Draft
GETS Optimization Work Plan
Queen City Farms
Maple Valley, Washington

April 6, 2017

Prepared for

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Seattle, Washington

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Date:	April 6, 2017
Project No.:	0025178.130.404
File path:	Y:\025\178\R\2017\GETS Opt Work Plan\Sig Page.docx
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LIST OF ABBREVIATIONS AND ACRONYMS

cDCE cis-1,2-dichloroethene
EPA ..... US Environmental Protection Agency
GETS ..... groundwater extraction and treatment system
gpm ..... gallons per minute
Hz ..... hertz
LAI ..... Landau Associates, Inc.
µg/L ..... micrograms per liter
QCF ..... Queen City Farms
RAO ..... remedial action objective
TCE ..... trichloroethene
VOC ..... volatile organic compound

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1.0 INTRODUCTION

This document presents a work plan for design and implementation of optimization measures relevant to the groundwater extraction and treatment system (GETS) at the Queen City Farms (QCF) Superfund Site (Site; U.S. Environmental Protection Agency [EPA] Identification Number WAD980511745), located approximately 3 miles northwest of Maple Valley in King County, Washington. The GETS was constructed as a contingent remedial action to address trichloroethene (TCE) groundwater contamination in the southwest portion of Aquifer 2 at the Site. A detailed description of the Site setting, regulatory background, physical characteristics, and hydrogeologic unit designations and recent monitoring results are provided in previous project documents (e.g., LAI 2011, 2016a, b)L. The Site vicinity is shown on Figure 1.

The GETS was designed to provide hydraulic containment of the TCE plume near the S well area of Aquifer 2, and to minimize migration of TCE in groundwater to meet the short-term remedial action objective (RAO) which is reduction in the size of the Aquifer 2 plume (EPA 1992). System monitoring results to date indicate that the GETS has achieved hydraulic containment in the southwestern portion of the Aquifer 2 TCE plume and is effectively treating influent groundwater TCE concentrations to below treated groundwater discharge limits. Since system startup in February 2015, observed influent TCE concentrations have been between 5.4 micrograms per liter (µg/L) and 3.5 µg/L. This concentration range is 17 percent to 26 percent of the design concentration of 21 µg/L. Influent (i.e., pre-treatment) concentrations have been below the TCE discharge limit of 4 µg/L since 2016. A plot of GETS influent TCE concentrations over time is presented on Figure 2.

1.1 GETS Optimization Objective

While the system is currently accomplishing the objectives of the contingent remedial action, further optimization of the GETS may enhance cleanup processes in Aquifer 2. The optimization measures described in this work plan would increase the maximum system flow capacity, allowing for greater rates of groundwater withdrawal and recharge. Because extraction wells are screened in the bottom of the aquifer, higher system flow capacity should enhance flushing and dilution in the lower half of Aquifer 2. The current conceptual Site model indicates that flushing of clean water (from Main Gravel Pit Lake) is relatively limited in the lower part of Aquifer 2 (LAI 2011, 2016a). Consequently, TCE concentrations in the lower portion of the aquifer have generally been higher and more persistent than in the upper portion of the aquifer. Higher flow rates from the extraction system would increase flushing in lower Aquifer 2, which in turn, should further reduce concentrations through enhanced dispersion. Lower concentrations in Aquifer 2 should increase TCE desorption and back-diffusion, thereby reducing the restoration time frame for the portion of the Aquifer 2 TCE plume on the south end of the QCF property.

The primary purpose of considering optimization measures is to be consistent with the long-term Site RAO of accelerating restoration of Aquifer 2 to its beneficial use (EPA 1992).

1.2 Current GETS System Limiting Factors

The GETS flow capacity is currently limited by the hydraulic loading capacity of the existing air stripper unit, a six-tray Carbonair STAT 80 low-profile air stripper. Field-testing of the air stripper indicated that a functional maximum flow occurs at approximately 97 gallons per minute (gpm), or a maximum air backpressure[1] of 47 inches of water column, whichever is lower. Current extracted groundwater flow through the system regularly nears this functional maximum flow rate. Therefore, the air stripper capacity is currently the primary factor limiting groundwater extraction rates and system flow. While other factors also impose limits on the maximum system flow that is attainable (e.g., maximum pump capacity, pump intake depths, and available hydraulic head), these factors are secondary to the air stripper capacity.

