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LMS/MND/S11608

OU-1 Enhanced Attenuation Field Demonstration Edible Oil Deployment Design Mound, Ohio, Site

June 2014

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Abbreviations

cVOCs	chlorinated volatile organic compounds
ft	foot
gpm	gallons per minute
lb	pound
MCL	maximum contaminant level
MNA	monitored natural attenuation
OU-1	Operable Unit 1
P&T	pump-and-treatment
PCE	tetrachloroethene (perchloroethene)
TCE	trichloroethene

1.0 Introduction

At the Mound, Ohio, Site, groundwater in Operable Unit 1 (OU-1) has been impacted by chlorinated volatile organic compounds (cVOCs) originating from the former solid waste landfill. Contaminated groundwater from the former landfill is currently being controlled using two extraction wells. Since the source materials have been removed from the landfill, the feasibility of switching from the active remedy of pump-and-treatment (P&T) to capture contaminated groundwater originating beneath the former landfill to a more passive attenuation remedy is being considered as a viable alternative at the Mound site. Results of a recent aquifer rebound study show that the concentrations of cVOCs increase above the U.S Environmental Protection Agency maximum contaminant levels (MCLs) when the P&T system is shut off. In the process of considering a transition to monitored natural attenuation (MNA), the U.S. Department of Energy will conduct a field demonstration to evaluate the use of edible oils to enhance natural attenuation processes.

A field demonstration will be conducted to determine whether the use of edible oils can establish and stimulate discrete treatment zones that expedite the attenuation of cVOCs in the OU-1 groundwater. Edible oils (neat and emulsified) will be deployed into the subsurface to create treatment zones to reduce the concentrations of trichloroethene (TCE) and tetrachloroethene (PCE) in groundwater and enhance the ongoing attenuation of these parent compounds and degradation (daughter) products. The design criteria for implementing this approach are outlined in the *Field Demonstration Work Plan for Using Edible Oils to Achieve Enhanced Attenuation of cVOCs and a Groundwater Exit Strategy for the OU-1 Area, Mound, Ohio* (Field Demonstration Work Plan) (DOE 2013). This design document presents the specific material and equipment requirements necessary to deploy the neat and emulsified oils. The locations and construction specifics for the temporary wells are also included.

2.0 Remedial Technology Overview

Enhanced attenuation uses active engineering solutions to alter the target site in such a way that the contaminant plume will passively stabilize and shrink. The strategy recognizes that attenuation remedies are fundamentally based on a mass balance; therefore, long-term plume behavior can be altered either by reducing the contaminant loading from the source or by increasing the rate of natural attenuation processes within all or part of the plume volume.

Edible oils have emerged as an effective treatment to enhance anaerobic bioremediation and sequestration of chlorinated solvent contamination in groundwater. At sites with relatively low contaminant concentrations, use of edible oil has also proven to be a cost-effective alternative compared to traditional active approaches, such as P&T.

Edible oil deployment serves to decrease chlorinated compound concentrations in two ways: (1) physical sequestration, which reduces effective aqueous concentrations and mobility; and (2) stimulation of anaerobic, cometabolic, and abiotic degradation processes that degrade the cVOCs to less toxic, non-toxic, and/or more readily biodegradable compounds. Edible oils can be deployed to form structured geochemical zones—a series of reaction zones that provide sequential anaerobic and aerobic conditions to maximize beneficial performance, constrain the amount of reagent addition, and minimize collateral impacts of the remediation.

The combination of technologies that will be used for the enhanced attenuation field demonstration at OU-1 includes (1) neat (pure) vegetable oil deployment in the deep vadose zone in the former source area, (2) emulsified vegetable oil deployment within the footprint of the groundwater plume, and (3) monitoring of concentration trends, attenuation mechanisms, and rates in the plume. In the first part, neat oil spreads laterally and forms a thin layer on the water table beneath presumptive soil sources to intercept and reduce future cVOC loading (via partitioning) and reduce oxygen inputs to the local groundwater (via biostimulation). In the second part, emulsified oil forms active bioremediation reactor zones within the plume footprint to degrade existing groundwater contaminants (via reductive dechlorination, cometabolism, or both) and stimulates long-term attenuation capacity in the distal plume (via cometabolism). The third part consists of ongoing monitoring to ensure that groundwater quality does not degrade downgradient of these treatment zones.

3.0 Field Demonstration Goals

The goal of the field demonstration is to show that structured geochemical treatment zones can be established and effectively maintained to decrease cVOC concentrations in groundwater to MCLs in a reasonable time frame.

The overall objectives of the field demonstration are to:

- Assess the performance and viability of attenuation using structured geochemical zones as a remediation strategy for OU-1 groundwater
- Stabilize the plume and minimize/mitigate the potential for plume growth
- Develop the biogeochemical conditions to accelerate progress to remedial goals and transition the strategy to MNA

Data will also be collected to evaluate the feasibility of MNA as a remedy to address cVOC contamination in the OU-1 groundwater. Factors to be evaluated include stability of the plume, degradation rates, and downgradient groundwater quality. The sampling program is presented in the *OU-1 Enhanced Attenuation Field Demonstration Sampling and Analysis Plan Mound, Ohio, Site* (DOE 2014).

4.0 Edible Oil Deployment Design

The selection of edible oil deployment approaches is based on the current configuration of cVOCs in residual soil and groundwater. The design is derived from two mechanisms—partitioning and degradation—combined with standard hydrology and engineering calculations. Injection point construction and oil deployment methods are prepared that emphasize the strategic application of edible oils to address residual secondary cVOC sources in soil beneath the former landfill, as well as in downgradient tertiary sources. Further, the design of the injection points takes into account site lithostratigraphy and the water table surface to assist in developing deployment zones that have the correct geometry to intercept contaminants and effectively treat the groundwater plume.

