March 16, 2015

Project 0087700012

Mr. Ed Jones
Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, Washington 98008-5452

Sent via e-mail: ejon461@ecy.wa.gov

Subject: **1,4-Dioxane Remediation Approach Focused Feasibility Study Response to Comments**
Stericyle Georgetown Site, Agreed Order DE 7347
Seattle, Washington

Dear Mr. Jones:

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), has prepared this response to comments on behalf of Burlington Environmental LLC, a wholly owned subsidiary of PSC Environmental Services, LLC (PSC), which is a wholly owned subsidiary of Stericycle Environmental Solutions, Inc. (Stericycle), for the Stericycle Georgetown site located in Seattle, Washington (the site). This letter addresses comments on the 1,4-Dioxane Remediation Approach Focused Feasibility Study (FFS) memorandum, received by Stericycle on February 13, 2015 from the Washington State Department of Ecology (Ecology). Ecology requested the submittal of supplemental information for several comments (1, 3, 6, 9, 10, 19, and 20) within 21 days, but did not request further revision of the FFS. On February 17, 2015, Stericycle requested and Ecology approved an extension to 30 days for response submittal (to March 16, 2015). Ecology also provided a draft of the agreed order amendment for Agreed Order No. DE 7347 (draft AO) to Stericycle on February 18, 2015.

Ecology's comments are pasted below with Stericycle's response following in italics.

Comment 1:

"Page 5, Section 3.0. In our comments on the draft (October 1) Memorandum Ecology asked that the language in this section (Remedial Action Objectives) be supplemented with more specific objectives for the 1,4-dioxane cleanup action. Specifically, we asked that Section 3.0:

- provide the 1,4-dioxane cleanup standard for the site, including the cleanup level concentration, the exposure pathway this cleanup level is intended to protect (i.e., ingestion of contaminated fish/shellfish, harvested from the Duwamish River), and the Point(s) of Compliance where dioxane groundwater cleanup levels must be met;
- identify the restoration timeframe goal (or goals, if goals differ per areal depth) for those groundwater areas and depths where dioxane currently exceeds cleanup levels east and west of 4th Ave. S; and,
- describe any dioxane "remediation levels" (or other short-term indicators of successful remediation progress) that PSC expects the action to attain. This would include

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> shorter-term goals the action needs to attain to ultimately achieve the desired restoration timeframe.

This information remains absent in the January 16 version of Section 3.0. The information will certainly be needed to develop the AO Amendment and during preparation of future Design documents. But Ecology asked that it also be included in the revised memorandum to communicate PSC's long-term restoration and short-term concentration reduction goals. Without presentation of this information, how does ·the company expect reviewers of the document (both at Ecology and among the public) to concur that the mass reduction alternatives the memorandum has developed and evaluated are likely to achieve the site's cleanup goals?

For example, the company has chosen to target mass reduction in the vicinity of well 127 because this is the area "containing the highest [1,4-dioxane] mass density." From Ecology's perspective, the reason for the new dioxane action is to hasten attainment of cleanup standards and improve our confidence that this attainment will occur within a reasonable time frame. We agree with PSC that the most cost-effective approach for doing this is to reduce dioxane mass in the most contaminated areas of the groundwater plume. We also agree that the 127 area is likely to contain the highest density of contaminant mass. But by not identifying the company's long-term restoration or short term concentration reduction goals and their associated timeframes, it is unclear: a) why the targeted area for mass reduction should be limited to the well 127 vicinity, and b) how much mass reduction needs to occur (in the well 127 vicinity or in other parts of the plume) for the action to be successful.

As part of the near-future process of developing a draft AO Amendment (which includes revisions to the 2010 CAP), please submit the following information: a) the restoration timeframe goal PSC proposes for site groundwater contaminated with 1,4-dioxane; and b) supporting rationale for why, based on this goal, the targeted area for full-scale ISCO mass reduction should be limited to the well 127 vicinity."

> *Ecology has proposed 2032 as a reasonable restoration timeframe for 1,4-dioxane cleanup attainment in the draft AO sent to Stericycle on February 18, 2015. Ecology notes that this is the same restoration timeframe as for other contaminants in the 2010 Cleanup Action Plan (CAP). Stericycle accepts 2032 as a reasonable restoration timeframe at this time, but would like to emphasize that 1,4-dioxane's source, potential exposure pathways, and behavior in situ are very different from the "other contaminants" that the 2032 time frame in the CAP is based on. The source for 1,4-dioxane is likely secondary, but has not been pinpointed (although extensive additional investigations have been completed since 2010). The source for 1,4-dioxane also spans several blocks over multiple different properties, making further delineation extremely difficult. This uncertainty in the exact location and extent of the source of 1,4-dioxane greatly reduces the accuracy of any prediction for attainment of cleanup levels. However, 1,4-dioxane concentrations above the cleanup levels are at depth (primarily greater than 35 feet below ground surface) and there are no drinking water sources in the affected groundwater plume. Since 1,4-dioxane is not volatile, is completely miscible in water, and has little affinity for soils, 1,4-dioxane will migrate with groundwater towards the Duwamish Waterway. As a result, the only current potential exposure pathway for 1,4-dioxane is discharge of groundwater to the Duwamish Waterway. The cleanup level for 1,4-dioxane for*

the site is based on discharge of groundwater to the Duwamish and the site cleanup level is 78.5 parts per billion (ppb). However, current concentrations of 1,4-dioxane in groundwater are already below cleanup levels prior to reaching the waterway; hence, there is no current risk to receptors. Under the Model Toxics Control Act (MTCA), the conditional point of compliance (CPOC) is set at the Stericycle property boundary and as a result the cleanup standard needs to ultimately be met at the CPOC despite the absence of any risk to receptors.

For the above reasons, Stericycle has worked with Ecology to provide remedial alternatives that focus on mass removal. As noted in the FFS, limited technologies are available for mass removal of 1,4-dioxane, and the effectiveness of these technologies is reduced when accounting for the type of soils in the affected aquifer. The pore water in the low permeability soils within the aquifer is the likely secondary source for 1,4-dioxane, and forcing treatment into these formations is a technical challenge. Each of the remedial technologies has drawbacks, but in situ chemical oxidation (ISCO) was deemed the technology most likely to provide fast, effective mass removal based on currently available information. Stericycle has focused treatment on the areas and depths with the highest mass density of 1,4-dioxane (as detailed in Appendix A of the FFS) with an ISCO pilot study in the area of CG-122-60 and full-scale ISCO treatment of the area around CG-127 due to high mass density at multiple depths (wells CG-127-40 and CG-127-75). In order to provide reasonable expectations for performance of ISCO, Stericycle has included bench-scale and pilot studies that will provide data to better predict what mass removal goals are attainable and to assess the longevity and severity of any possible side effects for the full-scale implementation of the remedial technology. Additional details on the monitoring being provided as part of the preferred remedial alternative are provided in the subsequent responses. In addition to ISCO, Stericycle is partnering with Rice University and their subsidiary, Sentinel Environmental Group, LLC, to study in situ bioehancement and bioaugmentation (ISB) for use on site. The effectiveness of these technologies is highly site specific and one of the primary goals of the Rice University study is to determine if this technology will work for the geology and groundwater chemistry on site. At the present time, ISB is not considered a proven remedial technology for degradation of 1,4-dioxane although laboratory testing indicates it should work in situ. Ecology's preferred alternative as proposed in the draft AO assumes that the Rice study finds ISB to be a likely successful long term remedy for further reducing 1,4-dioxane concentrations.

