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Project ref:
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From:
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Date:
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To:
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CC:
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Memorandum

Subject: Contingent Remedy Evaluation

Section 1 – Introduction and Background

This memorandum presents a comparison of alternative treatment technologies and selects (recommends) one alternative technology to remediate the residual contaminants of concern (COCs) associated with the shallow soil and groundwater impacts at the former General Electric (GE) facility located at 220 South Dawson St., Seattle, WA (site) (Figure 1). This assessment was conducted for use by the Washington State Department of Ecology (Ecology) in accordance with Section 7 (contingent remedy) of the Cleanup Action Plan[1] (CAP) after it was determined that the original in-situ chemical oxidation (ISCO) remedial alternative prescribed in the CAP was not effective at sufficiently reducing site COC groundwater concentrations.

GE implemented Phase I of the ISCO remedy during March 2017. The ISCO remedy included the injection of sodium persulfate into the shallow and intermediate groundwater, continued operation of the hydraulic control system, continued operation of the vapor intrusion mitigation system (VIMS), and institutional controls; a comprehensive description of the ISCO remedy can be found in the CAP and Engineering Design Report[2]. Following six months of monitoring after the ISCO injections were completed, no significant change was observed compared to historical groundwater COC concentration trends. Working with Ecology, GE supplemented Phase I of the remedy by installing sodium persulfate impregnated ‘cylinders’ into strategic injection and monitoring wells in October 2017. The purpose of this supplemental activity was to extend the longevity of sodium persulfate in the aquifer beyond that observed in March 2017 during the injection of the sodium persulfate solution.

Neither the March 2017 nor the October 2017 ISCO pilot programs provided a measurable or significant improvement in the historical trend of diminishing trichloroethylene (TCE) groundwater concentrations. The results of ISCO Phase 1 and supplemental persulfate cylinder studies are provided in the *ISCO Pilot Study Completion Report*[3] and the *Addendum to the ISCO Pilot Study Completion Report*[4], respectively.

[1] Ecology (Washington State Department of Ecology). 2014. *Cleanup Action Plan, GE South Dawson Street, Seattle, Washington*. March 2014.
[2] AECOM. 2016. Engineering Design Report GE South Dawson Street, Seattle, Washington. October 2016.
[3] AECOM. ISCO Pilot Study Completion Report, GE South Dawson Street. October 27, 2017.
[4] GE. 2017. Addendum to the In-Situ Chemical Oxidation Pilot Study Completion Report, General Electric South Dawson Street Site

Given the difficulties encountered with the ISCO approach during the Phase 1 pilot program and the extended persulfate cylinder trial, investigation of contingency remedies are warranted. The objective of this memorandum is to evaluate multiple technologies for use at the site, and provide a recommended alternative remedy for public comment and consideration by Ecology; the recommended remedial alternative should attain the remedial action objectives in a shorter time frame than ISCO technologies offer given the existing site conditions. In accordance with Section 7 of the CAP, GE has evaluated the following alternative technologies for use at the site

1. Optimized groundwater extraction and treatment;
2. Monitored natural attenuation (MNA);
3. Air sparging with soil vapor extraction (AS/SVE);
4. Enhanced anaerobic biodegradation (EAB); and
5. In-situ chemical reduction (ISCR).

Per the CAP, each of these technologies, if selected as an alternative remedy, would be accompanied by continued operation of the hydraulic control system, continued operation of the VIMS, and institutional controls; a complete description of these components and their requirements can be found in Sections 5 and 6 of the CAP. GE is currently coordinating with Ecology to relocate hydraulic recovery system recovery well RW-3, to allow site renovation by the property owner. As part of this relocation, GE will evaluate the combined capture zone of the system and recommend an optimized pumping rate for recovery well RW-2 and the new (relocated) recovery well RW-4. The installation and startup of RW-4 (shown on Figure 1) and abandonment of RW-3 will occur by July 2018, and optimization of the system is anticipated for the last quarter of 2018.

Each technology is reviewed individually for the specific purpose of accelerating remediation of the shallow zone impacts at the site, and achieving compliance with all cleanup standards in a reasonable time frame while protecting human health and the environment during remediation.