The GETS was designed assuming it would be necessary to treat influent TCE concentrations up to 21 μg/L (highest groundwater concentrations observed at that time). However, observed influent TCE concentrations have been considerably lower than this design concentration since GETS startup (ranging from 3.5 to 5.4 μg/L) and are typically near or below the treated groundwater discharge limit of 4 μg/L[2]. TCE has not been detected in treated effluent at the Site. Therefore, it is apparent that the treatment efficiency of the existing treatment unit is higher than necessary to treat groundwater at the actual influent concentrations. Additionally, if influent concentrations stay the same or continue to decline, it follows that the air stripper would not be necessary for attaining treatment standards.

1.3 GETS Optimization Evaluation

Given the limitations described above, Landau Associates, Inc. (LAI) performed an evaluation of possible optimization measures that would allow higher flows through the system and provide adequate treatment to attain treated groundwater discharge limits (LAI 2016b). The evaluation included two alternatives:

Alternative 1: Diffused Bubble Aerator. To allow a higher volumetric flow rate through the system, the air stripper could be converted into a diffused bubble aeration system (diffused aerator). Specifically, an aeration chamber would be created by removing the air stripper trays and placing a coarse-bubble aerator in the bottom of the air stripper sump that would be supplied with compressed air from the existing blower. Air introduced through the aeration chamber would rise through the water column, producing turbulence and volatilization of volatile organic compounds (VOCs) through air-water mixing.

Alternative 2: Open-Channel Aerator. To permit higher system flow capacities and eliminate the need to continuously operate the blower, the system could be modified to pass influent through an engineered open-air aeration channel, allowing "natural" volatilization of VOCs. The proposed channel would be engineered to maximize volatilization of TCE by creating

[1] Air backpressure is monitored by air pressure gage PIT-301 placed downstream of the blower and upstream of the air stripper unit. The backpressure represents flow resistance in the air stripper, such as that caused by iron oxide deposits occluding perforated trays, or by exceeding the hydraulic loading capacity of the unit.

[2] Observed influent cis-1,2-dichloroethene (cDCE) concentrations (0.8 to 1.5 μg/L) are close to the GETS design concentration (1.5 μg/L) and well below the discharge limit of 16 μg/L. CDCE has never been detected in treated effluent at the Site.

tortuous turbulent flow, minimizing water depth, and maximizing liquid surface area and liquid-air contact.

Selected Alternative. Based on email correspondence with Jeremy Jennings of EPA (EPA Comments on Queen City Farms GETS Optimization; January 24, 2017), EPA expressed a preference for Alternative 1, replacement of the existing tray-style air stripper with a diffused aerator.

2.0 DIFFUSED AERATOR DESIGN

The selected GETS optimization alternative is replacement of the existing tray-style air-stripper with a diffused aerator. The six trays in the existing air stripper will be removed, and the sump portion of the existing unit will be converted into an aeration chamber by installing a series of wide-band coarse bubble diffusers. The following sections describe design elements of the diffused aerator.

2.1 Operational Parameters

The diffused aerator will be designed to provide adequate treatment to influent groundwater while also increasing the system's total flow capacity. Relevant operation parameters include system flow capacity and VOC removal efficiency.

2.1.1 System Flow Capacity

Head losses through the aeration chamber will be reduced in comparison to losses through the existing tray-style air stripper. Since GETS startup, extraction well setpoints have been managed to maintain flows below the functional maximum total flow capacity of 97 gpm[3]. Average total system flows through the GETS since startup have ranged from 62 to 95 gpm. It is estimated that if all the extraction wells were operated at their maximum pumping rates (while maintaining at least 1 ft of safe operating head above the pump intake) the system could generate an additional 12 to 25 gpm flow during summer when groundwater elevations are low, and a somewhat greater amount during seasonally high groundwater conditions (LAI 2016b)[4]. Consequently, the diffused aerator will increase total system flow capacity.