Comment 3:

"Pages 15 and 16, Section 5.2.2. In our comments on the draft (October 1) Memorandum Ecology asked that the document be improved by referencing the applicable site literature, and for those sites where conditions are similar to those in the East of 4th area - discussing: the amounts of oxidant used; the remediation goals of the ISCO treatments at those sites; whether repeat injections (into the same locations) were deemed necessary, and if so, why, how many re-injections were needed, and [and] how much time was considered optimum between injections; and, any unwanted side effects associated with oxidant introduction.

Although Section 8.0 of the revised Focused FS memorandum includes five more references (only two or three of which are devoted primarily to ISCO), the discussions in Sections 5.2.2, 6.2.1, and 6.4

remain deficient in providing the information Ecology requested three months ago. This information will certainly be needed during preparation of ISCO treatability study and full-scale implementation Design documents. The consequence of not providing the information in the memorandum is that reviewers, both at Ecology and among the public, are unable to determine why PSC has proposed the particular conceptual-level injection design shown on Figure 4, what post-injection monitoring schemes are likely to be needed, and whether the estimated ISCO costs in Tables B1 and B2 are likely to adequately represent the costs associated with the cleanup action eventually described in the approved Design document.

As part of the process of developing a draft AO Amendment, please submit the following information associated with those successful ISCO applications at other sites that PSC has drawn upon to propose ISCO at the Georgetown site: a) the remediation goals of the ISCO treatments at those sites; b) the amounts of persulfate used at those sites to meet these goals; c) any unwanted side effects that occurred subsequent to persulfate injection at the sites, and d) any actions applied at the sites to either prevent unwanted side effects or mitigate the effects once they were apparent."

> *In order to evaluate the potential effectiveness for ISCO, specifically persulfate, Ecology has requested references and supporting information regarding persulfate's effectiveness at destroying 1,4-dioxane mass, the potential side effects, and any mitigating factors employed at sites that used persulfate. Enclosed Table 1 summarizes the references found that used persulfate to address 1,4-dioxane, the initial concentrations of 1,4-dioxane, the remediation goals and whether they were obtained, potential side effects, and any preventative measure employed to mitigate potential side effects. Most references included on Table 1 primarily targeted concentrations of 1,4-dioxane greater than 1 part per million. Both the GES and Regenesis studies had 1,4-dioxane concentrations in the ppb range that are similar to concentrations observed on site. The Regenesis reference was able to achieve the New Jersey Ground Water Quality Standard of 9.5 ppb in the targeted areas through one round of injections with alkaline activated persulfate. GES was able to reduce 1,4-dioxane concentrations from a maximum of 200 ppb to an average of 3.7 ppb in the target area. The majority of the references indicated some sulfate migration and metals mobilization but neither were a concern based on the monitoring performed, indicating that each issue was attenuated from subsurface flow, generally within a few tens of feet from the injection point. In addition, several examples include only a single injection event with successful mass removal (up to 84% per Borchert, et al.) or reduction of concentrations to less than 10 ppb (GES, Regenesis, and Redox Tech). Given that our cleanup level is 78.5 ppb and our current 1,4-dioxane concentrations are lower than or similar to the examples provided, a single concentrated injection event was proposed in the FFS memorandum. However, a second round of ISCO injections has been included in the revised estimated costs. Additional details on the second injection round as part of Ecology's preferred remedial alternative are provided in the subsequent responses.*
>
> *The challenge of developing a remediation goal for ISCO is that the 1,4-dioxane source area is clearly a secondary source, likely a result of lower permeability material within the aquifer or potentially a result of an unknown source. ISCO implementation will greatly reduce the mass of 1,4-dioxane in the plume area wherever it can make direct contact with 1,4-dioxane;*

> *however, the oxidant may not penetrate a significant percentage of the lower permeability zones where the secondary source resides. The result in this case could be a rapid decrease in mass followed by concentrations bouncing back some months following treatment. If this occurs, additional injections may be warranted depending on the extent of the bounce back in concentrations.*

Comment 6:

"Page 21, Section 6.2, and pages 22, 24, and 29. On these pages the memorandum discusses groundwater monitoring associated with Alternatives 1 and 2. In our comments on the draft (October 1) Memorandum Ecology requested that the revised document:

> *describe the type of groundwater monitoring the company intends to employ. The description can be conceptual at this point, but should provide the reader enough information so that it is clear how PSC intends to monitor treatment effectiveness as well as post-injection groundwater quality and geochemistry changes.*

However, while the revised memorandum states that monitoring will be performed during both treatability testing and full-scale implementation of ISCO and (for Alternative 2) enhanced ISB, and generally notes the objectives of this monitoring, there is no description of the types of monitoring points (wells or direct push) or the monitoring networks envisaged for collecting the necessary data. Detailed monitoring information will certainly be needed during preparation of Design documents, but the consequence of not providing additional "conceptual-level" information in the memorandum is that it is not then clear to reviewers, both at Ecology and among the public, *how* treatment effectiveness or post-injection groundwater quality and geochemistry changes will be monitored. Nor is it clear what the estimated monitoring costs in Tables B1 and B2 are based on and whether they are likely to adequately represent the costs associated with the selected action's approved Design.

Often, the monitoring associated with pilot or treatability studies is rigorous and includes monitoring points located both proximate to and distant from the injection locations. It also typically includes monitoring points located at depths bracketing the injection intervals, located in multiple lateral directions (within the general downgradient area) from the injection points. Among the monitoring wells installed near well 122-60 (where the ISCO treatability study will target the 50' to 60' bgs zone):

- 128-70 is about 325' downgradient (but is not screened between 50-60')
- 161-60 is about 400' down/cross-gradient
- 160-65 is about 725' downgradient
- 135-50 is about 975' due west (but is not screened between 50-60')
- BDC10-60 is about 1200' downgradient
- CI8-60 is about 1400' downgradient

It is not obvious to Ecology how the monitoring objectives associated with the ISCO treatability study can be met by only using existing monitoring wells when so few of these wells, screened across the same interval as the injection interval, are located close to well 122.

