6.7	
			12.0	10.0	17.8	
PZ-A15S	6/17/2011	11.0	14.0	1.5	2.9	Minor bubbling at grout seal/riser
			15.3	2.5	5.0	
			17.0	4.0	8.5	
			18.0	5.0	10.9	
PZ-A10I	6/17/2011	10.5	15.0	1.0		Geysering out of PZ-A10S
PZ-A5S	6/17/2011	5.0	8.0	3.0	4.5	
			8.0	12.0	18.2	
PZ-A20S	6/17/2011	5.5	8.0	1.5	2.3	
			9.0	3.0	4.7	
			12.0	5.0	8.9	
			14.8	10.0	19.7	
PZ-A5I	6/17/2011	5.0	8.3	1.0	1.5	Bubbling on ground surface, none around casing
			9.8	2.5	4.1	
			10.8	4.0	6.8	
			10.8	5.0	8.5	
			12.5	10.5	19.1	
PZ-A20D	6/17/2011	4.0	12.0	1.0	1.8	
			14.3	2.5	4.8	
			16.0	4.0	8.2	
			17.3	5.0	10.7	
PZ-A10D	6/17/2011	10.0	12.3	1.5	2.7	
			13.5	3.0	5.0	
			14.3	5.0	9.7	
			14.5	9.0	17.5	
PZ-A10S	6/17/2011	6.5	9.5	1.5	2.4	Bubbling along casing when flow increased to 10 scfm
			10.3	3.0	5.0	
			11.0	5.0	8.6	
			10.5	10.0	16.8	
PZ-A5D	6/17/2011	10.0	12.5	1.5	2.7	Minor Bubbling around grout
			14.0	5.0	9.6	
			14.8	9.0	17.7	

psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 6 Oxygen Injection Summary - IW-1AD
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/14/2011	1	11:11	17.5	2.0	4.3	
	1	11:12	13.5	1.0	1.9	Bubbling observed around casing
	1	11:21	12.0	1.0	1.8	
	1	11:24	12.0	1.0	1.8	
	2	12:11	15.0	1.0	2.0	
	2	12:13	12.5	1.0	1.8	
	2	12:19	12.5	1.3	2.3	
	2	12:20	13.0	1.5	2.8	
	2	12:20	14.0	2.0	3.8	
	2	12:20	15.0	2.5	5.0	
	2	12:21	16.0	3.9	8.0	
	2	12:23	16.8	4.5	9.4	
	2	12:24	17.0	5.0	10.6	
	3	13:58	25.0	4.7	12.5	
	3	14:00	20.0	5.0	11.6	
	3	14:02	19.0	5.0	11.2	
	3	14:05	18.5	5.0	11.1	
	3	14:10	18.0	5.0	10.9	
	4	14:55	25.0	5.0	13.2	
	4	14:58	18.5	5.0	11.1	
	4	15:05	15.5	3.0	6.0	
	4	15:10	14.5	2.5	4.9	
	5	15:43	17.5	3.0	6.4	
	5	15:47	16.3	3.0	6.2	
	5	15:49	16.3	3.0	6.2	Pressure at PZ-A5I = 7.0 psi
	5	15:52	14.8	2.0	3.9	Groundwater Surfacing at PZ-A20D
	5	15:54	14.5	2.5	4.9	
	5	15:56	14.0	2.0	3.8	
	5	15:58	14.0	2.0	3.8	
	6	16:31	17.0	1.5	3.2	
	6	16:32	16.0	1.5	3.1	
	6	16:35	15.0	1.5	3.0	
	6	16:40	15.0	1.5	3.0	
	6	16:43	14.5	1.5	2.9	
	6	16:46	14.3	1.5	2.9	
6/15/2011	1	8:56	15.0	1.5	3	
	1	8:58	14.5	1.5	2.9	
	1	9:01	14.5	1.5	2.9	
	1	9:07	14.0	1.5	2.9	
	2	9:40	14.0	1.5	2.9	
	2	9:43	13.5	1.5	2.8	
	2	9:50	13.5	1.5	2.8	
	3	10:25	16.0	1.5	3.1	
	3	10:26	14.8	1.5	3.0	
	3	10:30	12.0	1.5	2.7	Pressure at PZ-A5I = 6.5 psi
	3	10:33	13.0	1.5	2.8	
	3	10:36	13.0	1.5	2.8	
	4	11:10	22.0	1.5	3.7	
	4	11:11	15.0	1.5	3.0	
	4	11:14	13.5	1.5	2.8	
	4	11:17	13.5	1.5	2.8	
	4	11:20	13.5	1.5	2.8	
	5	13:07	18.0	1.5	3.3	Pressure at PZ-A5I = 6.5 psi
	5	13:08	13.5	1.5	2.8	
	5	13:12	13.5	1.5	2.8	