Section 2 – Alternative Remedial Options

Several contingent remediation technologies were identified following the ISCO pilot injection event (March 2017) and the slow-release cylinder test (October 2017) based on the lessons learned and an updated site conceptual model resulting from those activities. Previous feasibility studies for the site served as a starting point (CAP, 2008 Focused Feasibility Study[5]) for this assessment. The following section briefly describes each candidate technology and assesses them against the Model Toxics Control Act (MTCA) requirements for cleanup actions.

Technology Descriptions

Optimized Groundwater Extraction and Treatment System

This technology would actively recover part, or all, of the chemically-affected groundwater to prevent its downgradient migration and remove contaminant mass from the subsurface. Currently, groundwater is being recovered from two wells (RW-2 and RW-3, shown on Figure 1). The current recovery system has operated essentially continuously at a combined rate ranging from 12 to 17 gallons per minute. The extracted groundwater is being discharged to the King County sewer under permit. Optimization of the current system would involve assessing the performance of the current extraction system in terms of layout and operation, and potentially making modifications to both of those aspects (e.g., relocating recovery wells) based on that assessment. COC concentrations in groundwater would decline as mass is captured and removed from the subsurface by the extraction well network, which prevents further downgradient migration.

Monitored Natural Attenuation (MNA)

MNA refers to naturally occurring physical, chemical, or biological processes that can lead to the reduction of mass, toxicity, mobility, volume, or concentration of contaminants in soil and/or groundwater. These processes include biodegradation, dispersion, mixing, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of COCs.

[5] ENSR. 2008. Focused Feasibility Study, Version 3, GE South Dawson Street. October 2008.

MNA as a remedy is generally used following source reduction/removal measures where it can be demonstrated that the remaining contaminant plume is stable or shrinking, and no longer poses a risk to downgradient receptors. Several guidance documents provide the necessary site requirements and primary and secondary lines of evidence that would allow MNA to be used as the site remedy (e.g., Washington Administrative Code (WAC) 173-340-370). For chlorinated volatile organic compounds (CVOCs), lines of evidence may include confirmation that reductive dechlorination or other degradation pathways are occurring at the site and appropriate geochemical conditions for these intrinsic processes to proceed are present (i.e., relationships between contaminant source area, electron acceptors, reduced byproducts, and groundwater flow direction).

Air Sparging (AS)/Soil Vapor Extraction (SVE)

Air sparging is an in-situ technology in which air is bubbled into the aquifer to enhance volatilization and/or aerobic biodegradation, as appropriate for the site COCs. Air is dispersed radially from the injection points to create a subsurface “air stripper” that removes volatile contaminants and/or induces a bioactive zone where aerobic biodegradation is enhanced. The air is injected into the groundwater either in wells or trenches. AS also provides a degree of physical stripping, especially for volatile compounds. In these cases, the soil vapor and air quality may need to be monitored carefully or controlled with SVE to prevent release of potentially harmful concentrations of volatilized compounds. Vapors captured by SVE wells would be treated in an on-site system to remove CVOCs from the discharge stream. SVE would have the additional benefit of reducing the potential for vapor intrusion from the subsurface into overlying buildings.

Enhanced Anaerobic Biodegradation (EAB)

EAB is a process where compounds are added to the subsurface to stimulate the breakdown of target compounds. Carbon-based amendments are added to promote anaerobic conditions where chlorinated solvents undergo reductive dechlorination to form environmentally benign compounds (e.g., ethene and ethane). Several amendments can be used to stimulate anaerobic dechlorination including lactic acid or emulsified vegetable oil (EVO). The amendments may be injected into the subsurface using dedicated injection wells or temporary injection points from a direct push tool. Once injected, the carbon substrates break down and generate hydrogen, which is utilized by dechlorinating bacteria in the reduction process. EVO is not water soluble, and once injected into the subsurface the oil droplets will adhere to soil particles, which creates a biologically active zone around the injection well. As contaminants are transported through the biologically active zone they are degraded by the processes described above. The zone will generally remain active for 18 months to 2 years before requiring an additional injection of amendments.

In-situ chemical reduction (ISCR)

ISCR is a relatively new technology that may be implemented using several different techniques. The primary mechanism for treatment is the chemical reduction of CVOCs in a manner that is very similar to microbiological reductive dechlorination. Typically, chemical reductants and/or carbon substrates (electron donors) are added into the subsurface by a variety of methods including injection, soil mixing, and trenching. These amendments promote both beneficial abiotic and biotic processes to treat the target CVOCs. Commercially available products such as EHC® (PeroxyChem), which is a combination of zero-valent iron (ZVI) and slow-degrading carbon source, combine these two amendments for ease of handling and application. The addition of these amendments separately or in combination can generate conditions where highly reactive reduced mineral phases (mackinawite or FeS) may be formed that transform CVOCs into benign end products. The lifetime of these amendments can be greater than 5 years depending on the amount of materials added to the subsurface.