For full-scale implementation of ISCO the 35-45-' bgs and 65-75' bgs zones will be targeted in the vicinity of well cluster 127. For the shallower zone:

- Well 131-40 is about 350' downgradient
- Well 160-45 is about 400' cross-gradient (to the W-NW)
- Well 159-45 is about 600' downgradient
- Well 134-40 is about 650' downgradient
- BDC10-40 is about 750' downgradient
- CI8-40 is about 900' downgradient

For the 65-75' intermediate zone:

- Well 162-80 is about 300' cross-gradient (to the S)
- Well 160-65 is about 400' cross-gradient (to the W-NW)
- Well 134-80 is about 700' downgradient
- BDC10-60 is about 750' downgradient (but is not screened between 65-75')

Here again, it is not obvious to Ecology how the monitoring objectives associated with implementing ISCO can be met by only using existing monitoring wells, especially for those depths of interests corresponding to intermediate-zone injections.

We realize that even if the monitoring costs presented in Tables B1 and B2 are significantly underestimated, this is unlikely to affect the Alternative 1/Alternative 2 cost comparison. Both alternatives will need to similarly monitor ISCO performance and Alternative 1 - which only includes the ISCO component- will still be cheaper. But the draft AO Amendment must clearly describe how PSC intends to monitor treatment effectiveness and post-injection groundwater quality. We consider the availability of this "conceptual-level" information crucial to gaining public and Ecology acceptance of the proposed action. It should therefore be submitted as part of the near-future process of developing a draft AO Amendment."

> *Stericycle agrees that the current monitoring well network will need to be supplemented by additional monitoring points (direct push borings and monitoring wells not currently in the long term groundwater monitoring network). Additional monitoring is especially helpful during the pilot study components of the preferred alternative and a long term monitoring plan is required to evaluate the effectiveness of the alternative and to ensure that the cleanup action objectives are met. The monitoring plan will be developed as part of the remedial design work plan. Ecology requested conceptual-level information about the monitoring program that explains how treatment effectiveness and post-injection groundwater quality and geochemistry changes*

will be monitored. A combination of direct push borings, which allow flexibility in location and multiple depths of sampling, will be utilized in combination with the existing monitoring well network, as well as new monitoring wells for long term groundwater monitoring (if warranted). The direct push borings will allow field staff to respond to variable field conditions and plume movements. While monitoring wells are most useful for long term groundwater monitoring, the 1,4-dioxane plume may be significantly altered during ISCO and/or ISB injections. Sighting permanent wells will be performed as necessary based on a review of the data collected from direct push borings and existing groundwater monitoring wells during each phase of the project.

The conceptual outline of the monitoring program follows:

Monitoring Objective: *The purpose of ISCO is mass removal from the most problematic areas, defined as the areas with the highest 1,4-dioxane mass per square foot. ISCO will be followed by ISB implementation (so long as the Rice Study confirms it as a viable remedial technology). ISB implementation is meant to be a long term natural attenuation that will ultimately result in meeting the 1,4-dioxane cleanup standard at the CPOC. Monitoring of the ISCO implementation will evaluate the initial extent of mass removal within the vicinity of the treatment, and monitoring permanent wells over time will evaluate whether the pretreatment concentrations rebound and if so, to what level and for how long. Based on this objective, the following monitoring plan is proposed.*

Monitoring Program:

Treatability Study – Samples will be collected from CG-122 area for baseline analysis and to evaluate oxidant and dose. Results of the treatability study will be used to evaluate and amend (with Ecology's prior approval) the planned pilot study procedures, as appropriate.

Pilot Study – Four monitoring events will be conducted over three months after completion of the Pilot Study injections in the CG-122 area. Results of the pilot study will be used to evaluate and amend (with Ecology's prior approval) the planned full-scale ISCO implementation, as appropriate.

Full Scale ISCO – Initial samples will be collected from CG-161-60, CG-127-75, and CG-127-40 prior to the first round of injections. A second monitoring event for the three wells and two downgradient push probes (with water samples collected from two depths at each boring) will be conducted prior to a second injection event (if a second injection event is deemed necessary). After the last round of injections; two quarterly monitoring events will take place prior to implementation of ISB and long term monitoring. These monitoring events will include the three wells and four downgradient push probes (with water samples collected from two depths at each boring).

ISB – Assuming that ISB is found to be an appropriate technology during the Rice study and is therefore implemented, eight quarterly monitoring events will be conducted at approximately 10–15 permanent wells to monitor in situ bioremediation (depending on the size of the

1,4-dioxane plume at the time of implementation). This will include monitoring ISCO parameters in downgradient wells, as outlined below in the Scope section.

Long Term Monitoring – Remaining monitoring is anticipated to not exceed that described in the Long Term Monitoring Plan. If warranted, that plan may be modified to address specific locations identified during cleanup implementation.

Scope: *As part of the preferred alternative selected by Ecology and Stericycle, up to two rounds of ISCO will be performed to address the Outside Area east of 4th Avenue South with a second, follow-up injection event occurring approximately a month later (if necessary). Each injection event will consist of adding half of the oxidant dose as determined in the bench-scale study to be performed by Stericycle. The injection events will be followed with ISB if the Rice study conducted by Sentinel Environmental Group, LLC indicates that ISB may be effective at reducing 1,4-dioxane levels. To evaluate ISCO; a bench-scale study will be performed to determine the preferred oxidant to be used at the site and the potential effectiveness at 1,4-dioxane destruction. The bench-scale study will include soil and groundwater sample collection from the area adjacent to CG-122 at approximately 50–60 feet below ground surface (bgs) to cover the screened interval that will be targeted during the pilot study. An aliquot of the groundwater sample will be analyzed for initial concentration for 1,4-dioxane, pH, oxidation reduction potential (ORP), conductivity, sulfate, and the MTCA metals (arsenic, cadmium, chromium, and lead). The remainder of the groundwater and soil samples will be sent to a lab to perform soil oxidant demand tests and a treatability study on the soil and groundwater in a batch reactor to determine 1,4-dioxane mass destruction. The oxidant and activation method (if effective) will be selected to implement in the pilot study.*

Once the oxidant is selected and the target dose is determined for implementation in the Outside Area, a pilot study will be conducted adjacent to CG-122 (Figure 1). The pilot study will consist of injecting the full recommended oxidant dose in four locations adjacent to CG-122 over the 10 foot interval from 50–60 feet bgs, as shown on Figure 1. A three-month monitoring program will be implemented post-injection with the following primary objectives:

- *Determining the radius of influence*
- *Evaluating potential side effects of ISCO on metals mobilization, pH swings, and sulfate migration*
- *Evaluating attenuation of 1,4-dioxane from flowing through the subsurface*
- *Evaluating whether concentrations of 1,4-dioxane are rebounding, indicating the majority of 1,4-dioxane is likely from a secondary source*

It is assumed that four total monitoring events will take place as part of the evaluation period:

