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Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Glen Dodge, Cascade Columbia
From: Tom Colligan, Floyd|Snider
Date: May 15, 2014
Project: Fox Avenue
Re: **Biopolish Treatment Plan Addendum**

This addendum to the Biopolish Treatment Plan (provided to Ecology on December 31, 2013) provides an update on the current subsurface temperatures in the thermally treated areas of the Fox Avenue Site, provides additional details on the upcoming injections of substrate and amendments to site groundwater, and provides a schedule for performance monitoring of groundwater for the remainder of 2014.

SOURCE AREA BIOPOLISH INJECTION WELLS

Twenty-two new 2–inch-diameter injection wells were installed in February 2014 in the thermally treated source areas, as called out in the Biopolish Treatment Plan. Three of these were installed in the loading dock area and 19 were installed in the main source area. The three in the loading dock are all deeper injection wells targeting the contaminants in the 2nd Water Bearing Zone (WBZ); they complement the two existing shallow injection wells that were installed in the loading dock in late 2013.

The 19 new injection wells installed in the main source area include 8 shallow wells and 11 deeper wells. The biopolish treatment area is smaller than the thermal treatment footprint. The concentrations of carcinogenic volatile organic compounds (CVOCs) following thermal treatment are much reduced, indicating that thermal treatment has significantly improved groundwater quality. The site plan showing the current injection and monitoring well configuration is shown on Figure 1.

CURRENT GROUNDWATER TEMPERATURES

Temperature monitoring points (TMPs) B14 and E18 were left on-site by TRS to monitor underground temperatures following thermal treatment. B14 is located in the West Rail Area and reaches a depth of 17 feet. E18 is located in the Flammables Shed and reaches a depth of 65 feet. Each of these TMPs include multiple thermocouples that allow monitoring of subsurface groundwater temperatures at different depth intervals. Figure 2 shows a chart of post-thermal aquifer temperatures in both the 1st and 2nd WBZs up through April of 2014 and a future prediction line for continued cooling. This figure shows that temperatures in the 1st WBZ are higher than in the 2nd WBZ. Temperature trendlines predict that aquifer temperatures in the 2nd WBZ will all be less than 35 ºC in July. 1st WBZ temperatures may not drop to 35 ºC until August or September.

It is generally accepted that bacteria capable of dechlorination (*Dehalococcoides* spp.) cannot thrive at temperatures greater than 50 °C. The optimum temperature for injection is 35 °C.

POST-THERMAL BIOPOLISH TREATMENT PLAN

Loading Dock Area

1st Water Bearing Zone

Biopolishing has already been started in the Loading Dock Source Area. It began in late October 2013 when two new injection wells were installed to take advantage of the more rapid cooling that was occurring in this area. After well development, food-grade waste sugars were injected into the thermally treated area, followed by bioaugmentation. Bioaugmentation was accomplished by the injection of a limited amount of site groundwater from nearby well RI-IW-7. Prior bacterial census data for groundwater from this well indicated a strong population of dechlorinating bacteria. The introduction of these bacteria into the injection wells in the Loading Dock Source Area inoculated the thermally treated groundwater with the correct bacteria needed for dechlorination.

One more injection event of approximately 500 gallons total of soluble waste sugars will occur in May of 2014 in these two wells.

2nd Water Bearing Zone

Biopolishing will involve a series of three injections to treat the residual volatile organic compounds (VOCs) in this area. The goal of the first injection is to bioaugment the existing bacterial and establish stronger reducing conditions for subsequent growth of the bacteria. Cultured bacteria (AM3-S) and nutrients will be used for this purpose. A pH buffer will be added as well. The solution of buffer and bacteria will be injected into the three deeper injection wells. After the solution is injected, ethyl lactate (the substrate) diluted to 5 percent strength will be injected into the wells. Municipal water chase will be introduced to distribute the amendments and substrate away from the injection wells, which are located upgradient of the plume.

The second injection will occur approximately 60 days after the first injection and expand the distribution of organic carbon across the target treatment area. A total of 750 pounds of a solution of multiple electron donors, nutrients, and pH buffers (ReducED AQ) will be injected along with a biologically derived surfactant (ReleaSE-Gx) to promote release of tetrachloroethene (PCE) and trichloroethene (TCE) from soils. This solution will be dissolved into 1,000 gallons of municipal water and injected into each well. Following the amendment injection, a 1,000-gallon municipal water chase will be injected to distribute amendment away from each well.