GE recommends implementing ISCR using a product like EHC® instead of ZVI by itself (macroscale or microscale). There are several reasons for this. First, using ZVI alone would require TCE to come into direct contact with the iron surface in order to be degraded, while the organic phase in EHC® will release volatile fatty acids, which can move with groundwater and create effective treatment over larger areas, including areas down-gradient of the amendment emplacement. Second, the use of EHC® typically results in limited production and minimal accumulation of cis/trans 1,2-DCE and vinyl chloride as compared to reductive dechlorination alone[6]. Given the low TCE concentrations present at this site, substantial levels of these intermediates are not expected to be observed.

[6] Brown, Richard A.; Mueller, James G.; Seech, Alan G.; Henderson, James K.; and Wilson, John T., "Interactions Between Biological and Abiotic Pathways in the Reduction of Chlorinated Solvents" (2009). U.S. Environmental Protection Agency Papers. 116.

Evaluation of Technologies against MTCA Criteria

Cleanup actions selected under MTCA must comply with several basic requirements. This includes meeting all of the threshold (minimum) requirements for cleanup actions (WAC 173-340-360(2)(a)), as well as being evaluated against additional criteria as provided in WAC 173-340-360(2)(b). The threshold requirements listed in WAC 173-340-360(2)(a) are:

- Protect human health and the environment
- Comply with cleanup standards
- Comply with applicable state and federal laws
- Provide for compliance monitoring.

After confirming a remedial technology meets all of the threshold requirements, it must also be evaluated the additional criteria listed in WAC 173-340-360(2)(b). Those additional criteria are:

- Use permanent solutions to the maximum extent practicable
- Provide a reasonable restoration time frame
- Consider public concerns.

Each of the contingent remedial technologies was evaluated against the threshold requirements and additional criteria listed above; a separate step to disqualify technologies on the basis of the threshold criteria alone was not conducted as the one-step evaluation using all criteria was sufficient to determine which technologies were appropriate for the site. Table 1 presents the narrative results of this screening evaluation, and Table 2 presents a ranking score for each threshold requirement and additional criteria; remedy cost was added to Table 2 as an additional differentiator for the evaluation, although a full disproportionate cost analysis was not conducted.

As shown in Tables 1 and 2, both MNA and optimized groundwater extraction and treatment scored low as compared to the other technologies, and are not considered a feasible stand-along remedy for the site under existing conditions. AS/SVE, EAB, and ISCR meet all of the threshold requirements and additional criteria. Of those three technologies, ISCR (using EHC®) scored the highest. The use of ISCR has several advantages over AS/SVE and EAB, including:

1. EHC® facilitates dual degradation pathways of reductive dechlorination and beta-elimination to degrade and remove contaminants.
2. EHC® does not depend on fluids for distribution, so does not require a high water table to facilitate distribution.
3. EHC® can be injected equally well into high or low permeability soils, including low-permeability soils located above the water table that may contain residual concentrations of CVOCs.
4. EHC® is a solid and will remain in place once injected into the subsurface. It will not be transported out of the target treatment area.
5. EHC® has a long active lifetime in the subsurface, so should be able to degrade contaminants in low-permeability or vadose zone soils that will diffuse into or otherwise enter the groundwater over long time periods.
6. EHC® will not result in an increased vapor intrusion concern like AS/SVE.

A more detailed description of how ISCR will be used at the site is presented in Section 3 below, and Section 4 provides a more detailed explanation of how ISCR meets each of the threshold requirements and additional criteria.