- *Event 1; one week after injections:*
    - *Monitoring points are CG-122-60, CG-122-75 and two push probe points.*

  - *Analytes are pH, ORP, conductivity, persulfate (field kit), MTCA metals, and 1,4-dioxane.*

- *Event 2; three weeks after injections:*
  - *Monitoring points are CG-122-60, CG-122-75 and four push probe points.*
  - *Analytes are pH, ORP, conductivity, persulfate (field kit), MTCA metals, and 1,4-dioxane.*
- *Event 3; six weeks after injections:*
  - *Monitoring points are CG-122-60, CG-122-75 and four push probe points.*
  - *Analytes are pH, ORP, conductivity, persulfate (field kit), MTCA metals, and 1,4-dioxane.*
- *Event 4; twelve weeks after injections:*
  - *Monitoring points are CG-122-60, CG-122-75 and four push probe points.*
  - *Analytes are pH, ORP, conductivity, persulfate (field kit), MTCA metals, and 1,4-dioxane.*

After the three-month monitoring period for the pilot study, an injection work plan will be developed for full-scale ISCO implementation. The full-scale ISCO monitoring is anticipated to consist of wells CG-127-40, CG-127-75, and CG-161-60 (immediately upgradient of the injections). The initial round of sampling will consist of baseline samples collected prior to full-scale injections of ISCO using the three monitoring wells. After the initial round of ISCO, samples will be collected from the three monitoring wells and two downgradient push probe points immediately preceding the second round of injections (if necessary) to evaluate the effectiveness of the initial round and to monitor sulfate, metals, and pH. After the last round of injections, samples will be collected from the three monitoring wells and four downgradient push probe locations for two quarters prior to implementation of ISB. The samples will be analyzed for the same parameters analyzed in the pilot study.

The ISB monitoring events will include monitoring of the wells that make up the 1,4-dioxane plume under evaluation and treatment. This includes some wells currently in the Long Term Monitoring Plan program and some wells outside of it. The 14 monitoring wells anticipated to be monitored quarterly are: CG-122-60, CG-122-75, CG-165-45, CG-128-45, CG-128-70, CG-128-80, CG-161-60, CG-127-40, CG-127-75, CG-160-45, CG-160-65, CG-131-40, CG-134-40, and CG-135-50. The current monitoring network captures various depths and locations across the 1,4-dioxane plume; therefore, additional permanent monitoring wells are not anticipated to be required for this monitoring program. It is assumed that analytes monitored as part of the ISB monitoring plan will include pH, ORP, total organic carbon, sulfate, 1,4-dioxane, and potentially the substrate or breakdown products as determined in the ISB treatability study.

The long term monitoring program is anticipated to include the wells included in the current Long Term Monitoring Plan with the addition of several, but not all, wells included in the ISB monitoring events.

Comment 9:

"Page 24, Section 6.2.2. The second bullet on the page describes a bench-scale study performed by The Sentinel Environmental Group to select enhanced ISB substrate and "bioagugmentation requirements." This appears to be consistent with the goals of the bench-scale microcosm project proposed by Sentinel in the November 25, 2014, "Project Proposal," forwarded to Ecology on January 21. However, the Sentinel Project Proposal also includes a "pilot-scale" bioaugmentation "test" or "trial," where bacterial cells would be injected into two monitoring wells (one "near-source" and one "control"). It is unclear to Ecology if this part of the Project Proposal is also a component of Alternative 2.

It is also unclear why the cost of the "evaluation of enhanced biodegradation/bioaugmentation" work proposed for Alternative 2 (in Table B2) is the same as the cost estimated under Alternative 1 "to verify biodegradation is occurring." Sentinel's bench-scale study proposal includes a number of activities beyond determining whether dioxane is biodegrading naturally (and if so, at what rate(s)); for example, it also includes:

- the preparation of bioaugmented microcosms with groundwater collected from various parts of the plume/site;
- the preparation of bioaugmented microcosms with water not from the site, but spiked with dioxane to the same levels contained in groundwater samples (to assess co-contaminant inhibition and the effects of bioaugmentation on CVOCs vs dioxane); and,
- the preparation of "background microcosms to benchmark biodegradation patterns ..."

As part of the upcoming process of developing a draft AO Amendment, please inform Ecology whether the Sentinel "pilot-scale" bioaugmentation "test" or "trial" proposal, which includes injections into two monitoring wells, is a component of PSC's Alternative 2."

As outlined in the project proposal provided by the Sentinel Environmental Group, LLC dated 11/25/2014; Stericycle will work with the Sentinel Environmental Group to conduct "pilot-scale" bioaugmentation tests in two monitoring wells as a component of Alternative 2, with one well located near the source area and the other well used as a control.

Given the uncertainties with each of the remedial technologies proposed in the FFS memorandum, Stericycle believes there is value in performing the bioenhancement/augmentation study independent of the remedial action chosen. Thus, there was no difference in the work performed or the cost as proposed in the bioenhancement/augmentation study in Alternative 1 or Alternative 2 in the FFS memorandum. Bench-scale or pilot study results could show ISCO to be less effective than indicated in the literature. In that case, the remedial technologies from the FFS may be *reconsidered and the information from the bioenhancement/augmentation study may be invaluable in reassessing the remedial options.*

Comment 10:

“Page 24, Section 6.2.2. In the last paragraph PSC states that substrate and microorganisms (if required) would be injected via approximately 36 direct push points near wells 122 and 161. However, there is no corresponding figure depicting the proposed locations for these three dozen points. Such a figure was provided in the draft October 1 Memorandum (for that document's Alternative 3), but it is not clear if Alternative 2 is proposing the same, or different, locations. A new figure should be submitted that corresponds to the revised memorandum's Alternative 2.”

Figures 1 and 2 are attached providing proposed locations for the direct push points for ISCO and ISB.

Comment 19:

“Table B1. It is unclear to Ecology:

- what monitoring activities are being assumed during Alternative 1’s (and 2's) ISCO treatability study (near well122). A number of Phase II tasks are identified on page 29 (and page 22), and include injection-related and monitoring-related activities. The table estimates $2000 for these activities and refers to the monitoring as "monthly sampling." It is difficult to understand how the Phase II objectives will be met if the total monitoring-related outlay is limited to $2000. As discussed in Comments 3 and 6 above, PSC needs to provide more monitoring-related information for Alternatives 1 and 2 before the parties complete amendment/revision of the 2010 AO/CAP.
- why the Phase III persulate cost is only four times the Phase II persulate cost.
- why, under costs for Alternative 1’s biodegradation study, there is a reference to "Pilot Study Costs" and "Substrate Costs." Sentinel's November 2014 "Project Proposal" includes a bench-scale microcosm project followed by a "pilot-scale" bioaugmentation "test" or "trial." As discussed in comments above, if the sole objective of Alternative 1's biodegradation study is to "verify biodegradation is occurring," the memorandum should have clarified which Sentinel bench-scale and "pilot-scale bioaugmentation trial" tasks would and would not be undertaken as part of Alternative 1.”