Table 6 Oxygen Injection Summary - IW-1AD
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/15/2011	5	13:17	13.5	1.5	2.8	
	6	13:37	15.0	1.5	3.0	
	6	13:40	14.0	1.5	2.9	
	6	13:45	13.5	1.5	2.8	
	7	14:02	13.0	1.5	2.8	
	7	14:08	12.5	1.5	2.7	
	7	14:12	12.0	1.5	2.7	
	7	14:18	12.0	1.5	2.7	
	8	14:37	13.5	1.5	2.8	
	8	14:38	13.0	1.5	2.8	
	8	14:41	12.5	1.5	2.7	
	8	14:47	12.5	1.5	2.7	
	9	15:07	18.0	3.0	6.5	
	9	15:08	14.0	3.0	5.7	
	9	15:11	14.0	3.0	5.7	
	9	15:17	13.0	3.0	5.5	
	10	15:37	12.5	3.0	5.4	
	10	15:38	12.0	3.0	5.3	
	10	15:44	12.0	3.0	5.3	
	10	15:49	13.0	3.0	5.5	
	10	15:52	13.0	3.0	5.5	
	11	16:07	18.0	3.0	6.5	
	11	16:08	17.0	3.0	6.3	
	11	16:11	16.0	3.0	6.1	
	11	16:14	16.0	3.0	6.1	
	11	16:22	16.0	3.0	6.1	
	12	16:37	14.0	2.7	5.7	
	12	16:39	14.5	3.0	5.8	
	12	16:50	14.5	3.0	5.8	

psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 7 Oxygen Injection Summary - IW-1AS
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/16/2011	1	9:02	14.0	1.0	1.9	
	1	9:03	13.5	1.0	1.9	
	1	9:04	10.5	1.0	1.7	
	1	9:06	10.0	1.0	1.6	
	1	9:10	9.0	1.0	1.6	
	1	9:14	9.0	1.0	1.6	
	2	9:45	10.0	1.0	1.6	
	2	9:46	11.0	1.0	1.7	
	2	9:49	10.0	1.0	1.6	
	2	9:53	10.0	1.0	1.6	
	2	9:57	10.0	1.0	1.6	
	3	10:32	10.0	1.0	1.6	
	3	10:33	10.0	1.0	1.6	
	3	10:47	10.0	1.0	1.6	
	4	11:17	10.0	1.0	1.6	
	4	11:32	9.5	1.0	1.6	
	5	13:09	14.0	4.0	7.7	
	5	13:13	14.0	4.0	7.7	
	5	13:24	13.5	4.0	7.5	
	6	13:41	11.5	4.0	7.0	
	6	13:56	10.0	4.0	6.6	
	7	14:18	9.5	4.0	6.5	
	7	14:19	14.0	8.5	16.3	
	7	14:21	14.0	8.5	16.3	
	8	14:48	12.5	10.0	18.2	
	8	14:49	13.0	10.0	18.5	
	8	14:51	14.5	9.5	18.5	
6/17/2011	1	8:43	11.5	2.5	4.4	
	1	8:50	11.5	2.5	4.4	
	1	8:58	10.3	2.5	4.2	
	2	9:14	10.5	2.5	4.2	
	2	9:20	10.0	2.5	4.1	
	2	9:27	10.5	2.5	4.2	
	3	9:44	10.0	2.5	4.1	

psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 8 Oxygen Injection Summary - IW-1BD
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/14/2011	1	11:25	11.5	1.0	1.7	
	1	11:27	10.5	1.0	1.7	
	1	11:40	10.3	1.0	1.7	
	2	12:30	12.4	1.0	1.8	
	2	12:32	10.5	1.0	1.7	
	2	12:32	11.0	2.0	3.4	
	2	12:32	11.5	2.5	4.3	
	2	12:33	11.8	3.0	5.3	
	2	12:33	12.0	3.5	6.2	
	2	12:33	12.5	4.5	8.2	
	2	12:34	12.5	5.0	9.1	
	3	14:20	12.0	5.0	8.9	
	3	14:25	12.0	5.0	8.9	
	3	14:28	12.0	5.0	8.9	
	4	15:11	15.0	3.5	6.9	
	4	15:12	12.3	5.0	9.0	
	4	15:22	12.0	5.0	8.9	
	4	15:26	12.0	5.0	8.9	
	5	15:59	12.5	5.0	9.1	
	5	16:03	12.0	5.0	8.9	
	5	16:06	12.0	5.0	8.9	
	5	16:14	12.0	5.0	8.9	
	6	16:46	13.0	4.7	8.7	
	6	16:48	12.0	5.0	8.9	
	6	16:52	12.0	5.0	8.9	
	6	16:57	12.0	5.0	8.9	
	6	17:01	12.0	5.0	8.9	
6/15/2011	1	8:40	11.5	2.5	4.4	
	1	8:43	11.0	2.5	4.3	
	1	8:49	11.0	2.5	4.3	
	1	8:52	11.0	2.5	4.3	
	2	9:25	11.5	2.5	4.4	
	2	9:28	11.5	2.5	4.4	
	2	9:31	11.5	2.5	4.4	
	2	9:35	11.5	2.5	4.4	
	3	10:10	14.0	2.5	4.8	
	3	10:12	11.3	2.5	4.3	
	3	10:14	11.0	2.5	4.3	
	3	10:18	11.0	2.5	4.3	

Table 8 Oxygen Injection Summary - IW-1BD
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