Table 1. Contingent Remedy Technology Options Screening Evaluation

Technology Option	Protect Human Health and the Environment, and Comply with Cleanup Standards[1]	Comply with Applicable State and Federal Laws	Provide for Compliance Monitoring	Use Permanent Solutions to the Maximum Extent Practicable	Provide a Reasonable Restoration Time Frame	Consider Public Concerns
Monitored Natural Attenuation	Groundwater CVOC concentrations would continue to decline over time due to naturally occurring processes such as biodegradation, adsorption, and dispersion. CVOC concentrations have declined in monitoring wells at on-site and off-site areas over the last 10 years; however, CVOC concentrations remain above groundwater standards in one on-site area and two off-site areas. The lack of active treatment limits the protectiveness of MNA as a remedy, and will take longer to comply with cleanup standards than other active technologies.	This remedy complies with MTCA Cleanup Regulations and other applicable state and federal laws.	This remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP.	CVOCs in groundwater and saturated soil would eventually break down due to naturally occurring degradation processes; however, the lack of an active technology to quickly degrade/remove CVOCs is not a permanent solution to the maximum extent practical.	CVOCs in groundwater and saturated soil would eventually break down due to naturally occurring degradation processes; however, this timeframe may be much longer that active treatment technologies. MNA may not provide a reasonable restoration timeframe at this point in time.	MNA does not address all potential public concerns for the site, as COVCs exceeding cleanup standards are not immediately addressed with active treatment and CVOCs in groundwater would still migrate off-site.
Optimized Groundwater Extraction and Treatment	Optimizing the hydraulic control system will increase the protectiveness of the remedy by further limiting off-site migration of CVOCs in groundwater. It will also remove additional CVOC mass from the system, which will speed up the natural attenuation of the off-site areas that currently exceed cleanup standards. Groundwater CVOC concentrations would continue to decline over time due to naturally occurring processes such as biodegradation, adsorption, and dispersion. CVOC concentrations have declined in monitoring wells at on-site and off-site areas over the last 10 years; however, CVOC concentrations remain above groundwater standards in one on-site area and two off-site areas. The lack of active treatment limits the protectiveness of optimized groundwater extraction as a remedy, and will take longer to comply with cleanup standards than other active technologies.	This remedy complies with MTCA Cleanup Regulations and other applicable state and federal laws.	This remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP.	CVOCs in groundwater and saturated soil would eventually break down due to naturally occurring degradation processes; however, the lack of an active technology to quickly degrade/remove CVOCs is not a permanent solution to the maximum extent practical.	CVOCs in groundwater and saturated soil would eventually break down due to naturally occurring degradation processes; however, this timeframe may be much longer that active treatment technologies. Optimized groundwater extraction may not provide a reasonable restoration timeframe.	Optimized groundwater extraction likely does not address all potential public concerns for the site, as COVCs exceeding cleanup standards are not immediately addressed with active treatment.
Air Sparing/Soil Vapor Extraction	CVOCs in groundwater and soils would be volatilized by air sparging and captured by the soil vapor extraction system. This will effectively reduce groundwater CVOC concentrations below cleanup standards, and increase the protectiveness of the remedy for indoor air by lowering shallow saturated soil CVOC concentrations. Volatilization of CVOCs may increase the risk of vapor intrusion in the on-site buildings and modification/addition to the VIMs may be required. Soil heterogeneity may limit the ability to uniformly distribute air in the subsurface and increase the timeframe to comply with cleanup standards. This remedy is protective of human health and the environment, and will comply with cleanup standards.	This remedy complies with MTCA Cleanup Regulations and other applicable state and federal laws.	This remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP, plus construction monitoring during remedy implementation.	CVOCs in groundwater and saturated soil would be permanently removed from the subsurface via volatilization due to air sparging, which would be captured by the vapor extraction system. This remedy is a permanent solution to the maximum extent practical.	The expected restoration time frame for cleanup using this technology options is expected to be five years based on remedy implementation at similar sites and the levels of CVOCs present at the site. This is a reasonable restoration timeframe.	AS/SVE would likely address all potential public concerns for the site. CVOCs exceeding cleanup standards would be immediately addressed with active treatment. The VIMs system may need to be upgraded to address public concerns about vapor intrusion.
Enhanced Anaerobic Bioremediation	CVOCs would be degraded through reductive dechlorination in the biologically active zone created from a carbon substrate injection into the shallow soil/groundwater at the site. This will effectively reduce groundwater CVOC concentrations below cleanup standards, and increase the protectiveness of the remedy for indoor air by lowering shallow saturated soil CVOC concentrations. During reductive dechlorination, CVOC degradation intermediates (e.g., vinyl chloride) are likely be temporarily present. This remedy is protective of human health and the environment, and will comply with cleanup standards.	This remedy complies with MTCA Cleanup Regulations and other applicable state and federal laws.	This remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP, plus construction monitoring during remedy implementation.	CVOCs in groundwater and saturated soil would be permanently removed from the subsurface via anaerobic biodegradation. This remedy is a permanent solution to the maximum extent practical.	The expected restoration time frame for cleanup using this technology options is expected to be 2-7 years based on remedy implementation at similar sites and the levels of CVOCs present at the site. This is a reasonable restoration timeframe.	EAB would likely address all potential public concerns for the site. CVOCs exceeding cleanup standards would be immediately addressed with active treatment.
In-Situ Chemical Reduction	CVOCs would be degraded in the reactive (abiotic and biotic) zone created from an amendment injection into the shallow soil/groundwater at the site. This will effectively reduce groundwater CVOC concentrations below cleanup standards, and increase the protectiveness of the remedy for indoor air by lowering shallow saturated soil CVOC concentrations. The combination of biotic and abiotic treatment processes makes supplemental bacteria and nutrient injection less critical to overall technical effectiveness (as compared to EAB). CVOC degradation intermediates (e.g., vinyl chloride) may be temporarily present, but likely at lower concentrations than would occur using EAB. This remedy is protective of human health and the environment, and will comply with cleanup standards.	This remedy complies with MTCA Cleanup Regulations and other applicable state and federal laws.	This remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP, plus construction monitoring during remedy implementation.	CVOCs in groundwater and saturated soil would be permanently removed from the subsurface via abiotic chemical reduction and anaerobic biodegradation. This remedy is a permanent solution to the maximum extent practical.	The expected restoration time frame for cleanup using this technology options is expected to be 1-5 years based on remedy implementation at similar sites and the levels of CVOCs present at the site. This is a reasonable restoration timeframe.	ISCR would likely address all potential public concerns for the site. CVOCs exceeding cleanup standards would be immediately addressed with active treatment.