The updated monitoring plan was provided in response to Comment 6. In addition; revised Table B-2 is provided as an attachment to clarify the monitoring details for ISCO and ISB as part of proposed Alternative 2.

Phase III for Alternative 1 includes injection of persulfate into 30 injections points at the estimated oxidant demand and radius of influence. The full-scale injection also includes use of Regensis equipment and personnel over several days. Phase II, which includes the pilot study, only requires four injection points but still requires the injection system and personnel to apply the oxidant to the subsurface, which adds more cost per injection point.

As noted in the earlier responses, Stericycle intends to perform the same bioenhancement/augmentation study regardless of whether ISB is the selected alternative.

Comment 20:

"Table B2. Please see our comments above concerning ISCO and biodegradation study costs. In addition, the table estimates $10,000 for enhanced ISB monitoring costs and refers to the monitoring as "semi-annual." It is unclear what short and long-term monitoring activities are being assumed in the derivation of this estimate. As discussed in several comments above, before the parties revise the 2010 AO/CAP PSC needs to provide more monitoring-related information for Alternative 2, including the monitoring devoted specifically to assessing enhanced ISB performance."

Table B-2 (enclosed) has been revised in conjunction with the conceptual level monitoring plan provided as part of the response to Comment 6.

Sincerely yours,
Amec Foster Wheeler Environment & Infrastructure, Inc.

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Enclosure(s): Table 1
Table B-2
Figure 1
Figure 2

cc: William Beck, Stericycle
Project File

TABLE 1

1,4-DIOXANE ISCO REFERENCES
Stericycle Georgetown Site
Seattle, Washington

Reference	1,4-Dioxane Concentrations (ppb)	Remediation Goals	Persulfate Dose	Side Effects	Preventative Measures
GES, no date, Max-OX Project: ISCO via Alkaline-Activated Persulfate at Superfund Site.	200	Contaminant destruction and minimization of metals mobilization. Reduce 1,4-dioxane to average concentration of 3.7 ppb.	1 injection event: 570,000 pounds of sodium persulfate injected in 204 injection points with sodium hydroxide to activate.	None mentioned.	Performed pilot and bench scale testing to evaluate full scale implementation, contaminant destruction, oxidant persistence, ROI, changing geochemistry, and potential for metals mobilization.
Borchert, et al., 2014, Treatability Study and Full-Scale ISCO for Mixed VOCs and 1,4-Dioxane in Low Permeable Formation.	As high as 40,500	Reduce mass of COCs in groundwater of two hydraulically connected, perched aquifers. Up to 84 percent dioxane removal in source area; not as effective in less permeable till layer.	1 injection event: 10 grams of persulfate activated with sodium hydroxide per kg of soil in 19 injection wells.	Exothermic reaction observed when trying to use a analyzed hydrogen peroxide (due to presence of light nonaqueous phase liquid detected in wells) led to use of sodium hydroxide-activated persulfate application.	Bench-scale study performed.
Crawford and Hagelin, 2009, Evaluation of Residual Effects Following Alkaline Activated Persulfate Treatment.	3,000	Reduce groundwater to below 1 mg/L in source area.	2 injection events (18 wells at 5-foot ROI): 31,000 kg Klozur® (sodium persulfate by FMC Corporation) + 15,300 kg sodium hydroxide to activate.	Significant but temporary increases (~1 year to obtain background levels) in aluminum (~32 ppm), chromium (2 ppm), and arsenic (60 ppm dropped within 2 years and close to background levels ~200 feet downgradient). Sulfate as high as 500 ppm in ISCO area. Less than 20 ppm downgradient. pH increased to 14 in injection points (slowly recovered and attenuated prior to reaching downgradient monitoring points).	Accounted for surface water 500' feet downgradient. Measured buffering capacity of soils.
Regenesis (Project Profile), 1,4-Dioxane and 1,1, DCE in Fractured Bedrock Treated with ISCO.	580	Achieve New Jersey Groundwater Quality Standards (9.5 µg/L).	1 injection event: PersulfOx (activated persulfate) injected at 12,300 gallons of 8% solution through 12 boreholes in fractured bedrock & 800 gallons of 10% solution to injection gallery.	None mentioned.	Continued quarterly sampling to track treatment performance. Below New Jersey Groundwater Quality Standards five months post-injection.
Redox Tech and FMC Corp., In-situ Chemical Oxidation with Klozur Activated Persulfate: Co-Mingled Plume of Chlorinated Solvents and 1,4-Dioxane.	50,000	Reduction of 1,4-dioxane to concentrations less than 5 ppb. Reduce source area to non-detect.	1 injection event: Approximately 100,000 pounds of Klozur® persulfate over 90 injection points; catalyzed with high pH or heat.	Sulfate migration observed, but below 250 mg/L.	Kept pH of aquifer as close to neutral as possible to decrease metals solubility/mobilization. Continually monitored downgradient.
ISOTEC No. 67	Area A: 7,600 Area B: 20,000	Achieve significant reduction of 1,4-dioxane in groundwater to meet interim cleanup levels set for the site. All areas met interim cleanup levels or an acceptable range to transition to monitored natural attenuation.	2 injection events. **Area A:** 1st injection – 97,200 gallons of 18% ALK-ASP injected into 64 wells, then 1,800 gallons of 10% hydrogen peroxide injected into 10 wells. 2nd injection – 7,350 gallons of hydrogen peroxide injected into 13 wells, 25,800 gallons of ALK-ASP injected into 35 wells, and 22,900 gallons of MFR injected into 34 wells. **Area B:** 1st injection – 14,400 gallons of ALK-ASP injected into 30 wells, and 350 gallons of MFR injected into 8 other wells. 2nd injection – 2,075 gallons of hydrogen peroxide injected into 10 wells, 7,200 gallons of ALK-ASP injected into 28 wells, and 3,400 gallons of MFR injected into 24 wells.	None mentioned.	Performed full-scale pilot testing before designing the two injection events used in the study. First injection treated the whole area, and second injection targeted only highest-concentration areas. MFR treatment duringthe Area B first Injection was used instead of ALK-ASP for a small area to limit migration of the oxidant into a nearby brook.