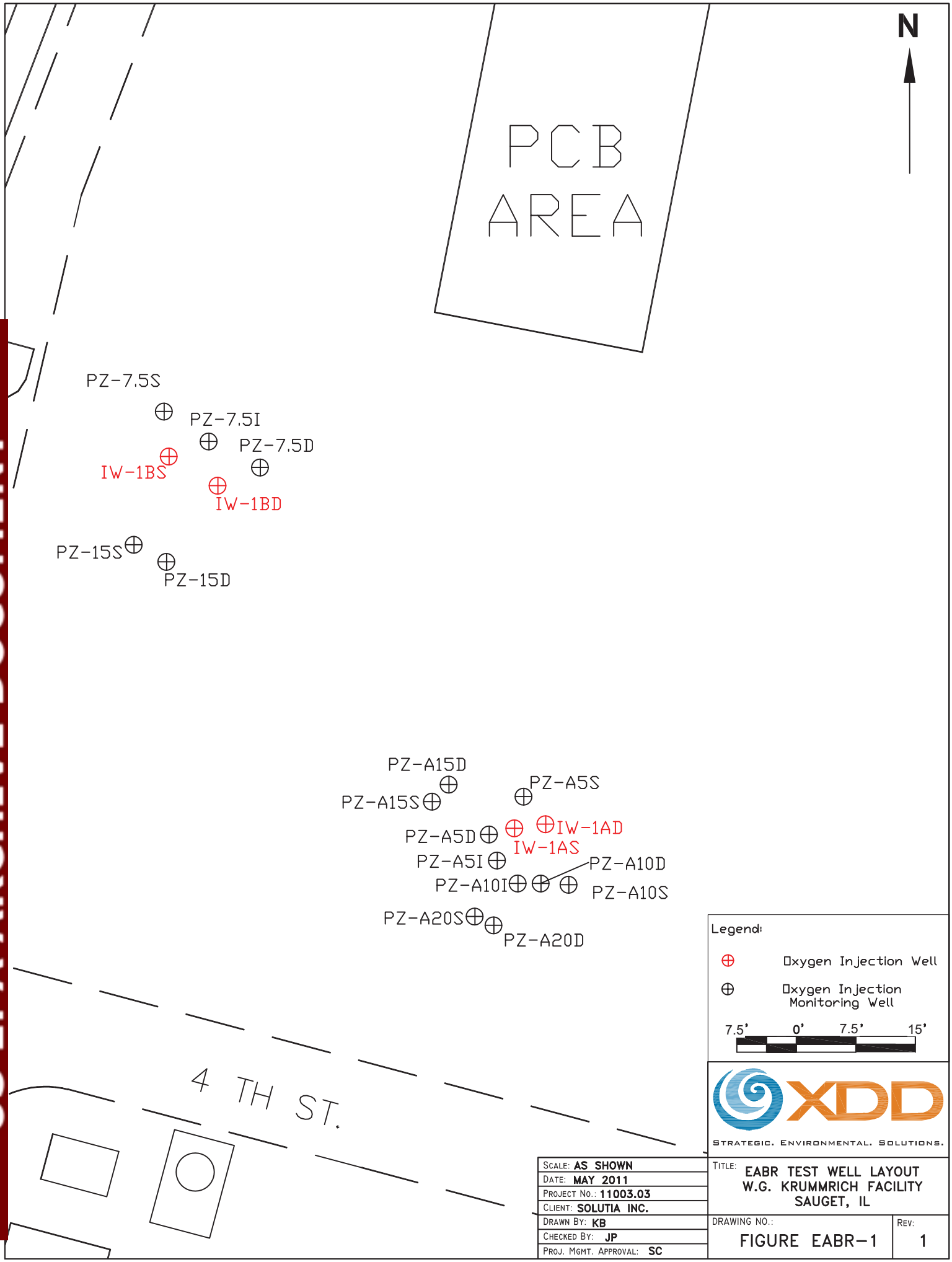
Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/15/2011	4	10:55	11.5	2.5	4.4	
	4	10:58	11.5	2.5	4.4	
	4	11:02	11.5	2.5	4.4	
	4	11:06	11.0	2.5	4.3	
	5	12:52	14.0	2.5	4.8	
	5	12:55	11.0	2.5	4.3	
	5	13:00	11.0	2.5	4.3	
	5	13:07	11.0	2.5	4.3	
	6	13:37	11.3	2.5	4.3	
	6	13:40	11.0	2.5	4.3	
	6	13:45	11.5	2.5	4.4	
	6	13:52	11.5	2.5	4.4	
	7	14:22	13.0	2.5	4.6	
	7	14:23	11.5	2.5	4.4	
	7	14:26	11.0	2.5	4.3	
	7	14:30	11.0	2.5	4.3	
	8	15:07	12.0	2.5	4.5	
	8	15:11	11.0	2.5	4.3	
	8	15:17	11.0	2.5	4.3	
	9	15:52	12.0	2.5	4.5	
	9	15:54	11.5	2.5	4.4	
	9	15:58	11.5	2.5	4.4	
	9	16:05	11.0	2.5	4.3	
	10	16:37	11.5	2.5	4.4	
	10	16:39	11.0	2.5	4.3	
	10	16:50	11.0	2.5	4.3	

psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute

Table 9 Oxygen Injection Summary - IW-1BS
EABR Field Testing
Former Chlorobenzene Process Area
Solutia Inc., W.G. Krummich Facility, Sauget, Illinois