<u>Notes:</u>

1. For each technology, continued operation of the hydraulic control system will capture on-site CVOC impacted groundwater and limit the movement of CVOCs to off-site areas. Continued operation of the VIMs will protect on-site properties from the risk of CVOC impacts to indoor air.

CVOC = chlorinated volatile organic compound; MNA = monitored natural attenuation; VIMs = vapor intrusion mitigation system; EAB = enhanced anaerobic biodegradation; MTCA = Model Toxics Control Act; CAP = Cleanup Action Plan;
AS/SVE = air sparging and soil vapor extraction.

Table 2. Contingent Remedy Technology Options Ranking

Technology Option	Protect Human Health and the Environment, and Comply with Cleanup Standards	Comply with Applicable State and Federal Laws	Provide for Compliance Monitoring	Use Permanent Solutions to the Maximum Extent Practicable	Provide a Reasonable Restoration Time Frame	Consider Public Concerns	Relative Cost	Total Ranking Score
Monitored Natural Attenuation	2	5	5	2	2	1	5	22
Optimized Groundwater Extraction and Treatment	3	5	5	2	2	2	4	23
Air Sparing/Soil Vapor Extraction	4	5	5	4	4	4	2	28
Enhanced Anaerobic Bioremediation	5	5	5	4	4	5	3	31
In-Situ Chemical Reduction	5	5	5	4	5	5	3	32

Notes:
A score of 5 is considered the highest (best) ranking, and a score of 1 is considered the lowest (worst) ranking.

Costs are approximate; a detailed cost estimate was not prepared for each technology option.

Section 3 – Description of EHC® Remedy

EHC® is a solid material composed of a plant-based carbon source and zero-valent iron (ZVI). The material will support two pathways to destroy chlorinated organics such as TCE. The first pathway (biotic) is supported by the presence of the organic phase and involves the stimulation of biological reductive dechlorination of TCE to daughter products and ultimately to ethene. The second pathway (abiotic) is supported by the presence of the ZVI and involves the direct reduction of TCE at the iron (elemental ZVI or reactive iron mineral) surface. In the case of ZVI, elemental iron is oxidized to ferrous and ferric iron while the TCE is directly reduced to ethane and ethene through unstable intermediates via a beta-elimination pathway.