Abbreviations:

µg/L = micrograms per liter
ALK-ASP = alkali activated persulfate
COC = constituent of concern
ISCO = in situ chemical oxidation
kg = kilogram
MFR = modified fenton's reagent
mg/L = milligrams per liter
ppb = parts per billion
ROI = radius of influence

TABLE B-2

ALTERNATIVE 2 ISCO + ISB COSTS
Stericycle Georgetown Site
Seattle, Washington

Phase/ Task	Subtasks	Line Items	Unit	Unit Cost	# of Units	Contractor/Agency Lump Sum 1	AMEC Total Labor hours	Total Cost per Subtask
Phase I								
Reports								
	Bench Scale WP:						46	$4,573
	Treatability Study WP:						75	$7,596
	Final Injection SOP:						207	$24,519
	Health and Safety Plan:						43	$4,496
	Completion Report						200	$23,896
	Correspondence with Ecology:						200	$23,896
Total Reports Cost:								**$88,977**
Permitting								
	SDOT Major Utility Permit:							
		Utility Major Transmittal Form				$2,500	17	$4,143
		Permit Application					17	$1,643
		Pavement Restoration Plan Checklist					17	$1,643
		Plans					26	$2,544
		Profile					0	$0
		Restoration Plan					19	$1,828
		Traffic Control Plan					63	$7,153
		Total Cost:						**$18,954**
	Well Start Permit[1]							
	Underground Injection Permit						25	$2,384
Total Permitting Cost								**$21,339**
Locates								
	Public						2	$185
	Private					$300	8	$1,051
Total Locates Cost								**$1,236**
ISCO Bench Scale Study								
	Lab Study					$6,000		$6,000
	Results Analysis/Communication						18	$1,803
	Final Reporting						32	$3,502
	Sample Collection						0	$0
		AMEC Oversight					16	$1,617
		Probe Rig[3, 4]	per day	$2,500	1			$2,500
		WA Start Cards[4]	each point	$65	2			$130
		WA Decommission Cards[4]	each point	$35	2			$70
		Waste Disposal/Profiling	each	$500	1			$500
	Total Bench Scale Cost:							**$16,122**

TABLE B-2

ALTERNATIVE 2 ISCO + ISB COSTS
Stericycle Georgetown Site
Seattle, Washington

Phase/ Task	Subtasks	Line Items	Unit	Unit Cost	# of Units	Contractor/Agency Lump Sum 1	AMEC Total Labor hours	Total Cost per Subtask
ISCO Treatability Study								
	AMEC Oversight[2]						39	$3,950
		Probe Rig[3, 4]	per day	$2,500	1			$2,500
		Utility Truck[3]	per day	$450	1			$450
		WA Start Cards[4]	each point	$65	4			$260
		WA Decommission Cards[4]	each point	$35	4			$140
	PersulfOx+Regenesis[4,5]					$8,000		$8,000
	Forklift		per day	$650	1			$650
	GPS Survey Equipment					$2,000		$2,000
	Total Treatability Study Cost							**$17,950**
ISCO Injections								
	Initial Round of Injections							
	AMEC Oversight[2]						94	$9,383
	Push Probes							
		Probe Rig[3, 6]	per day	$2,500	7			$17,500
		Utility Truck[3]	per day	$450	7			$3,150
		WA Start Cards[6]	each point	$65	32			$2,080
		WA Decommission Cards[6]	each point	$35	32			$1,120
	PersulfOx+Regenesis[5,6]					$32,000		$32,000
	Water Truck[6]		per month	$4,029	1			$4,029
	Forklift		per month	$2,000	1			$2,000
	GPS Survey Equipment					$2,000		$2,000
	Waste Disposal and Profiling					$3,500		$3,500
	Total Initial ISCO Injection Cost							**$76,762**
	Follow Up Round of Injections							
	AMEC Oversight[2]						94	$9,383
	Push Probes							
		Probe Rig[3, 5]	per day	$2,500	7			$17,500
		Utility Truck[3]	per day	$450	7			$3,150
		WA Start Cards[5]	each point	$65	32			$2,080
		WA Decommission Cards[5]	each point	$35	32			$1,120
	PersulfOx+Regenesis[5,6]					$32,000		$32,000
	Water Truck[7]		per month	$4,029	1			$4,029
	Forklift		per month	$2,000	1			$2,000
	GPS Survey Equipment					$2,000		$2,000
	Waste Disposal and Profiling					$3,500		$3,500
	Total ISCO Follow Up Injection Cost							**$76,762**
Total ISCO Injection Cost								**$153,525**
Total ISCO Cost:								**$187,596**

TABLE B-2

ALTERNATIVE 2 ISCO + ISB COSTS
Stericycle Georgetown Site
Seattle, Washington

Phase/ Task	Subtasks	Line Items	Unit	Unit Cost	# of Units	Contractor/Agency Lump Sum 1	AMEC Total Labor hours	Total Cost per Subtask
Pilot Study Monitoring (4 events over 3 month period after pilot study)								
	AMEC Oversight						134	$13,555
	Push Probes							
		Probe Rig[9,10]	per day	$2,500	4			$10,000
		WA Start Cards[11]	each	$65	4			$260
		Street Use Permit and Signage	each	$2,000	4			$8,000
	Laboratory Analysis and Data Validation (event 1)[13]		each	$1,788	1			$1,788
	Laboratory Analysis and Data Validation (events 2-4)[14]		each	$2,407	3			$7,222
	Waste Disposal and Profiling		each	$1,000	4			$4,000
Pilot Study Monitoring Cost								**$44,824**
Monitoring (3 events over 6 month period after injections near CG-127)								
	AMEC Oversight[9]						87	$8,631
	Push Probes							
		Probe Rig[9,10]	per day	$2,500	3			$7,500
		WA Start Cards[11]	each	$65	3			$195
		Street Use Permit and Signage	each	$2,000	3			$6,000
	Laboratory Analysis and Data Validation (event 1)[15]		each	$2,717	1			$2,717
	Laboratory Analysis and Data Validation (events 2-3)[16]		each	$3,955	2			$7,910
	Waste Disposal and Profiling		each	$1,000	3			$3,000
Injection Monitoring Cost								**$35,954**
Total Monitoring Cost								**$80,778**
Total Phase I Cost								**$379,926**
Phase II								
Reports								
	Final Injection SOP:						207	$24,519
	Review Sentinel Environmental Group Report:						43	$4,496
	Completion Report						200	$23,200
	Completion Report						120	$13,400
	Correspondences with Ecology:						200	$23,200
Total Reports Cost:								**$88,815**
Permitting								
	SDOT Major Utility Permit:							
		Utility Major Transmittal Form				$2,500	17	$4,218
		Permit Application					17	$1,643
		Pavement Restoration Plan Checklist					17	$1,643
		Plans					26	$2,544
		Profile						$0
		Restoration Plan					19	$1,828
		Traffic Control Plan					63	$7,153
		Total Cost:						**$19,029**
	Underground Injection Permit						25	$2,384
Total Permitting Cost								**$21,414**