The third injection will occur approximately 90 days after the second injection to maintain and further distribute organic carbon across the target treatment area. This will involve injection of additional nutrients and pH buffer along with approximately 1,000 pounds of ethyl lactate (at 2 percent strength with 1,000 gallons of chase water) per well to further promote dechlorination across a wider downgradient area.

Main Source Area

Given the existing residual concentrations of CVOCs in the Main Source Area, bioremediation will be achieved through biostimulation and bioaugmentation complimented by abiotic (i.e., non-bacteriological) destruction. Biostimulation is achieved through injection of electron donor substrate(s) to create reduced aquifer redox conditions required for complete reductive dechlorination and to "feed" the bacteria responsible for reductive dechlorination. For this purpose, an emulsion of vegetable oil (Textrol BR, or TBR) will be the primary electron donor injected to the Main Source Area, supplemented with a smaller mass of sugar. Vegetable oil more slowly ferments and so provides a long-term, sustained source of donor to aquifer bacteria and also impacts aquifer pH much less than simple, soluble donors (e.g., sugar). Emulsified vegetable oil also provides additional benefits. For example, vegetable oil becomes immobile in the source zone at residual saturation within the aquifer matrix, which keeps the dissolved and partitioned contaminant mass from moving downgradient. It also preferentially adsorbs residual chlorinated source mass. Supplemental donor in the form of soluble sugar will be used along with the TBR to provide a fast-release donor to quickly achieve the highly reducing aquifer conditions required for complete reductive dechlorination.

Bioaugmentation will be performed within the 1st WBZ only through use of site groundwater for mixing injection fluid. Groundwater will be extracted from wells along Fox Avenue (downgradient of the Electrical Resistance Heating [ERH] area) where aquifer temperature did not increase substantially and prior testing has indicated elevated concentrations of desired dechlorinating bacteria.

In contrast, the elevated post-thermal vinyl chloride (VC) concentrations in the 2nd WBZ indicate substantial rebound of dechlorinating micro-organisms following ERH and no need for bioaugmentation. Bioaugmentation is, therefore, not necessary in this zone and City of Seattle water will be used for mixing injection fluids in the 2nd WBZ wells.

Approximately 52,000 pounds of TBR (composed of soy oil and soy lecithin as a surfactant) will be emulsified with mix water and injected to the aquifer. TBR will constitute 5 percent of the overall injection volume, although individual wells will receive approximately 3 to 7 percent TBR in order to focus treatment on zones of greater contamination. Corn syrup will be diluted to 1 percent sugar by weight in the injection solution delivered to each well.

Ferrous sulfate will also be injected to supplement naturally occurring iron and sulfide for enhanced formation of iron sulfide minerals responsible for the abiotic destruction (reductive elimination) of TCE and cis-dichloroethene (cDCE). Biostimulation and ferrous sulfate injection will be performed in both WBZs. Yeast extract and phosphate will be provided as nutrients. Yeast extract serves as an electron donor and provides the micronutrients important to bacterial growth. Phosphorus, an essential micronutrient for bacterial growth and metabolism, is provided by the soy lecithin component of the TBR. All wells will receive sugar and iron sulfate at approximately 1 percent and 2 percent weight, respectively.

Northwest Corner

The last enhanced reductive dechlorination (ERD) injection event occurred in the first half of 2013 and included the injection of soluble sugar in wells in the Northwest Corner. One more injection event of soluble sugar will occur in May of 2014.

MONITORING

Wells

Four new monitoring wells will be installed in the Main Source Area and three in the Loading Dock Source Area to measure compliance and monitor the performance of the biopolish as shown on Figure 1. Two of these new wells will be shallow to monitor the 1st WBZ and the other four will monitor the deeper 2nd WBZ. Baseline samples will be collected in May 2014 following well development. These wells, as well as 15 existing wells (including 4 wells on the Whitehead Property), and several injection wells will be sampled quarterly to semi-annually during the first year after the injections to monitor performance site-wide. Samples will be analyzed for the same suite of analytes as those previously done for ERD performance monitoring (e.g., VOCs, total organic carbon, sulfate, ethene, ethane, methane). Results will be provided to Washington State Department of Ecology (Ecology) in a summary 2014 annual report.