In order to address the cVOC contamination in both residual soil and groundwater, a two-part deployment has been selected: (1) neat (pure) vegetable oil at the water table beneath areas with the highest residual cVOC concentrations in soil, and (2) emulsified vegetable oil substrate in the areas of highest concentrations of cVOCs in the groundwater plume. In the first part, neat oil injected into the vadose zone spreads laterally and forms a thin layer on the water table to intercept and reduce future cVOC input from residually contaminated soils in the vadose zone. In the second part, emulsified oil injected below the water table stimulates the formation of an active bioremediation treatment zone within the active plume footprint to degrade existing groundwater contamination and any future inputs.

The following sections detail the design elements of the two deployment approaches. In addition, material and equipment specifications, general system layouts, and well point designs are included in appendixes to this document.

4.1 Neat Oil Deployment

The objective of neat oil deployment is to intercept and reduce future cVOC inputs to the groundwater from discrete areas of residually contaminated soil present within the footprint of the landfill. This is accomplished as the neat oil is introduced to the vadose zone immediately above the water table and spreads out, forming a thin but laterally extensive layer at the water table surface. This neat oil layer reduces cVOC loading to the groundwater through the mechanisms of sequestration and reductive dechlorination.

For this design, neat oil will be used. The locations where neat oil will be deployed are based on soil cVOC concentrations greater than 1 milligram per kilogram (DOE 2013), as measured following the waste removal activities in the OU-1 landfill (Figure 1). The amount of oil to be deployed is determined by the following geometric calculation:

$$V_{oil} = \text{(target area) (approximate thickness) (volumetric oil saturation after equilibration)}$$

A zone of influence having a diameter ranging from 30 feet (ft) to 35 ft will be targeted at each deployment point. Table 1 presents the design parameters for the neat oil deployment within the OU-1 landfill footprint.

Table 1. Neat Oil Deployment Design Parameters

Oil type	Food-grade soybean oil
Number of deployment point	6
Area to be treated at each point	700 sq ft–960 sq ft
Thickness of oil layer formed	1 ft
Oil saturation after equilibrium	0.1
Vadose zone porosity	0.25
Calculated volume of neat oil per deployment point	800 gal
Calculated total volume of neat oil required	4,800 gal