TABLE B-2

ALTERNATIVE 2 ISCO + ISB COSTS
Stericycle Georgetown Site
Seattle, Washington

Phase/ Task	Subtasks	Line Items	Unit	Unit Cost	# of Units	Contractor/Agency Lump Sum 1	AMEC Total Labor hours	Total Cost per Subtask
Locates								
	Public					$0	2	$185
	Private					$300	8	$1,051
Total Locates Cost								**$1,236**
Evaluation of Enhanced Biodegradation/Bioaugmentation								
	Sentinel Environmental Group Lab Study Cost					$110,000		$110,000
	AMEC Oversight						220	$25,750
	Sample Collection							
		Probe Rig[3, 4]	per day	$2,500	1			$2,500
		Waste Profiling/Disposal				$3,000		$3,000
	Results Analysis/Communication						60	$6,901
	Pilot Study Costs							
		Substrate Costs				$5,000		$5,000
		Permitting Costs				$5,000		$5,000
		AMEC Field Costs					100	$10,609
	Final Reporting						100	$10,609
	Results Analysis/Communication						160	$22,866
	Total Sentinel Environmental Group Study Cost:							**$202,235**
ISB Injections								
	AMEC Oversight[9]						136	$13,277
	Substrate/Bioaugmentation					$25,000		$25,000
	Push Probes							
		Probe Rig[9,10]	per day	$2,500	9			$25,000
		Utility Truck[9]	per day	$450	9			$4,500
		WA Start Cards[11]	each	$65	36			$2,470
		WA Decommission Cards[11]	each	$35	36			$1,330
	Water Truck/Fire Hydrant[8]					$4,029		$4,029
	GPS Survey Equipment					$2,000		$2,000
	Forklift		per month	$2,000	1			$2,000
	Waste Disposal and Profiling					$3,500		$3,500
Total Injection Cost								**$83,106**

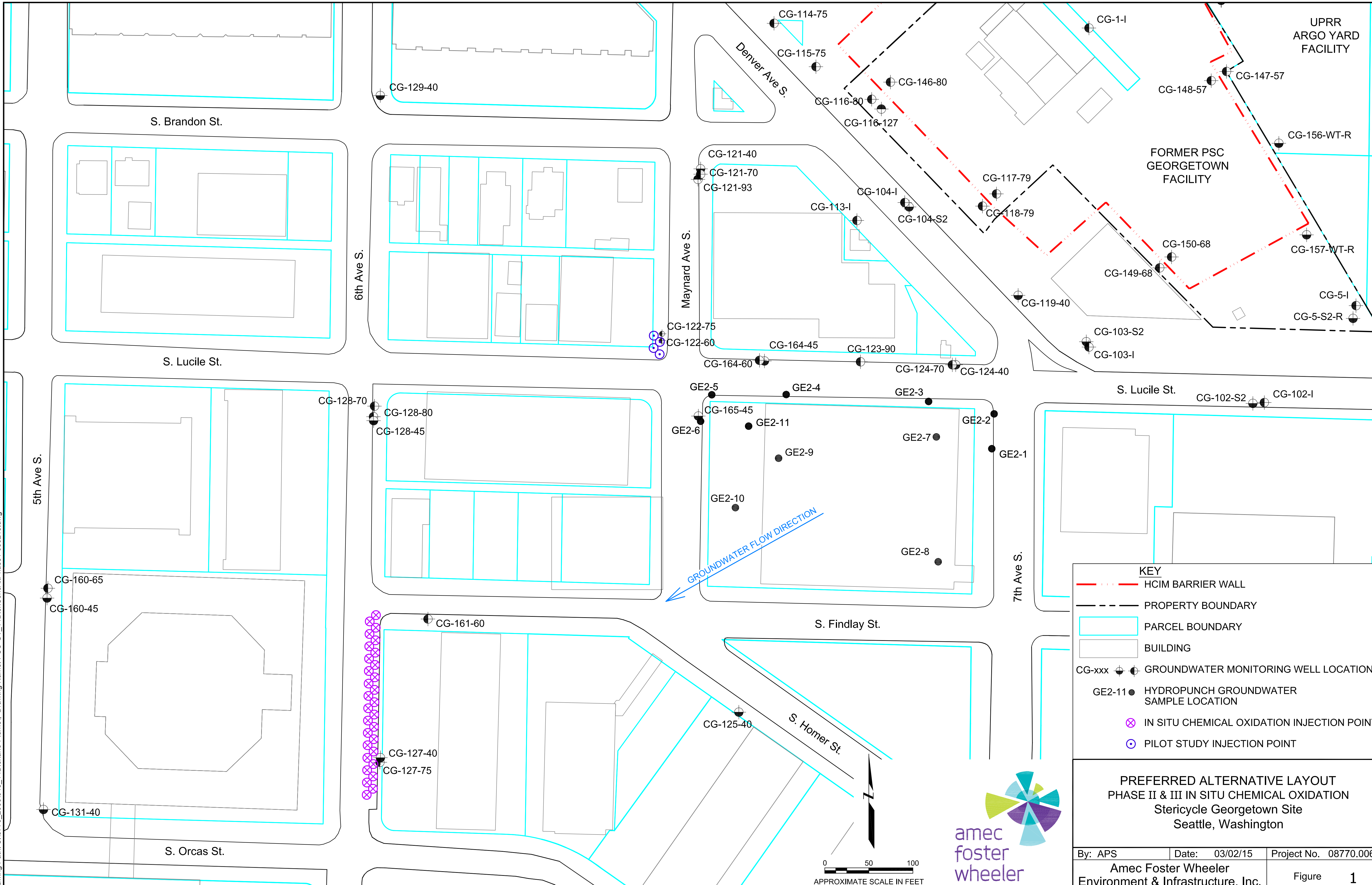
TABLE B-2

ALTERNATIVE 2 ISCO + ISB COSTS
Stericycle Georgetown Site
Seattle, Washington

Phase/ Task	Subtasks	Line Items	Unit	Unit Cost	# of Units	Contractor/Agency Lump Sum 1	AMEC Total Labor hours	Total Cost per Subtask
Monitoring (8 quarterly events over the plume)								
	AMEC Oversight[9]						456	$45,279
	Laboratory Analysis and Data Validation (event 1)[17]		each	$2,304	8			$18,432
	Waste Disposal and Profiling		each	$500	8			$4,000
Total Monitoring Cost								**$67,711**
Total Phase II Cost								**$464,516**
Total Cost								**$844,442**
Contingency (10%)								$84,444
Tax								$80,222
Total Cost								**$1,010,000**