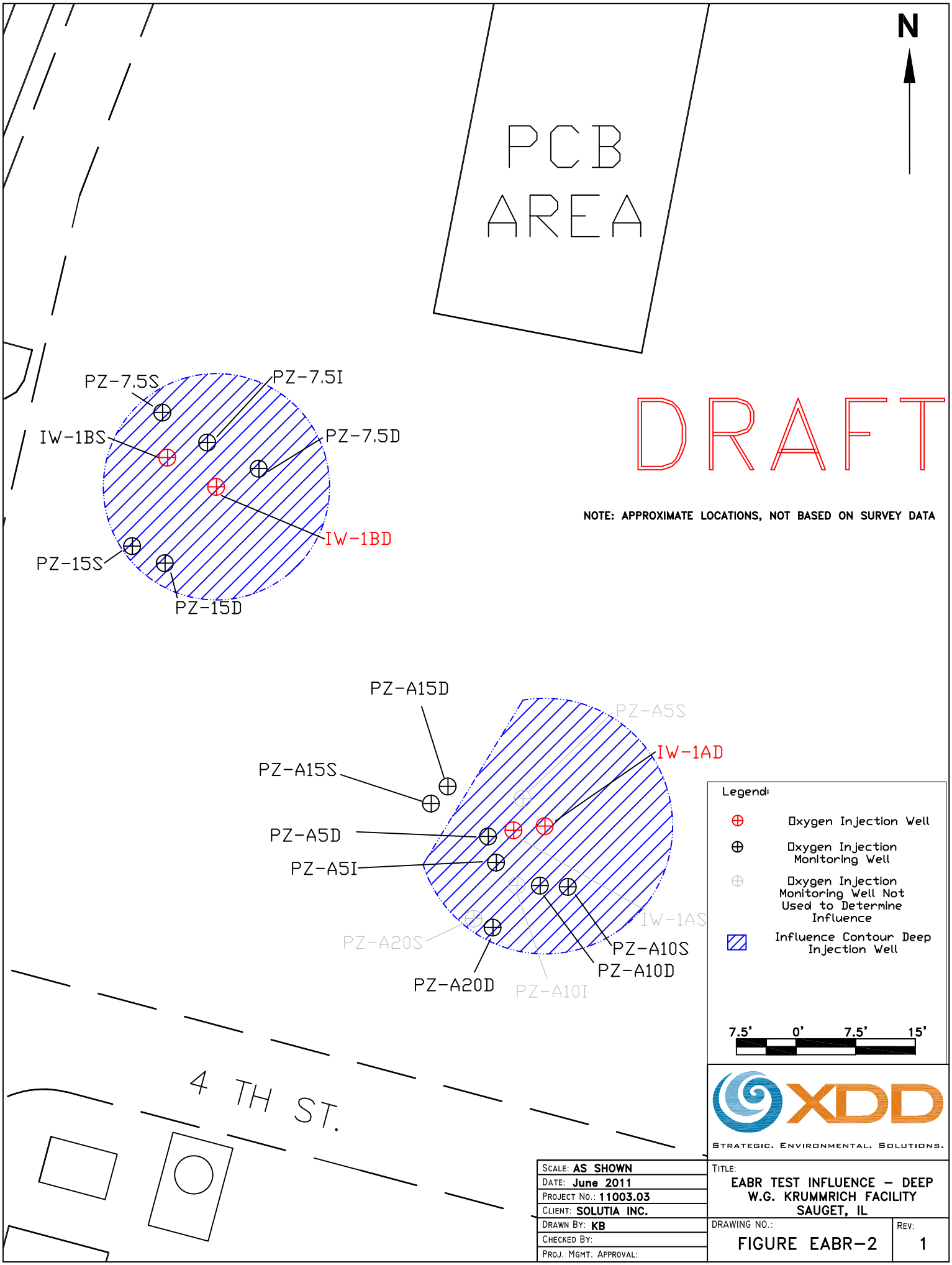
Date	Pulse	Time	Operating Pressure (psi)	Flow (cfm)	Flow (scfm)	Notes
6/16/2011	1	8:47	8.5	1.0	1.5	
	1	8:50	8.5	1.0	1.5	
	1	8:53	8.5	1.0	1.5	
	1	8:56	8.5	1.0	1.5	
	1	9:00	8.5	1.0	1.5	
	2	9:30	8.5	1.0	1.5	
	2	9:33	8.5	1.0	1.5	
	2	9:41	8.5	1.0	1.5	
	3	10:17	9.0	1.0	1.6	
	3	10:18	8.5	1.0	1.5	
	3	10:24	8.0	1.0	1.5	
	3	10:28	8.0	1.0	1.5	