Abbreviations:
gal = gallon
sq ft = square feet

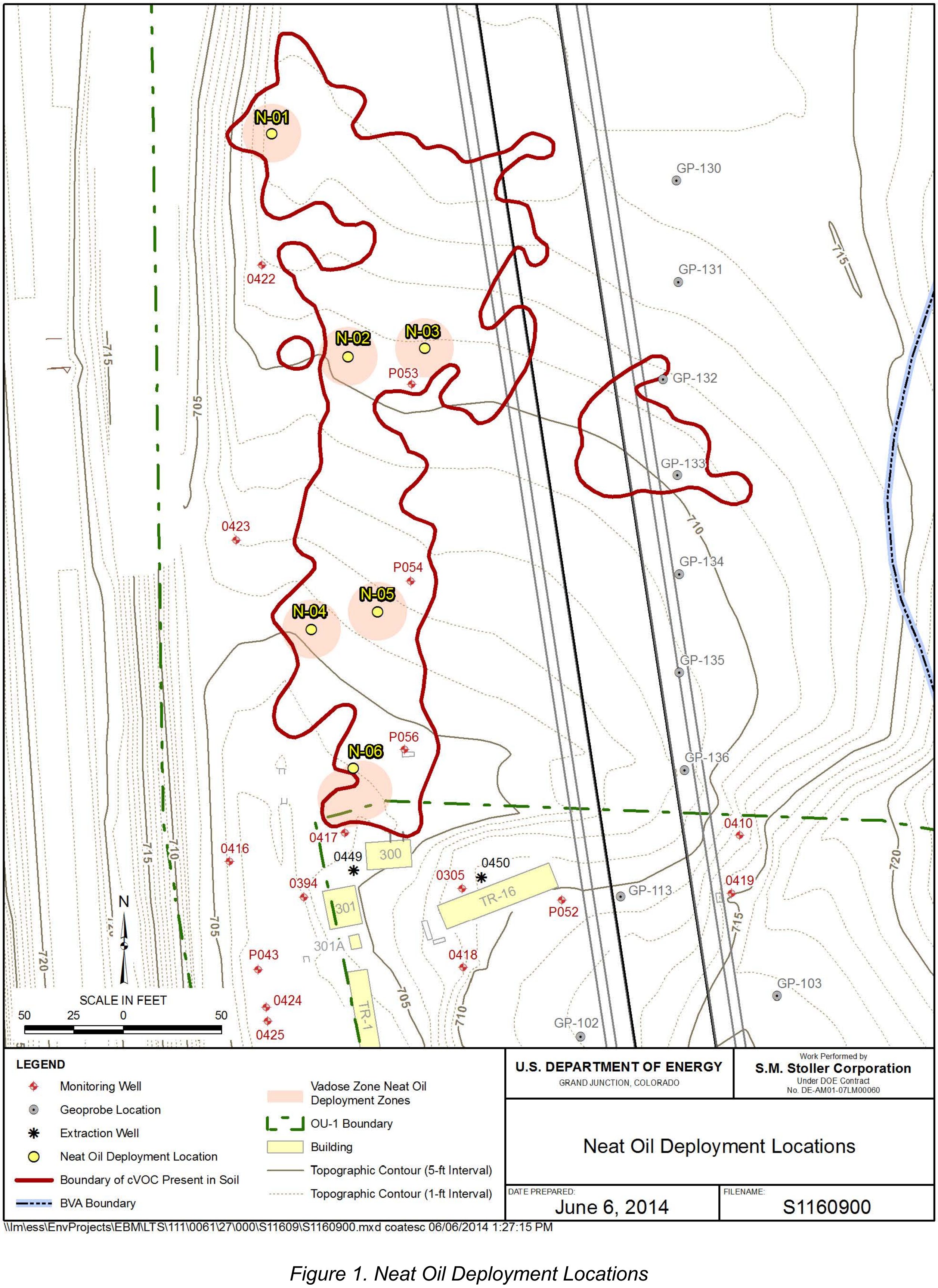

Figure 1. Neat Oil Deployment Locations

The neat oil will be delivered and staged onsite in bulk tanks (e.g., Agmark tank or similar) or smaller volume totes to facilitate simultaneous injection at multiple locations. The oil will be deployed by gravity feed and the target delivery flow rate is 0.1 to 2.0 gallons per minute (gpm) at each location. It is anticipated that the deployment of the neat oil will take 5 to 10 days in the field. Equipment layout schematics, which include equipment and material specifications, are presented in Appendix A.

Neat oil will be emplaced at discrete treatment zones using temporary well points screened directly above the water table in areas with elevated cVOC concentrations in the soil. The temporary wells will be constructed from 1.5-inch Schedule 40 PVC materials and have 5-ft screens. Specific construction requirements for the temporary wells are presented in Appendix B.

Emulsified Oil Deployment

The primary purpose of deploying emulsified oil into the subsurface is to stimulate the formation of active bioremediation treatment zones within the active plume footprint to degrade existing groundwater cVOC contamination and any future inputs. The areas below were selected to create deployment zones to achieve the following objectives:

- Former landfill area—provide treatment of existing groundwater contamination and future mass discharge into the groundwater beneath the residual soil sources
- Mid-plume—limit the magnitude of rebound within the plume
- Downgradient contaminated zone—provide treatment of the contaminated groundwater near wells 0451, 0452, and P060
- Distal zone—provide additional protection to limit plume expansion

For this design, factory-prepared emulsion with amendments will be used. The undiluted emulsion will contain approximately 45 percent soybean oil, carbon substrate initiators (e.g., lactate), appropriate emulsifiers, vitamin B12, and nutrients (e.g., yeast extract). Emulsion shall have median droplet size less than or equal to 1 micrometer and be a commercially available reagent with a documented record of successful use.

Injection locations (Figure 2) were determined using the recent distribution of cVOCs in groundwater and the geochemistry of the aquifer (DOE 2013). Three areas of cVOC contamination above the MCL have been identified in the OU-1 area: (1) beneath the southwest corner of the former landfill, (2) in the vicinity of wells 0410 and 0419, and (3) in the vicinity of wells 0451, 0452, and P060. Groundwater quality data from wells within the cVOC plume footprint depict lower dissolved oxygen concentrations and negative oxidation-reduction potential values, indicating that anaerobic environments occur locally.