Notes:
1. WA Start Cards costs included in Cascade Drilling Cost Proposal.
2. Assumes ISCO injections will take approximately one day for the pilot study and an additional 20 hours of preparation. To complete all injections will require six days at fourteen hours per day.
3. Assumes one push probe rig completing four injections per day. And assumes only one utility truck is required for the probe rig.
4. Four total injection points for ISCO treatability study.
5. Regenesis costs includes chemicals and equipment for injections.
6. Thirty total ISCO injection points.
7. Regenesis costs includes chemicals and equipment for injections.
8. Water truck rental cost assumes a 2,000 gallon capacity truck.
9. Assumes ISB injections will take approximately nine days for all injections at approximately fourteen hours per day
10. Assumes one push probe rig completing four injections per day per rig. Assumes one utility truck is required for a push probe rig.
11. Thirty-six total ISB injection points.
12. The Sentinel Environmental Group study will be performed independent of alternative selected to evaluate biodegradation, enhanced biodegradation, and bioaugmentation.
13. Assumes 2 wells and 2 borings tested for 1,4-D, metals, sulfate, and field kit pursulfate.
14. Assumes 2 wells and 4 borings tested for 1,4-D, metals, sulfate, and field kit pursulfate.
15. Assumes 3 wells and 2 borings tested for 1,4-D, metals, sulfate, and field kit pursulfate.
16. Assumes 3 wells and 4 borings tested for 1,4-D, metals, sulfate, and field kit pursulfate.
17. Assumes 14 wells tested for 1,4-D (CG-122-60, CG-122-75, CG-165-45, CG-128-45, CG-128-70, CG-128-80, CG-161-60, CG-127-40, CG-127-75, CG-160-45, CG-160-65, CG-131-40, CG-134-40, and CG-135-50), 2 person sampling team.

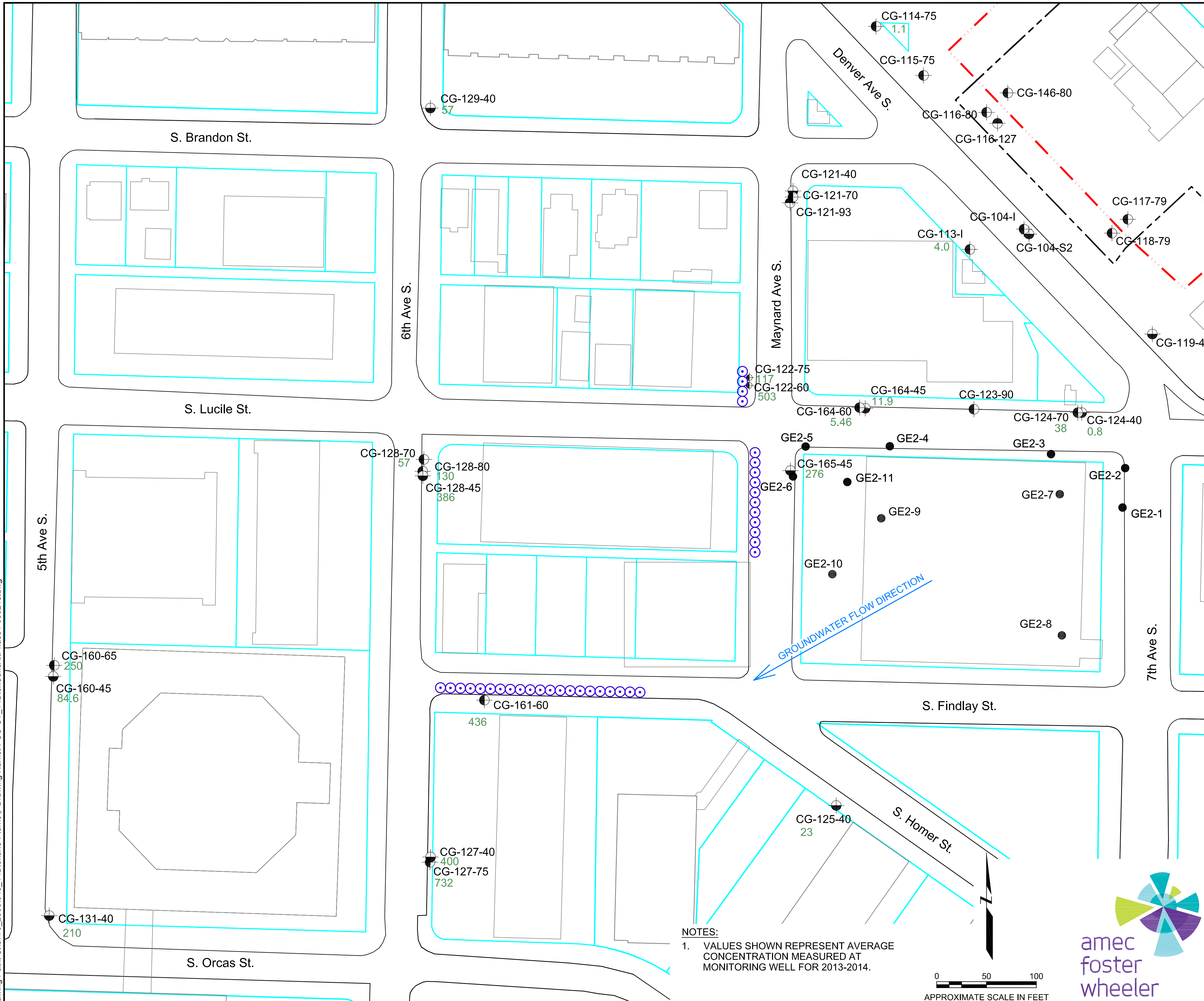
Abbreviations:
AMEC = Amec Foster Wheeler Environment & Infrastructure, Inc.
Ecology = Washington State Department of Ecology
GPS = Global Positioning System
ISB = in situ bioremediation
ISCO = in situ chemical oxidation
SDOT = Seattle Department of Transportation
SOP = standard operating procedure
WA = Washington
WP = Work Plan



PREFERRED ALTERNATIVE LAYOUT
PHASE II & III IN SITU CHEMICAL OXIDATION
Stericycle Georgetown Site
Seattle, Washington

By: APS	Date: 03/02/15	Project No. 08770.006
Amec Foster Wheeler Environment & Infrastructure, Inc.		Figure 1

Plot Date: 03/02/15 - 5:52pm, Plotted by: adam.stenberg
Drawing Path: S:\8770_2006\045_14Dioxane-Plume\, Drawing Name: PSC-GT_14DioxConcAltPhase1-030215.dwg



NOTES:
1. VALUES SHOWN REPRESENT AVERAGE CONCENTRATION MEASURED AT MONITORING WELL FOR 2013-2014.

amec foster wheeler

PREFERRED ALTERNATIVE LAYOUT
PHASE IV IN SITU BIOREMEDIATION
Stericycle Georgetown Facility
Seattle, Washington

By: APS	Date: 03/16/15	Project No. 08770.006
Amec Foster Wheeler Environment & Infrastructure, Inc.		Figure 2

Plot Date: 03/16/15 - 12:02pm, Plotted by: adam.stenberg
Drawing Path: S:\8770_2006\045_14Dioxane-Plume\, Drawing Name: PSC-GT_14DioxConcAltPhase1-030215.dwg