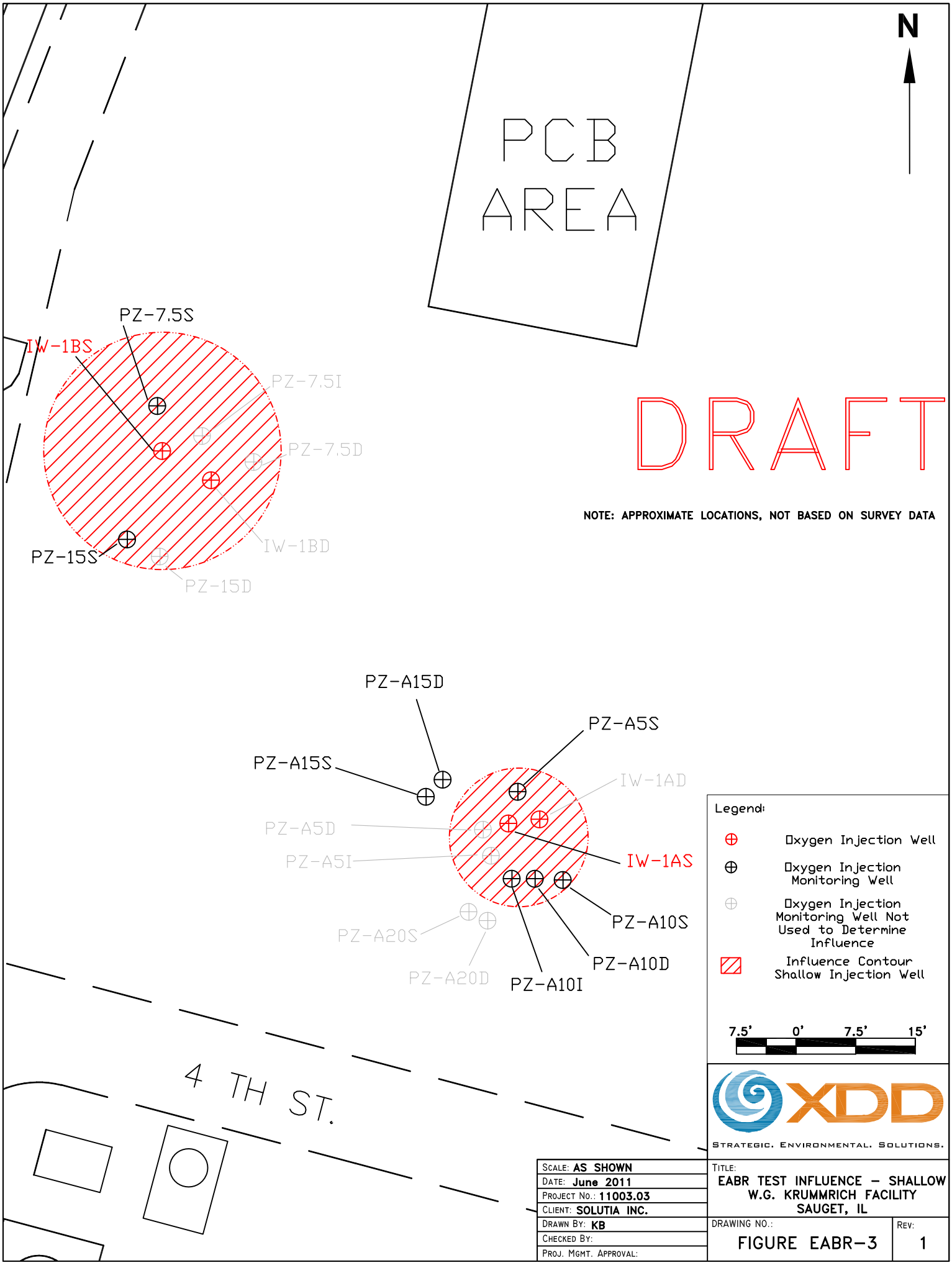
psi = pounds per square inches
cfm = cubic feet per minute
scfm = standard cubic feet per minute



XDD
STRATEGIC. ENVIRONMENTAL. SOLUTIONS.

SCALE: AS SHOWN	TITLE: EABR TEST WELL LAYOUT W.G. KRUMMRICH FACILITY SAUGET, IL
DATE: MAY 2011	
PROJECT NO.: 11003.03	
CLIENT: SOLUTIA INC.	
DRAWN BY: KB	DRAWING NO.: FIGURE EABR-1
CHECKED BY: JP	REV: 1
PROJ. MGMT. APPROVAL: SC	


N
PCB
AREA
PZ-7.5S
PZ-7.5I
IW-1BS
PZ-7.5D
IW-1BD
PZ-15S
PZ-15D
DRAFT
NOTE: APPROXIMATE LOCATIONS, NOT BASED ON SURVEY DATA
PZ-A15D
PZ-A5S
IW-1AD
PZ-A15S
PZ-A5D
PZ-A5I
IW-1AS
PZ-A20S
PZ-A10S
PZ-A10D
PZ-A20D
PZ-A10I
Legend:
Oxygen Injection Well
Oxygen Injection Monitoring Well
Oxygen Injection Monitoring Well Not Used to Determine Influence
Influence Contour Deep Injection Well
7.5' 0' 7.5' 15'
4 TH ST.
XDD
STRATEGIC. ENVIRONMENTAL. SOLUTIONS.
SCALE: AS SHOWN
DATE: June 2011
PROJECT NO.: 11003.03
CLIENT: SOLUTIA INC.
DRAWN BY: KB
CHECKED BY:
PROJ. MGMT. APPROVAL:
TITLE:
EABR TEST INFLUENCE – DEEP
W.G. KRUMMRICH FACILITY
SAUGET, IL
DRAWING NO.:
FIGURE EABR-2
REV:
1