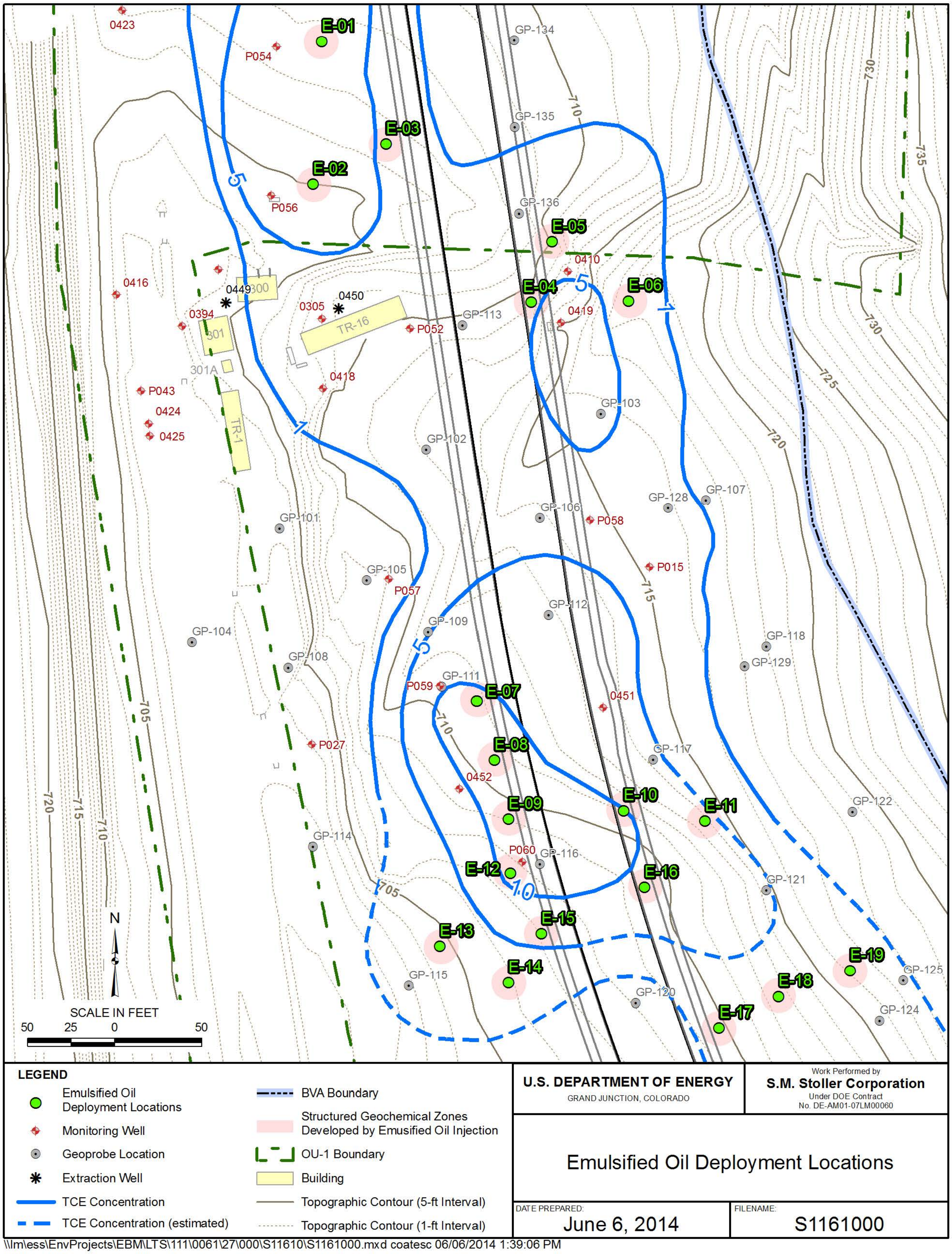

Figure 2. Emulsified Oil Deployment Locations

The amount of emulsified oil to be deployed is based on sediment retention and is determined by the following calculation:

$$\text{Amount of Oil (lbs)} = (\text{Area})(z_e)(\rho_b)(O_R)$$

Where:

Area = πr^2 target deployment area assuming radial flow (ft^2)
z_e = effective treatment height (ft) (screen length)
ρ_b = sediment bulk density pounds per cubic foot (lb/ft^3) (125 lb/ft^3 for a silty sand)
O_R = oil retention (lb oil/lb sediment; based on product used and lithology, values of 0.001 to 0.002 are typical for soybean oil) (0.0015 to take into account silt and clay) (Borden 2006)

The quantity of emulsion needed is then calculated by:

$$\text{V (emulsion in gal)} = \text{lb Oil} / 0.45 / 8.3 \text{ lb/gal}$$

Where:

0.45 = percentage (%) of oil in the standard emulsion

A zone of influence with a minimum diameter of approximately 20 ft will be targeted at each deployment point. Table 2 presents the design parameters for the emulsified oil deployment within the OU-1 landfill footprint. The calculated minimum amounts of emulsified oil and volumes of emulsion and blending water for each location are presented in Appendix C.

Table 2. Emulsified Oil Deployment Design Parameters

Emulsified oil type	45% soybean oil with water balance
Amendments	Lactate, yeast extract, and vitamin B12
Number of deployment point	19
Area to be treated at each point	315 sq ft (approximate)
Blending water	P&T-extracted groundwater
Emulsion mixing ratio	50:1
Calculated total volume of emulsified oil required	4,442 gal

The emulsified oil blended with nutrients will be delivered and staged onsite in either bulk tanks (e.g., Agmark tank or similar) or totes. This will facilitate simultaneous injection at multiple locations and eliminate mixing of the oil and nutrients onsite. The emulsified oil will be blended with treated groundwater from the P&T system to create an emulsion. Mixing will be performed using a mechanic proportioning system (i.e., Dostron) to deliver an emulsified oil and blending water ratio of 50:1. The emulsion will be injected in the subsurface and the target delivery flow rate is 6 to 10 gpm at each location. A distribution manifold system will be used that will allow for simultaneous deployment at multiple locations. The configuration of the deployment well groupings is presented in Appendix C. It is anticipated that the deployment of the emulsified oil mixture will take 30 to 45 days in the field. Equipment layout schematics, which include equipment and material specifications, are presented in Appendix D.

Blending water will be obtained from the P&T system. Groundwater will be extracted from wells 0449, 0450, and 0452 and passed through the air stripper prior to use as blending water. Well 0452 will be converted into an extraction well for the field demonstration and connected to the P&T system in Building 300. Extracting water from well 0452 during the deployment of the emulsified oil will help mitigate the potential to spread contamination downgradient, especially during the injection operations near well P060. Operation of the P&T system using wells 0449, 0450, and 0452 will continue during the deployment of the emulsified oil and for a period of 3 to 4 months following the completion of injection. However, if emulsion is observed in any of the extraction wells during the deployment phase, the well(s) in question will be removed from service to prevent damage to the P&T system and to prevent alteration of the structure of the structured treatment zone.

The emulsified oil mixture will be deployed using temporary wells screened below the water table within the outwash unit at the locations shown on Figure 2. The emulsified oil mixture will be injected under low pressures (i.e., pressure not to exceed 20 pounds per square inch). The temporary wells will be constructed from 1.5-inch Schedule 40 PVC materials. Specific construction requirements for the temporary wells are presented in Appendix E.

5.0 References

DOE (U.S. Department of Energy), 2013. *Field Demonstration Work Plan for Using Edible Oils to Achieve Enhanced Attenuation of cVOCs and a Groundwater Exit Strategy for the OU-1 Area, Mound, Ohio* (Draft), LMS/MND/S11039, prepared for the U.S Department of Energy Office of Legacy Management, December.

DOE (U.S. Department of Energy), 2014. OU-1 *Enhanced Attenuation Field Demonstration Sampling and Analysis Plan, Mound, Ohio, Site* (Draft), LMS/MND/S11745, prepared for the U.S Department of Energy Office of Legacy Management, April.