2.1.2 Volatile Organic Compound Removal Efficiency

According to EPA (2016), "Bubble aerators are effective in removing carbon dioxide, VOCs, gasoline components, hydrogen sulfide, methane, and radon from contaminated groundwater." The reported TCE removal efficiency[5] of diffused aeration systems ranges from 53 to 95 percent, depending on the air-to-water ratio delivered by the system (Wang 2006). The recommended minimum range of air-to-water ratios for a diffused aerator is from 5 to 1 (5:1) to 15:1 (Wang 2006) with a recommended contact time of 10 to 15 minutes.

[3] Each of the seven existing extraction well pumps is controlled by a variable frequency drive, which is used to adjust pumping rates to maintain a groundwater level setpoint in each well.

[4] Additional pumping capacity of 12 to 25 gpm was estimated by examining the relationship between pump operating frequency and discharge for each of the seven pumps. For each pump that did not reach maximum pump frequency (60 hertz [Hz]) in summer 2016 when groundwater elevations were near the seasonal minimum, additional capacity was estimated from the frequency/discharge for relationship. Two pumps (EW-2 and EW-5) had reached 60 Hz in summer 2016, so no additional pumping capacity was estimated from them. Additional pumping capacity is estimated to be higher during the winter and spring months when regional groundwater elevations are high.

[5] Removal efficiency of a treatment process is the ratio of the reduction in influent concentration (influent minus effluent concentration) to the total influent concentration).

Under the proposed modification, the system is estimated to produce an influent flow rate of up to 130 gpm. The blower generates a typical airflow rate of around 200 cubic feet per minute. Thus, the anticipated air-to-water ratio will be around 12:1. The estimated contact time in the aeration chamber (120-gallon capacity) would be slightly less than 1 minute (assuming a plug flow scenario).

Although the short contact time anticipated in the modified system is not optimal for VOC removal, the removal efficiency is expected to be adequate to achieve treated effluent discharge limits based on the current and anticipated influent TCE concentrations. Influent water entering the GETS is already near or below the discharge limits, and TCE has a relatively high vapor pressure (58 mm Hg at 20°C) and a high Henry's Law constant of 9.1 x 10^{-3} atm-m^3/mole at 25°C (Watts 1998). Thus, VOC removal rates through the diffused aerator are expected to meet discharge limits while also allowing higher flow rates through the system.

2.2 Mechanical Modifications

To implement the GETS optimization, existing equipment will be modified and new equipment added as follows:

- Existing air stripper modifications:
  - All of the air stripper trays will be removed and stored on-Site
  - Air stripper lid will be attached directly to the top of the air stripper sump
  - Inlet water line will require modification to enter the sump at the new/lower height
  - Air discharge stack will require modification to vent from top of the new/lower height of the lid.
- New equipment added to convert the air stripper sump to a diffused bubble aeration chamber:
  - Weld flange onto inside of air intake or cut exterior ducting off and add bulkhead to air intake opening
  - Add a series of 14 parallel 12-inch long wide-band coarse bubble diffusers down the length of the chamber
  - Add PVC ducting inside sump to wide-band coarse bubble diffusers.

The planned modifications to the air stripper are illustrated on Figures 3 and 4.

2.3 Operational Modifications

Groundwater flow rates from existing extraction wells EW-1 through EW-7 will be raised to the maximum achievable using variable frequency drive pumps subject to the following constraints:

- Individual extraction well drawdown is limited to 1 ft above the pump intake; or
- The total system flow reaches 130 gpm; or
- The maximum pump capacity is reached.

2.4 Performance Monitoring

The goal of performance monitoring is to estimate the VOC removal efficiency, confirm that discharge limits are achieved, and assess groundwater capture under the modified system. Performance monitoring will be conducted in four monthly events as follows:

1. Initial performance monitoring will be conducted within 4 hours of completing the modifications described in Sections 2.2 and 2.3 (allowing time for drawdown levels to stabilize).
2. Confirmation performance monitoring will be conducted at approximately monthly intervals for three consecutive months after the initial monitoring.

Performance sampling will include analysis of VOC concentrations in GETS influent groundwater, treated groundwater effluent, and vapor effluent. Sampling and analysis will be performed consistent with the Field Sampling Plan (LAI 2014). Water samples collected in the initial performance monitoring event will be analyzed for VOCs on an expedited 48-hour turnaround. Concurrent with each performance monitoring event, water level measurements will be collected from Group 1 and Group 2 monitoring locations and extraction wells (LAI 2014). Performance monitoring locations are listed in Table 1.