N
PCB AREA
PZ-7.5S
IW-1BS
PZ-7.5I
PZ-7.5D
IW-1BD
PZ-15S
PZ-15D
DRAFT
NOTE: APPROXIMATE LOCATIONS, NOT BASED ON SURVEY DATA
PZ-A15D
PZ-A5S
PZ-A15S
IW-1AD
PZ-A5D
PZ-A5I
IW-1AS
PZ-A10S
PZ-A20S
PZ-A10D
PZ-A20D
PZ-A10I
4 TH ST.
Legend:
Oxygen Injection Well
Oxygen Injection Monitoring Well
Oxygen Injection Monitoring Well Not Used to Determine Influence
Influence Contour Shallow Injection Well
7.5' 0' 7.5' 15'
XDD
STRATEGIC. ENVIRONMENTAL. SOLUTIONS.
SCALE: AS SHOWN
DATE: June 2011
PROJECT NO.: 11003.03
CLIENT: SOLUTIA INC.
DRAWN BY: KB
CHECKED BY:
PROJ. MGMT. APPROVAL:
TITLE:
EABR TEST INFLUENCE – SHALLOW
W.G. KRUMMRICH FACILITY
SAUGET, IL
DRAWING NO.:
FIGURE EABR-3
REV:
1

Appendix C

Oxygen Utilization and Biodegradation Rate Estimates

1.0 OXYGEN UTILIZATION AND BIODEGRADATION RATE ESTIMATES

Theoretical contaminant biodegradation rate and oxygen utilization calculations were performed to confirm that the required oxygen (O_2) volumes could be delivered to the subsurface at reasonable injection flowrates (e.g., between 3 and 5 standard cubic feet per minute [scfm] based on industry standard practice). Various methods were used as cross-checks, and the most conservative results were selected to ensure that the mechanical design would be conservative.

In practice, the oxygen delivery rate will be adjusted during system optimization as needed to supply oxygen to increase the dissolved oxygen (DO) concentrations in the range of 40 mg/L (to be monitored using the proposed piezometer well network). Therefore, these oxygen utilization rate estimates are conservative to assure that the oxygen injection system design has a reasonable capacity, and can be flexible in response to actual field conditions.

Between 11,200,000 and 62,400,000 cubic feet (CF) of oxygen gas was estimated to be required over a four year operation period to treat the estimated 386,000 pounds (Lbs) of contaminant of concern (COC) mass in the target depth interval. This volume of oxygen gas can be realistically delivered at a relatively low injection flowrate per well of 3 to 5 scfm. The methods and parameters that were used to develop the above oxygen utilization estimates are discussed below.

1.1 OXYGEN UTILIZATION BASED ON COC DEGRADATION RATIOS

The stoichiometric monochlorobenzene/dichlorobenzene (MCB/DCB) mass degradation ratios were estimated in the 2006 Solutia Inc. (Solutia) treatability study[1] in terms of oxygen equivalents:

[1] GSI. *Mass Removal Treatability Tests, Enhanced Aerobic Bioremediation, Saturated Shallow Hydrogeologic Unit, Solutia Inc., W.G. Krummrich Facility, Sauget, Illinois.* May 2006.

- MCB degradation ratio: 2.0 Lbs O_2 per Lb of MCB.
- DCB degradation ratio: 1.4 Lbs O_2 per Lb of total DCBs (1,2-, 1,3-, and 1,4-isomers).

Experimental results confirmed the above assumptions were reasonable (i.e., an average of 1.7 Lbs O_2 was estimated to be consumed per Lb of MCB/DCB in the column studies).

Based on these stoichiometric ratios, the minimum amount of oxygen required for full-scale treatment is estimated using the following equation:

Eq.1 – Required O_2 Volume = 386,000 Lbs CO Cs x (2.0 Lbs O_2/Lb COC) x (12.08 C F O_2/Lb O_2)] x 1.2 Safety Factor

Assuming a maximum oxygen consumption rate of 2.0 Lbs/O_2 per Lb of COCs degraded, and an assumed 20% safety factor to account for degassing and advection beyond target area, the oxygen utilization was estimated at 11,200,000 CF (or 930,000 Lbs O_2).

1.2 OXYGEN UTILIZATION BASED ON BIODEGRADATION RATES

The aerobic biodegradation rate can be expressed in terms of a "half-life". The half-life is the estimated time to decrease the COC concentrations by one-half (expressed in units days).