Appendix A

Neat Oil Deployment Equipment and Materials Specifications

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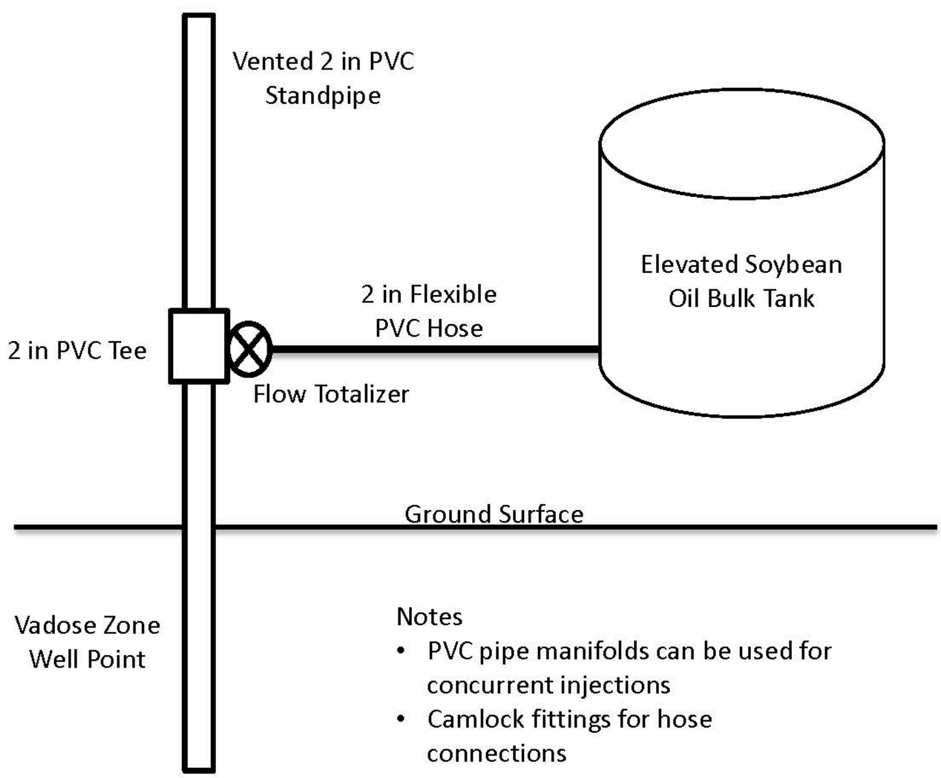

Figure A-1. Neat Oil Deployment—Equipment Layout

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Appendix B

Neat Oil Deployment Temporary Well Point Details

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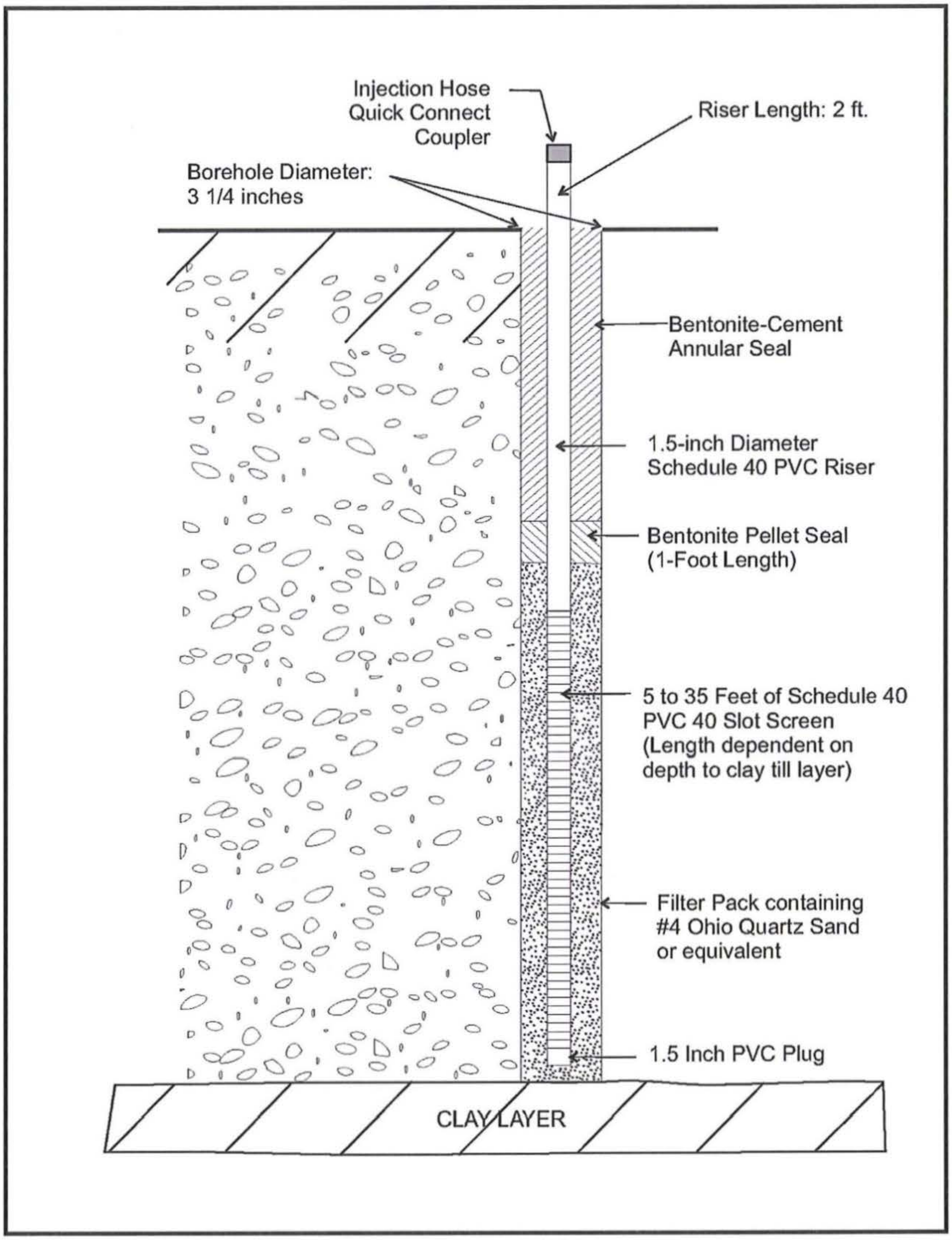