The proposed modifications are expected to achieve treated effluent discharge limits. However, if initial performance monitoring results indicate that discharge limits are not met by the modified system, EPA will be notified within 24 hours of receipt of laboratory results. GETS flow rates will promptly be reduced to the pre-modification flow rate and a supplemental round of performance sampling will be conducted within 4 hours of achieving the pre-modification flow rate.

If supplemental performance monitoring is necessary, water samples will be analyzed on expedited 48-hour turnaround. The system will be shut down after collection of the supplemental performance samples and will remain off until receipt of laboratory results. Supplemental performance monitoring results would be communicated to EPA within 24 hours of receipt. If results indicate discharge limits are met under the lower pre-modification flow rate, the system will be restarted for continuous operation at the lower flow rate. If discharge limits are not met at the lower flow rate, the system will remain off while additional system modifications are evaluated.

In any event where the bubbler system is deemed not to be effective at obtaining effluent discharge limits, a system evaluation and recommendations for additional modifications will be presented for EPA approval before the restarting the system. System modifications might include installation of a baffle system to control the flow regime in the aeration chamber, for example. Additional performance sampling would be completed after further system modifications, as determined in consultation with EPA.

2.5 Schedule

The modifications to the GETS system and extraction wells described above are planned to occur in June 2017. Initial performance sampling will follow within 4 hours of drawdown stabilizing under the mechanical and operational modifications.

2.6 Health and Safety

LAI employees will follow the Site-specific health and safety plans for sampling (LAI 2014) and for GETS operations and maintenance (LAI 2015) during implementation of this work plan. Prior to the start of each workday, a brief safety meeting will be conducted with all field personnel, and a daily health and safety form will be completed.

3.0 REPORTING

A GETS optimization completion report will be prepared following completion of the modifications described herein. The purpose of this report will be to document the "as-built" configuration of the modified GETS treatment unit and provide post-construction performance monitoring results. The report will include a summary of system modifications, as-built drawings, discussion of new operational parameters (e.g., new flow rates, drawdown, and capture), tabulated performance sampling results, and laboratory reports. A draft report will be submitted to EPA within 60 days of receipt of final performance monitoring laboratory results.

4.0 USE OF THIS REPORT

This work plan has been prepared for the exclusive use of The Boeing Company and EPA for specific application to the subject property. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

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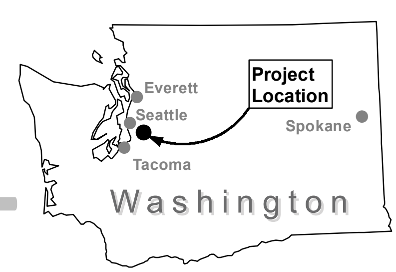