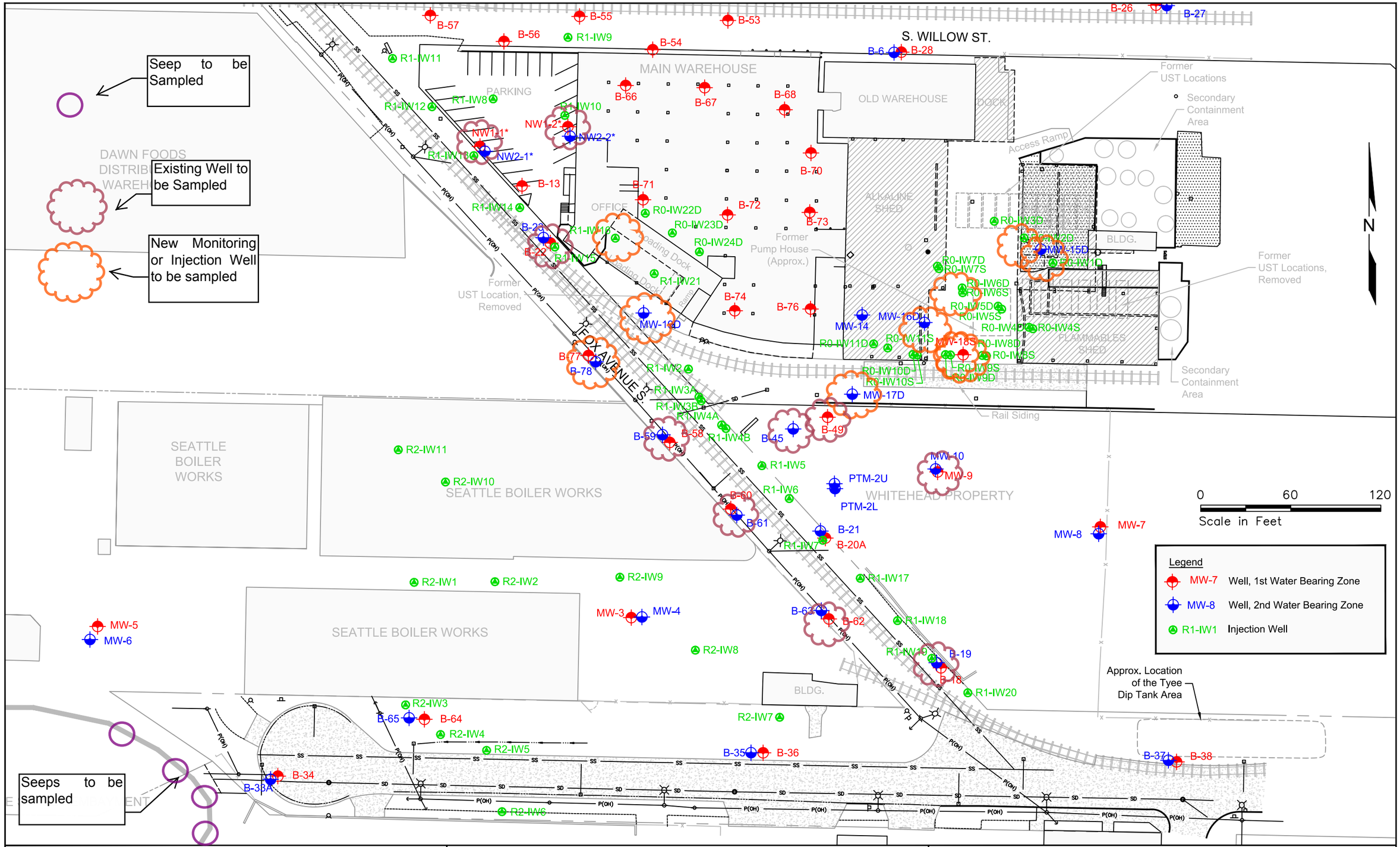
Seeps

In 2013, contaminant concentrations in three of the four seeps were in compliance with the final cleanup levels. Resampling of the seeps will occur in May 2014 during a minus tide to evaluate whether contaminant concentrations in all of the seeps have achieved the cleanup levels. If not, installation of additional injection wells upgradient of the seeps will be considered, and a plan for seep treatment will be proposed to Ecology at that time.