Figure B-1. Neat Oil Deployment—Temporary Well Design

Table B-1. Neat Oil Temporary Well Construction Specifics

Location ID	Northing	Easting	Ground Elevation	Total Depth
N-01	597323	1463928	712.71	35.0
N-02	597210	1463967	710.13	32.5
N-03	597214	1464006	710.74	33.0
N-04	597071	1463949	705.04	27.5
N-05	597080	1463982	706.43	28.5
N-06	597000	1464399	703.90	25.5

Notes:
Total depth is based on water table being present at 678 ft
Screen length = 5 ft

Appendix C

Emulsified Oil and Blending Water Volumes

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Table C-1. Emulsified Oil Volumes

Location ID	z_e (ft)	Oil (lb)	Emulsion (gal)	Volume of Treatment Area (gal)	Volume of Emulsion + Water (gal)	Volume of Water for 50:1 (gal)
E-01	9	530.14	141.26	5,287.30	7,204.19	7,062.93
E-02	9	530.14	141.26	5,287.30	7,204.19	7,062.93
E-03	6	353.43	94.17	3,524.87	4,802.79	4,708.62
E-04	17	1,001.38	266.82	9,987.12	13,607.92	13,341.10
E-05	7	412.33	109.87	4,112.34	5,603.26	5,493.39
E-06	6	353.43	94.17	3,524.87	4,802.79	4,708.62
E-07	17	1,001.38	266.82	9,987.12	13,607.92	13,341.10
E-08	18	1,060.29	282.52	10,574.60	14,408.38	14,125.87
E-09	21	1,237.00	329.60	12,337.03	16,809.78	16,480.18
E-10	10	589.05	156.95	5,874.78	8,004.66	7,847.70
E-11	5	294.52	78.48	2,937.39	4,002.33	3,923.85
E-12	23	1,354.81	360.99	13,511.99	18,410.71	18,049.72
E-13	30	1,767.15	470.86	17,624.33	24,013.97	23,543.11
E-14	29	1,708.24	455.17	17,036.86	23,213.51	22,758.34
E-15	25	1,472.62	392.39	14,686.95	20,011.64	19,619.26
E-16	13	765.76	204.04	7,637.21	10,406.05	10,202.01
E-17	19	1,119.19	298.21	11,162.08	15,208.85	14,910.64
E-18	12	706.86	188.34	7,049.73	9,605.59	9,417.24
E-19	7	412.33	109.87	4,112.34	5,603.26	5,493.39
TOTALS		**16,670.08**	**4,441.80**	**166,256.22**	**226,531.81**	**222,090.01**

Notes

Oil needed based on sediment retention:

lb oil (retention based) = (Area)(z_e)(ρ_b)(O_R)

Where:
Area = πr^2 target deployment area assuming radial flow (ft^2) [314.16]
r = 10 ft
z_e = effective treatment height (ft) [screen length]
ρ_b = sediment bulk density (lb/ft^3) [125 lb/ft^3 for a silty sand]
O_R = oil retention (lb oil / lb sediment; based on product used and lithology, values of 0.001 to 0.002 are typical for soybean oil) [0.0015 to take into account silt and clay] (Borden, 2006)

The quantity of emulsion needed is then calculated by:

Volume emulsion (gal) = lb Oil / 0.45 / 8.3 lb/gal (to account for the fact that standard emulsions are approximately 45% oil)

The total volume of the treatment area is calculated by simple geometry:

Total volume (gal) = (Area)(z_e)(η_e)(7.48)

Where:
η_e = effective porosity (--) [0.25]
7.48 = conversion from ft^3 to gal

The total volume of blending water needed for a 50:1 ratio:

Total volume blending water (gal) = (emulsion)(50)

If the volume of blending water + emulsion is greater than the total volume of the treatment area, then adequate coverage will be achieved.