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Data Source: ESRI 2008

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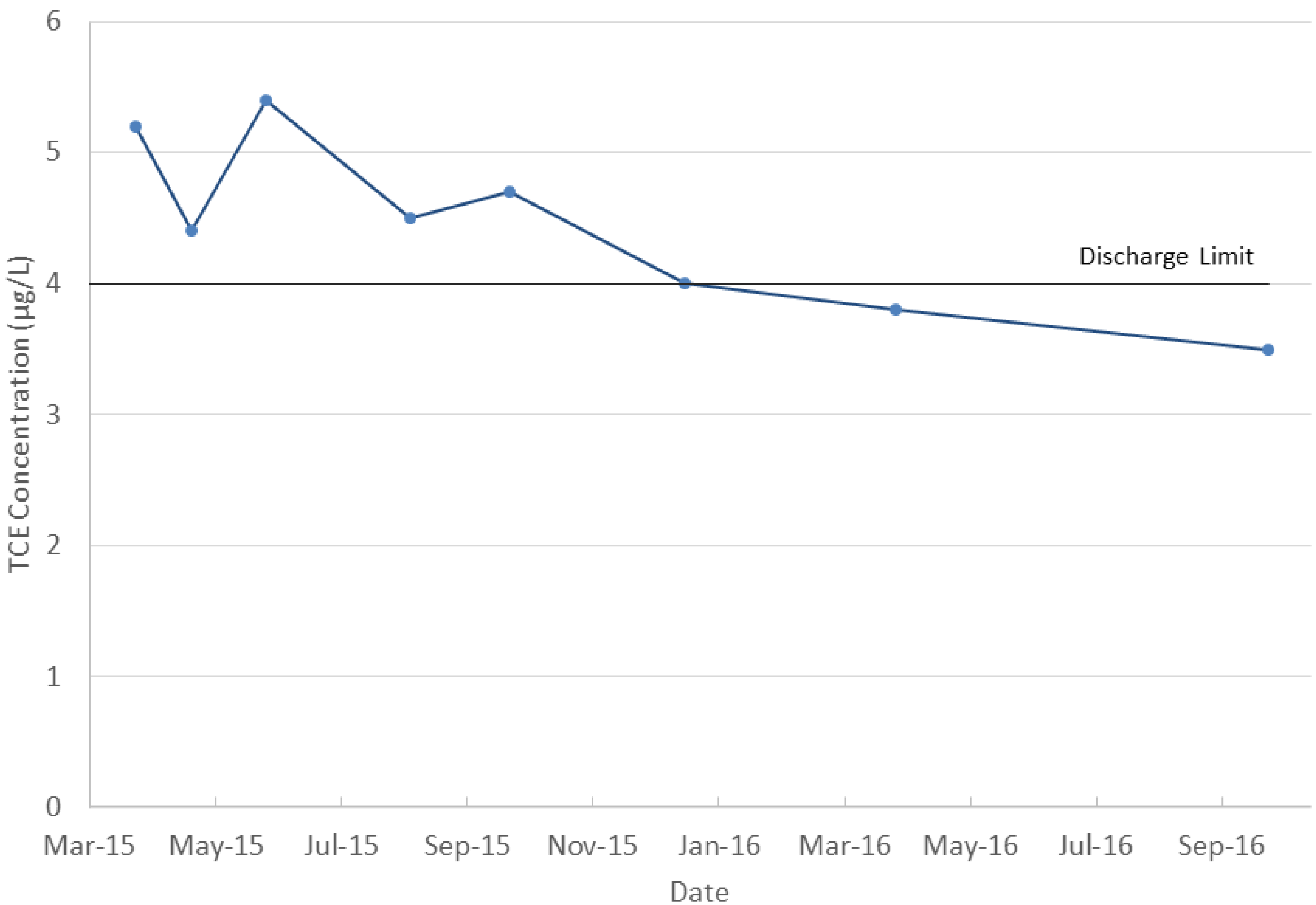
Queen City Farms Maple Valley, Washington	**Vicinity Map**	Figure 1