A first order decay rate function is typically used to estimate the anticipated change in target COC concentrations over time, where:

Eq.2 – First Order Decay Equation: $\mathbf{Ct = Co\ e^{-kt}}$

t = Elapsed time (days).
Ct = Concentration (milligrams per Kilogram [mg/Kg]) after elapsed time, t.
Co = Initial concentration (mg/Kg).
k = decay rate constant (day^{-1}).
e = exponential constant (approximately = 2.718).

For a first order decay function, the half-life can be converted to the decay rate constant, k, using the following equation:

Eq.3 – Decay Rate Constant Conversion: k = *ln*2 / half-life

k = Decay rate constant (day^{-1}).

ln = Natural logarithm (or logarithm of base *e*). Natural logarithm of 2 = 0.693.

The minimum estimated aerobic degradation half-life was estimated to be between 100 and 300 days from the 2006 Solutia[2] treatability study and from literature/case study values. Based on the first order decay equations above, the biodegradation rate constant, k, can range between 0.00693 and 0.00231 $days^{-1}$.

A calculation was performed that assumed that the soil concentrations would decay according to the above first order decay rate function and the estimated half-life/biodegradation constants. For example, assuming an initial soil concentration of 4,000 mg/Kg (total MCB/DCB), the COCs can theoretically be reduced significantly in approximately 1 to 2 years (assuming 100 to 200 day half lives).

Based on the change in soil concentrations over time predicted by the first order decay equation, the anticipated cumulative mass reduction over time was then calculated (i.e., calculated based on the remaining soil concentrations [Ct] at each time interval, and the total soil volume of the treatment zone).

Assuming a maximum oxygen consumption rate of 2.0 Lbs/O_2 per Lb of COCs degraded, the cumulative oxygen utilization was estimated at approximately 17,000,000 CF of O_2 (or 1,400,000 Lbs of O_2) using this method.

[2] GSI. *Mass Removal Treatability Tests, Enhanced Aerobic Bioremediation, Saturated Shallow Hydrogeologic Unit, Solutia Inc., W.G. Krummrich Facility, Sauget, Illinois.* May 2006.

1.3 OXYGEN REQUIREMENT BASED ON OXYGEN SATURATION LEVELS

A calculation was performed to estimate the mass of oxygen that would be required to increase the DO concentration to approximately 40 mg/L in the saturated zone. It was assumed that a mass of oxygen would be injected on a pulsing schedule to raise the ambient DO level in the aquifer from 5 milligrams per liter (mg/L) to 40 mg/L. The oxygen injection would then stop, and oxygen would be consumed by the bacteria at a given oxygen utilization rate. When the DO levels declined again to 5 mg/L, another oxygen pulse would be applied to raise the DO to 40 mg/L. This is a simulation of how the oxygen injection would be applied at the site (pulsed-mode), and these calculations formed the basis for the conceptual oxygen injection pulsing cycle (see **Section 1.4** of this **Appendix C** below).

The oxygen consumption rate was assumed to be proportional to the COC mass degradation rate determined using the first order decay rate equation. The initial oxygen utilization rates were estimated to range from 0.5 to 1.4 Lbs O_2/hour, per injection well screen (assumes COCs degradation half-lives between 100 to 300 days, and a maximum oxygen consumption rate of 2.0 Lbs/O_2 per Lb of COCs degraded). These were the initial maximum oxygen utilization rates, which will decline as a function of the first order decay equation, and as the COC mass is depleted over time.

Based on the average oxygen utilization rate over the life of the project of approximately 0.8 Lbs O_2/hour, per well, a cumulative oxygen utilization of 62,400,000 CF (or 5,200,000 Lbs of O_2) was calculated. A 20% safety factor was included to account for losses of oxygen from degassing and groundwater flux out of the target area.

1.4 OXYGEN PULSING CYCLE ESTIMATE

The anticipated initial EABR system pulse cycle times were estimated using a similar evaluation as was conducted in **Section 1.3** of this **Appendix C**.

Biosparging is typically conducted using a pulse-injection mode. Pulse injection is conducted by injecting into individual sub-groups of wells using an "on/off" cycling approach (i.e., one sub-group at a time will be "on" while the others are "off").

The pulse "on" injection time was estimated to range between 10 and 30 minutes. This was time required to inject the required mass of oxygen to raise DO levels from 5 mg/L to 40 mg/L. This assumes oxygen is fully distributed within the soil in a 15 foot radius around the injection well, at the design flow rate of 3 to 5 scfm.

The duration of the pulse "off" time was estimated to range from 2 to 8 hours. The pulse "off" time was based on the estimated rate of oxygen utilization, and the time it would take to deplete DO from 40 mg/L down to 5 mg/L. The COC mass degradation rate within a 15 foot radius of influence was estimated using the first order decay rate equations (see **Section 1.2** of this **Appendix C**). The oxygen equivalent required to degrade this COC mass over the calculation time period (assuming the 2.0 Lbs O_2/Lb of COC ratio) was then estimated. This value was assumed to be the oxygen utilization rate during the pulse "off" cycle. The time that it takes to deplete the mass of oxygen within the 15 foot radius of influence (i.e., assuming DO starting concentration of 40 mg/L being reduced to 5 mg/L) at this oxygen utilization rate is the maximum pulse "off" time. The oxygen utilization rates used in the above calculations assumed a fully acclimated bacteria population, and initial soil concentrations of 4,000 mg/Kg total COCs.