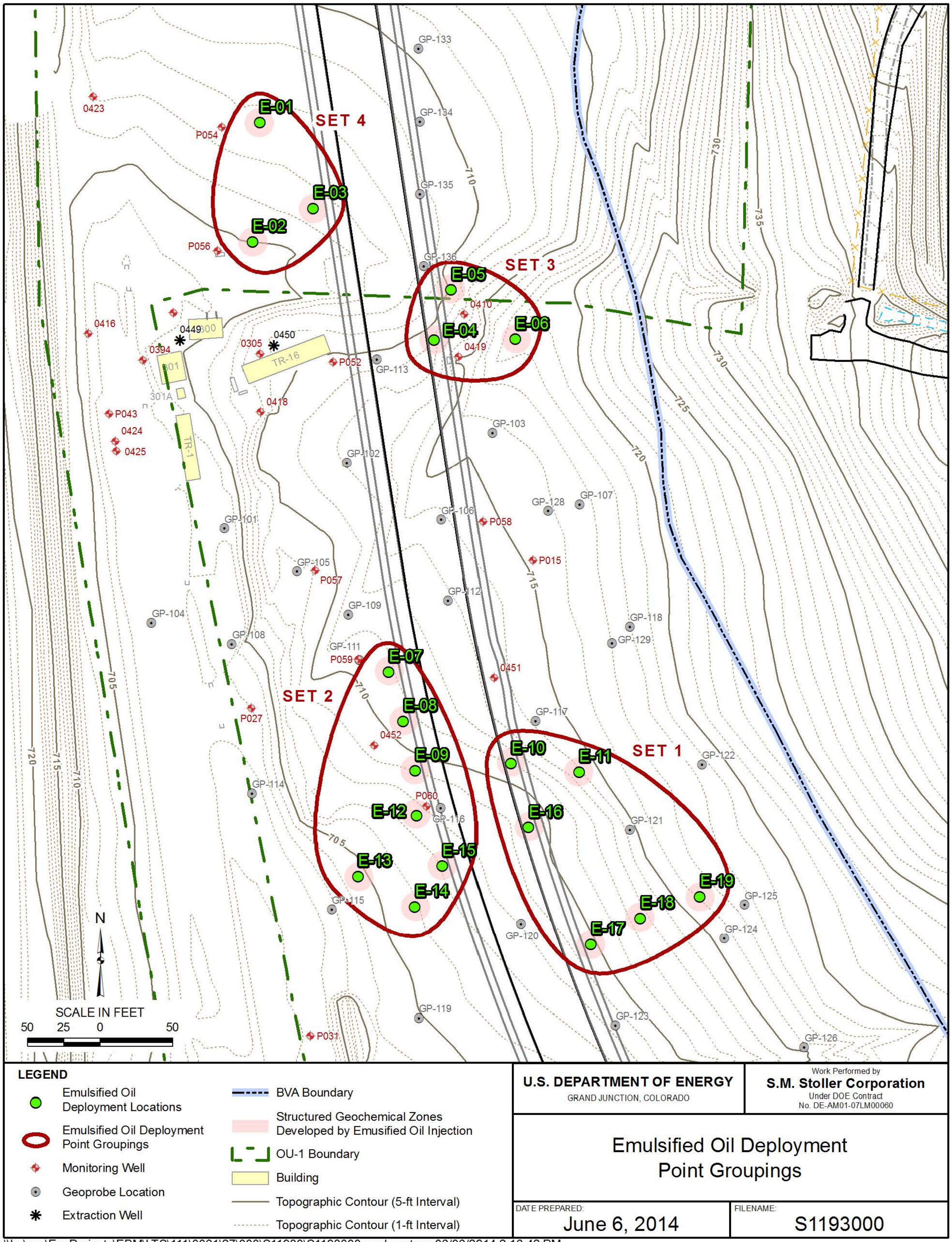

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Figure C-1. Emulsified Oil Deployment—Point Groupings

Appendix D

Emulsified Oil Deployment Equipment and Materials Specifications

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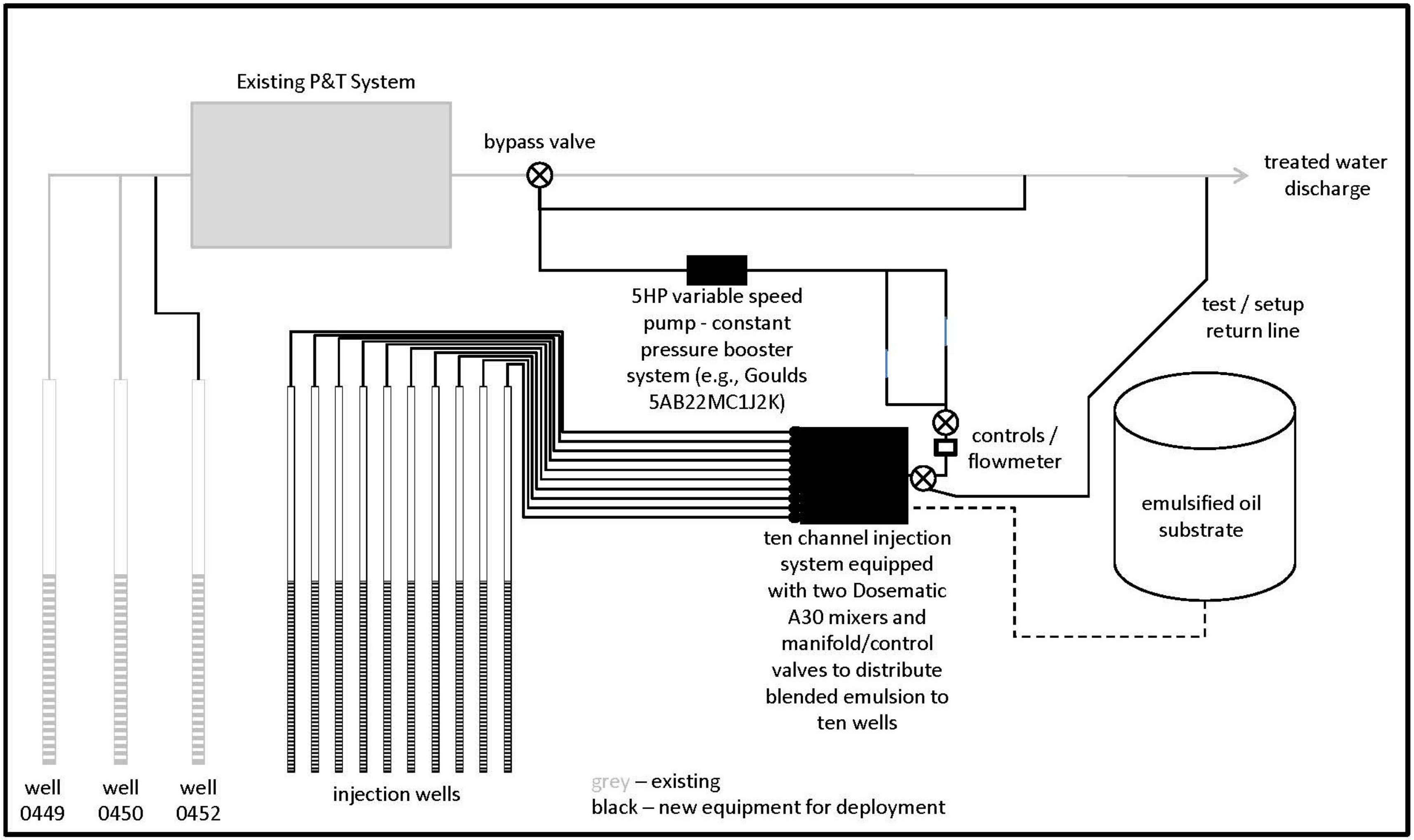