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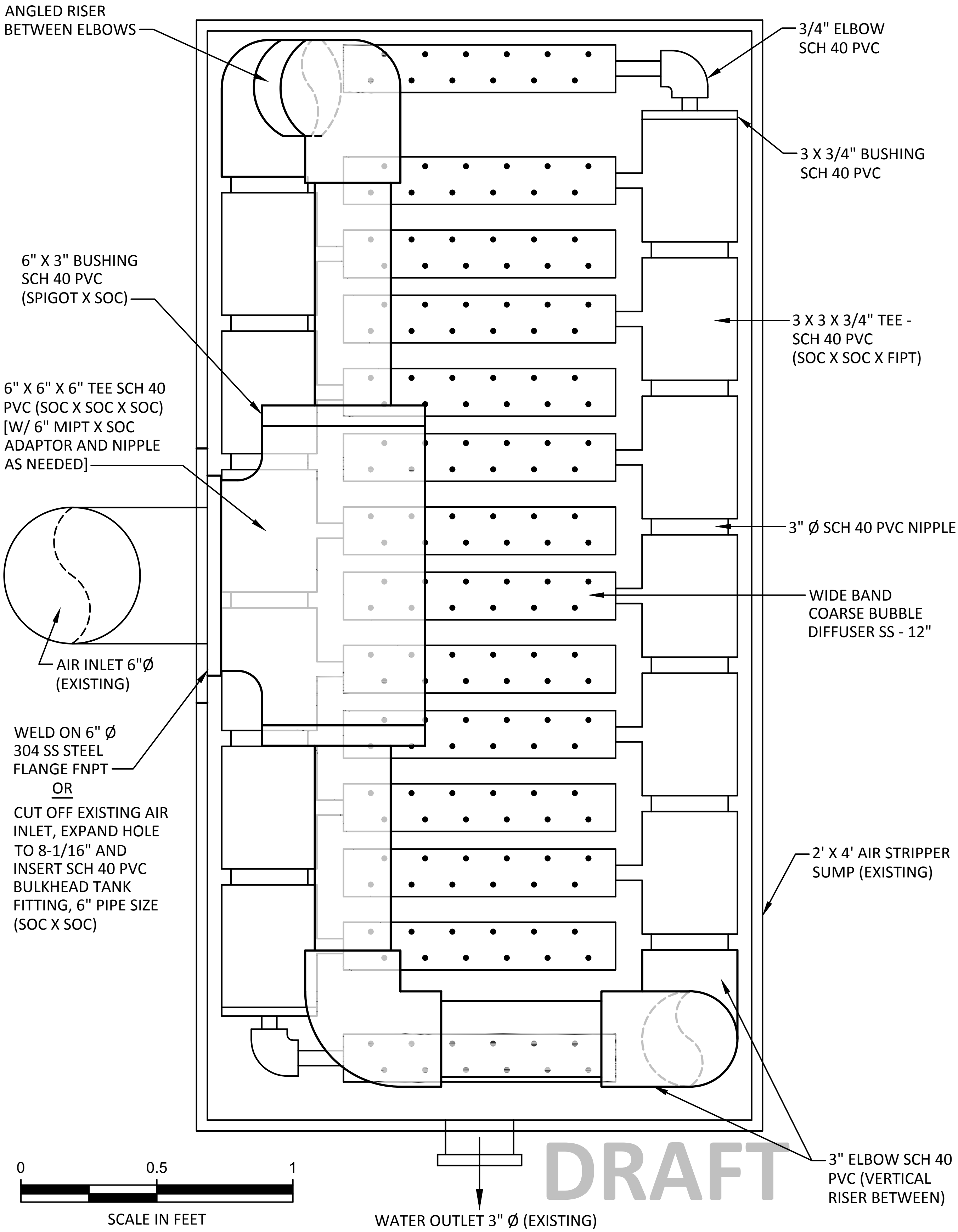
Queen City Farms Maple Valley, Washington	**Influent Trichloroethene Concentrations**	Figure 2



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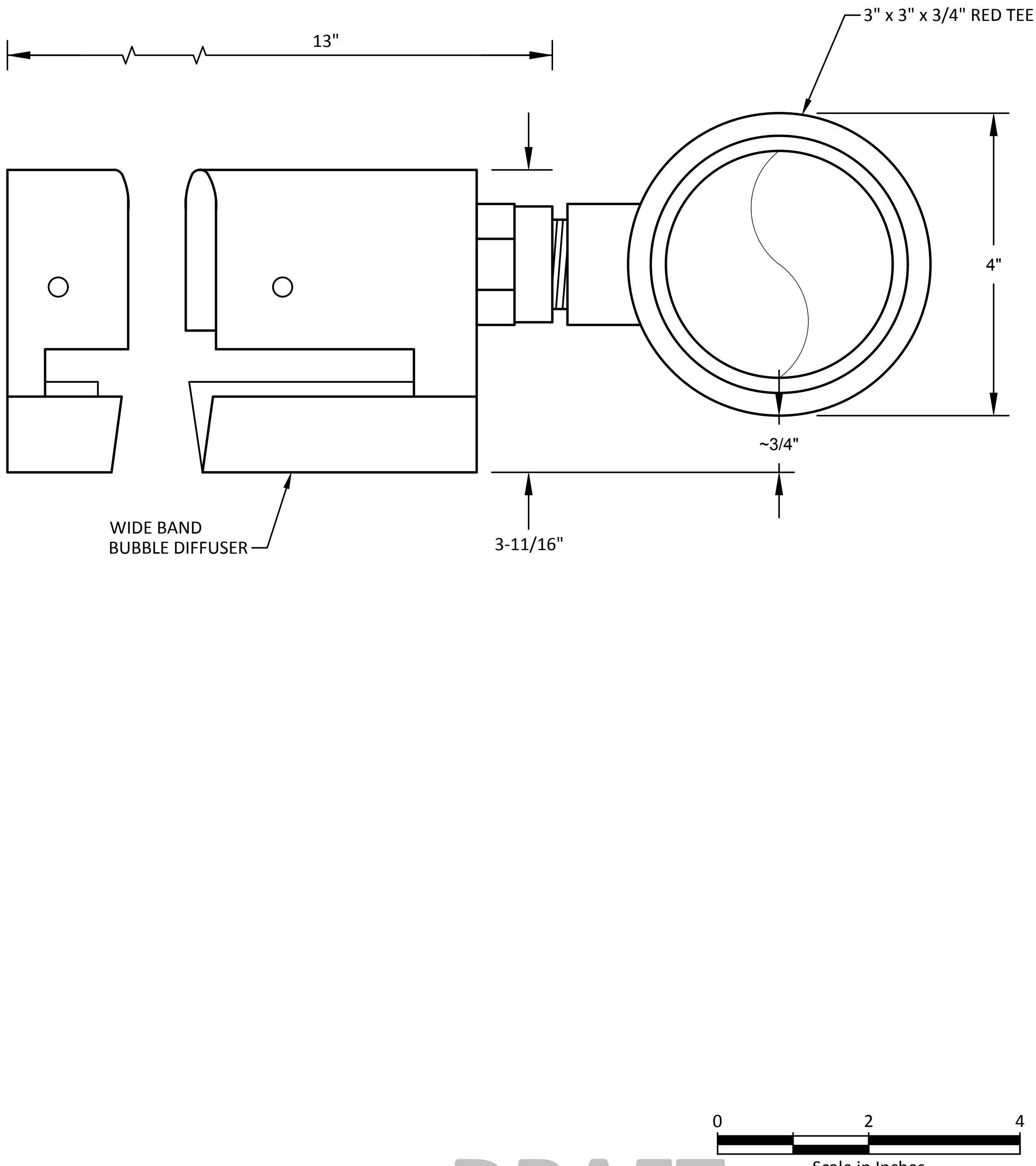
Queen City Farms
GETS Optimization