Appendix D

EABR Shutdown Protocol

MEMORANDUM

To:	Jerry Rinaldi (Solutia)	**Date:**	April 13, 2011
From:	Scott Crawford (XDD)	**Cc:**	Mike Marley (XDD) John Conner (GSI) XDD File (p1103)
RE:	**Protocol for Completing Enhanced Aerobic Bioremediation Operations** **Former Chlorobenzene Process Area** **Solutia Inc., W.G. Krummrich Facility, Sauget, Illinois**		

Dear Mr. Rinaldi,

XDD, LLC (XDD) has prepared this protocol to determine when it is appropriate to cease Enhanced Aerobic Bioremediation (EABR) operations in the Chlorobenzene Process Area (CPA) area at the Solutia Inc. (Solutia) W.G. Krummrich facility. The EABR system is designed to address the 15 to 30 foot saturated zone interval of the Shallow Hydrogeologic Unit (SHU).

The steps in this protocol will provide the basis for making the recommendation, which will be approved by the United States Environmental Protection Agency (U.S. EPA), to shut down EABR operations. EABR operations will continue in the CPA area until U.S. EPA approval of the recommendation to shut down.

The decision to shut down EABR operations is recommended to be based upon the following steps:

1. **Process Monitoring** - Conduct performance monitoring of the EABR operations, which includes:
    a. Dissolved oxygen (DO) levels will be measured in the saturated zone to demonstrate that enough oxygen is being supplied to support aerobic biodegradation.
    b. Periodic assessment of oxygen utilization rates:
        i. Oxygen utilization will be measured by temporarily halting the injection of oxygen for one or two weeks and observing the rate of oxygen depletion. A conservative tracer (e.g., helium) may be used to differentiate between biological oxygen uptake versus oxygen depletion due to non-biological processes.
        ii. This assessment would be conducted within the first six months of EABR operation (after the bacterial population is acclimated) to establish initial oxygen utilization rates. Oxygen utilization rates will be assessed quarterly thereafter.

iii. As COC mass is depleted over time and becomes mass-transfer limited, the oxygen utilization rate would be expected to decline. A reduction in oxygen utilization rates can be considered the primary line of evidence for anticipating the completion of EABR operations.

c. Groundwater Monitoring: Groundwater monitoring will be conducted at piezometers within the EABR area. A baseline event will be conducted prior to start-up, and monitoring will be conducted on an annual basis thereafter. The monitoring program will include similar parameters as the Long Term Monitoring (LTM) program. Groundwater data will be assessed as an additional line of evidence that conditions for biological treatment have been created, and remain favorable to support biological degradation processes.

2. **Soil Sampling** – Conduct soil sampling to assess reductions in soil concentrations and soil COC mass during EABR operations:
   a. Soil sampling is to be conducted on an annual basis.
   b. The initial COC mass estimates in the 15 to 30 foot saturated zone interval have been provided in Table D-3 of the *Former Chlorobenzene Process Area Characterization Report*. The estimated mass of benzene and chlorinated benzenes is 385,000 pounds.
   c. Soil COC mass remaining in the 15 to 30 foot saturated zone interval will be calculated following each annual soil sampling event and compared to the initial mass estimates to estimate percent mass reduction.

3. **Assess COC Mass Remaining on Soils** – Following the second and subsequent annual soil sampling events, evaluate COC mass reduction and evaluate the impact, if any, of residual COC mass remaining on soils:
   a. The COC mass remaining on the soils will be compared to the initial COC mass provided in 2.b. (385,000 pounds).
   b. If appropriate based on the level of COC mass reduction that is observed, modeling will be conducted to evaluate potential impact to groundwater posed by the remaining COC mass in the 15 to 30 foot saturated zone interval. Note that potential impacts to groundwater from COC mass within the overlying unsaturated zone (0 to 15 foot interval) will be evaluated concurrently during the Thermally-Enhanced Soil Vapor Extraction System (T-SVE) performance evaluations.
   c. Residual soil concentrations will also be evaluated to determine if there are any potential human health risks and if these are addressed by institutional controls.
   d. If a., b., or c. above suggest the need for further action, an evaluation to determine if continued operation of the EABR or if Monitored Natural Attenuation (MNA) will address the residual soil concentrations will be conducted.

4. **Recommendation for Shutdown of EABR Operations** – Based on the data collection and evaluations conducted in Step #1 through #3, prepare a report for U.S. EPA to recommend whether to continue EABR operations or discontinue and transition to MNA.

    a. The performance of the EABR system will be evaluated based on several lines of evidence:
        i. Oxygen utilization rates (1.b.iii.).
        ii. Groundwater data (1.c.).
        iii. COC mass remaining on soils (3.a).
        iv. Potential risk posed by remaining COC (3.b. and 3.c.).

    Note that it may be appropriate to recommend shutdown of portions of the EABR system in a phased manner if sub-areas and/or specific depth intervals meet the performance criteria.

    Upon U.S. EPA's agreement, the EABR system (or portions of the EABR system, as appropriate) would be shut down.