Figure D-1. Emulsified Oil Deployment—Equipment Layout

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Appendix E

Emulsified Oil Deployment Temporary Well Point Details

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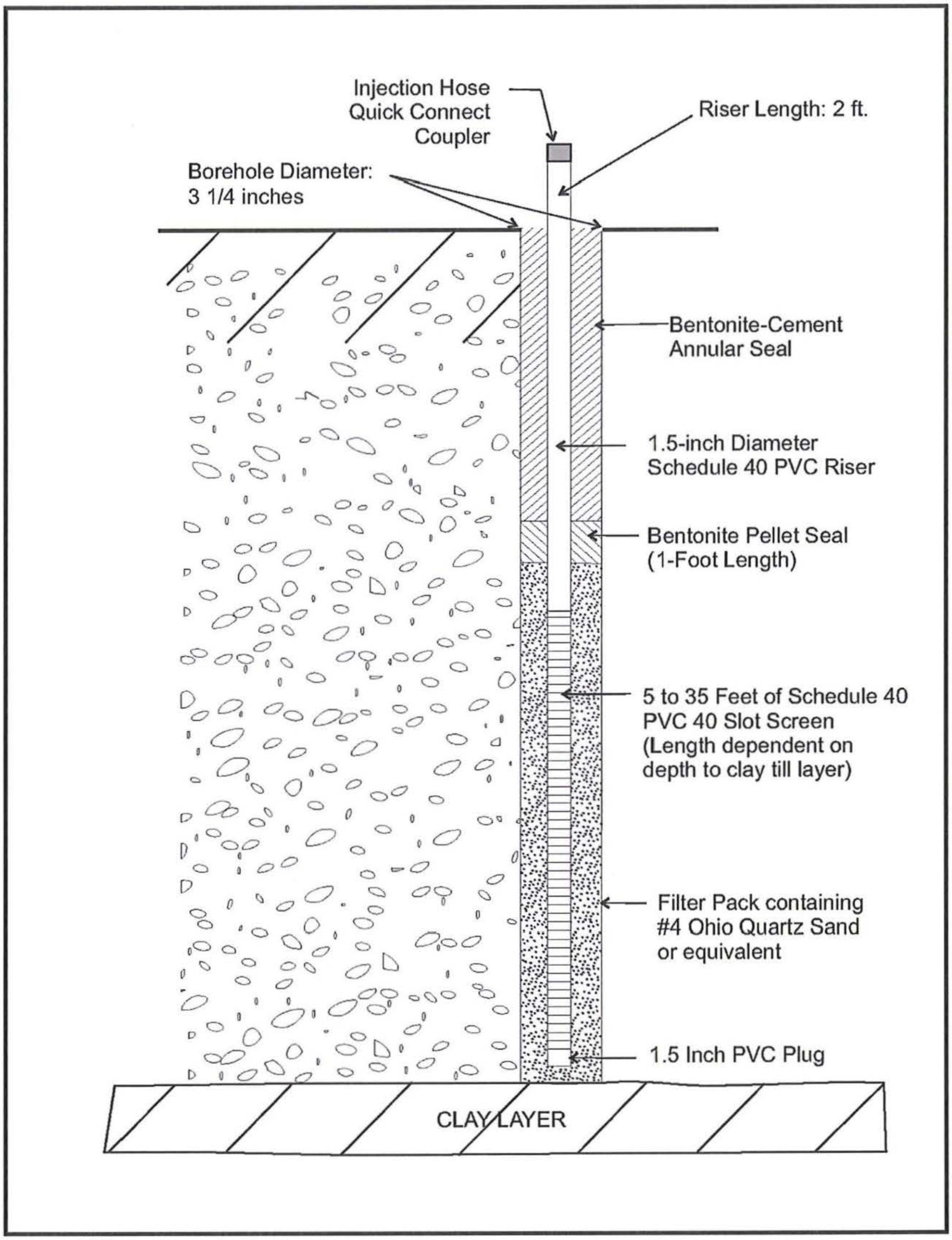

Figure E-1. Emulsified Oil Deployment—Temporary Well Design

Table E-1. Emulsified Oil Temporary Well Construction Specifics

Location ID	Northing	Easting	Ground Elevation (ft MSL)	Bedrock Elevation (ft MSL)	Total Depth (ft)	Screen Length (ft)
E-01	597098	1464025	708.43	668	40	9
E-02	597016	1464020	704.60	6668	37	9
E-03	597039	1464062	712.64	671	42	6
E-04	596948	1464145	713.75	660	54	17
E-05	596983	1464157	713.34	670	43	7
E-06	596949	1464201	718.38	671	47	6
E-07	596719	1464114	711.83	660	52	17
E-08	596685	1464124	712.32	659	53	18
E-09	596651	1464132	712.91	656	57	21
E-10	596656	1464198	713.41	667	46	10
E-11	596650	1464245	713.43	672	41	5
E-12	596620	1464133	711.37	654	57	23
E-13	596578	1464093	704.48	647	57	30
E-14	596557	1464132	705.79	648	58	29
E-15	596585	1464151	712.97	652	61	25
E-16	596612	1464210	713.43	664	49	13
E-17	596531	1464253	712.55	658	55	19
E-18	596549	1464287	712.53	665	48	12
E-19	596564	1464328	716.03	670	46	7

Abbreviations:
ft MSL = feet above mean sea level