Air Stripper Sump Conversion to Aeration Chamber Detail

Figure 3



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Wide Band Diffuser Connection Detail

Figure
4

Table 1
GETS Optimization Performance Monitoring Matrix
Queen City Farms
Maple Valley, Washington

Event / Date [a]	First		Second		Third		Fourth	
	Jun-17		Jul-17		Aug-17		Sep-17	
LOCATION ID	**WL**	**WQ**	**WL**	**WQ**	**WL**	**WQ**	**WL**	**WQ**
GROUP 1 WELLS								
S-2	x		x		x		x	
SA-2	x		x		x		x	
SB-2	x		x		x		x	
SC-2	x		x		x		x	
SD-2	x		x		x		x	
SE-2	x		x		x		x	
H-2	x		x		x		x	
I-2	x		x		x		x	
N-2	x		x		x		x	
O-2	x		x		x		x	
U-2	x		x		x		x	
GROUP 2 WELLS								
D-2	x		x		x		x	
I-2a	x		x		x		x	
IB-2	x		x		x		x	
IB-2a	x		x		x		x	
R-2	x		x		x		x	
S-2a	x		x		x		x	
SF-2 (piezometer)	x		x		x		x	
U-2a	x		x		x		x	
I-3a	x		x		x		x	
IA-3a	x		x		x		x	
IB-3a	x		x		x		x	
SD-3a	x		x		x		x	
U-3a	x		x		x		x	
EXTRACTION WELLS								
EW-1	x		x		x		x	
EW-2	x		x		x		x	
EW-3	x		x		x		x	
EW-4	x		x		x		x	
EW-5	x		x		x		x	
EW-6	x		x		x		x	
EW-7	x		x		x		x	
OTHER								
GETS Vapor Discharge [b]		x		x		x		x
GETS Influent		x		x		x		x
GET System Effluent		x		x		x		x
Lake Level Monitoring	x		x		x		x	
MGPL Staff Gauge	x		x		x		x	

Notes:

(a) Monitoring dates are approximate.
(b) For GET System Vapor Discharge, "WQ" represents air quality sampling, not water quality sampling.

Abbreviations/Acronyms:

ID = identification
GETS = groundwater extraction and treatment system
MGPL = Main Gravel Pit Lake
WL - water level measurement
WQ = water quality analysis