ATTACHMENTS

Figure 1 Current Site Map with Wells to be Sampled

Figure 2 Post Thermal Aquifer Temperatures



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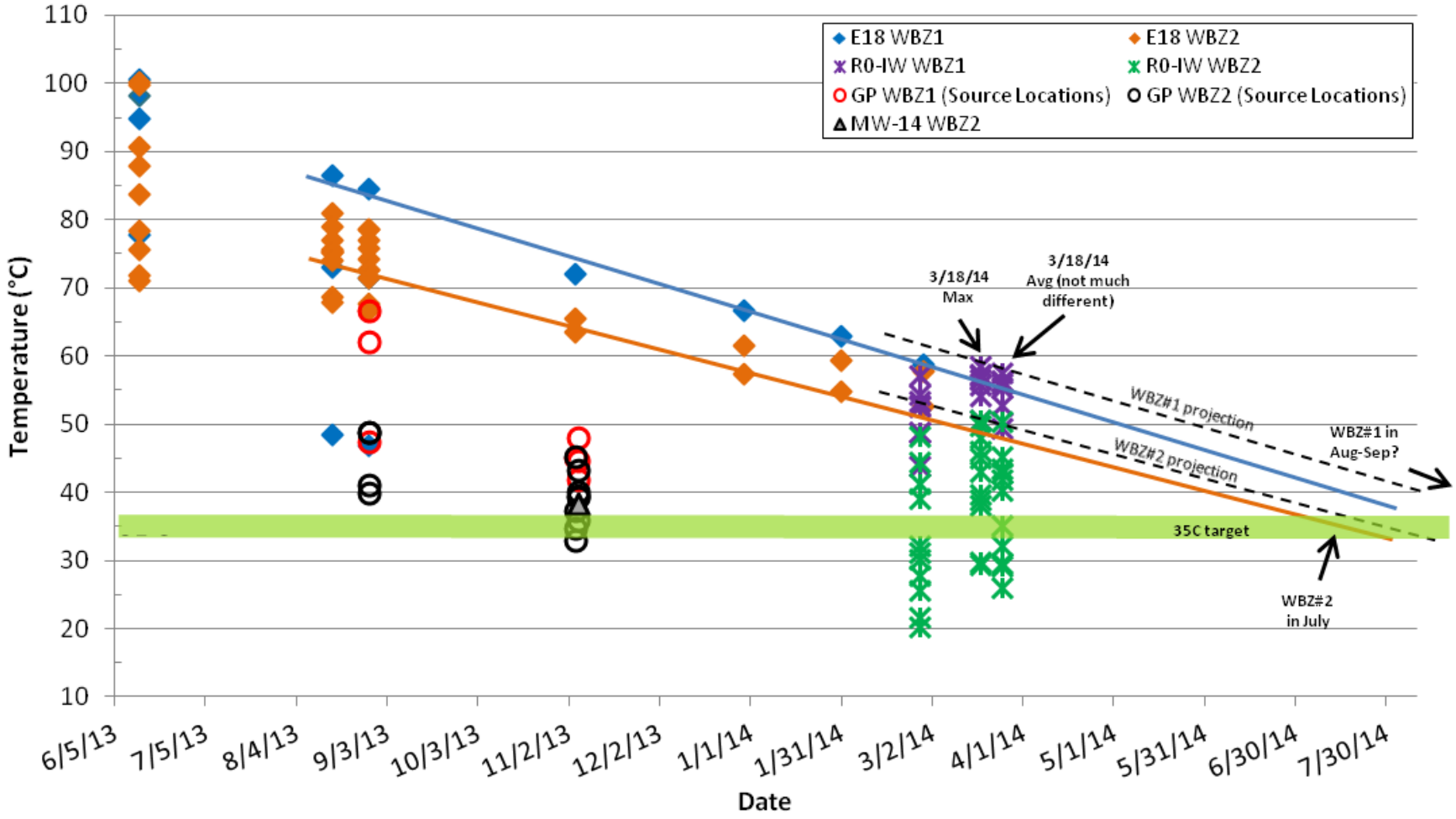
Fox Avenue Site
Seattle, Washington

Figure 1
Site Plan with Wells to be Sampled

DWG NAME: K:\Project\clients\Floyd and Snider\Fox Ave 2012\CAD\FoxAve2012_021.dwg
DATE: 5/7/2014 1:27 PM



LANDAU ASSOCIATES

Fox Avenue Remediation Trust Fox Avenue Site Seattle, Washington	**Post Thermal Aquifer Temperatures**	Figure 2