The EHC® formulation is designed to combine both short- and long-term availability of soluble carbon and ZVI. ZVI will provide aquifer conditioning, creating reducing zones where oxidation reduction potential (ORP) may drop to between –200 millivolts (mV) to –600 mV. The soluble plant carbon is designed to provide a relatively long-term (e.g., up to five years) source of food and energy for native dechlorinating bacteria. The ZVI is also expected to remain active for at least five years. The material used in this application will consist of an EHC® blend that includes 50% by weight micro-scale ZVI and 50% by weight plant carbon. The target particle size for the ZVI may range from 50 to 600 microns. The EHC® blend is a solid slurry with a consistency similar to oatmeal; this consistency, unlike the liquid mixture used for the ISCO injections, is well suited for a longer residency time within the aquifer and is less susceptible to bypassing the target zone through preferential flow pathways.

Injections will be performed using a Geoprobe™ rig through an injection tool located at the rod tip. EHC® slurry will be delivered to the subsurface using a piston-type Chem-Grout pump. Injection pressures at the well head are expected to vary from 50 to 200 pounds per square inch and may be modified in the field as necessary to achieve target EHC® distribution or to prevent surfacing. Injecting the EHC® at a higher pressure disrupts the soil structure, minimizing the potential impact of preferential pathways due to small difference is soil structures (which dominate under lower pressure injections). GE will actively monitor for daylighting of the EHC® due to higher injection pressures and relatively shallow injection depths, which is commonly visually observed or accompanied by a severe drop in injection pressure; daylighting remedies include physically plugging preferential pathways (such as old boreholes) or adjusting injection conditions (injection volume, slurry density) to minimize daylighting. It is estimated that each injection will have a radius of influence of approximately 5 to 6 feet. The proposed remedy in the on-site source area will consist of approximately 19 direct injection locations in the alley adjacent to the McKinstry building (see Figure 2). At each location, injections will occur every 2 to 3 feet from approximately 7 to 12 feet below ground surface. The Geoprobe™ rod will be advanced to the shallowest depth at each location, then injections will proceed from the top down. The target EHC® loading over the treatment area is 0.5% EHC® by weight of soil, so that an estimated total of 3,000 to 3,500 pounds of EHC® will be injected throughout the treatment zone as part of the remedy.

Distribution of the EHC® in the formation will be verified during the field program using confirmation soil cores and magnetic susceptibility (MS) measurements. MS can detect the presence of the ZVI in the soil and provides a reliable measure of EHC® distribution. A hand-held MS meter will be used to make the measurements by sliding a MS probe along the plastic liners containing the confirmation soil cores. The MS method has been previously tested at other sites and is both rapid and accurate. Field standards will be used to correlate the MS readings to the mass loading of EHC® in the soil. The amount of ZVI that will be added to the system is significantly more than required to degrade the low levels of CVOCs present at the site; this is by design, to mitigate against any deterioration of iron reactivity by scavenging/passivation processes through natural interaction with the groundwater, and eliminates the need to use products like sulfidated iron which are less susceptible to these processes.

A groundwater monitoring program will accompany the application of the on-site EHC® remedy. A baseline sampling event will be conducted before injections begin. The post-injection monitoring program will focus on those shallow groundwater intervals currently exceeding groundwater standards, including monitoring wells MW-1, MW-22, MW-25, and MW-28. These wells will be monitored one month after the completion of the treatment program and then quarterly moving forward for CVOCs, field parameters (e.g., dissolved oxygen, ORP, pH, temperature, and conductivity) and a basic suite of MNA parameters (including total organic carbon) using a low-flow sampling procedure. Additional analyses (e.g., metals) may be added to the monitoring program to satisfy the requirements of GE's discharge authorization permit with King County for the groundwater hydraulic control system. Monitoring for daughter products of the abiotic degradation of TCE (e.g., acetylene and chloride) will not be conducted as the level of these chemicals are not expected to be measureable or distinguishable from background concentrations given the low CVOC concentrations at the site. Monitoring wells MW-23, MW-26, and MW-29 will also be monitored, although monitoring for these wells may be discontinued if no CVOC exceedances are observed after the first two monitoring events. Monitoring wells MW-5 and MW-4 are located upgradient and downgradient of the treatment zone, respectively, and currently do not exceed groundwater standards. These wells will be monitored quarterly for CVOCs only as part of the ongoing groundwater monitoring program. The duration of the monitoring program will be sufficient to ensure that any immediate, short-term drop in CVOC concentrations due to dilution from the injections is not mistaken for CVOC degradation, and that the seasonal influence on CVOC concentrations is accounted for in the performance assessment. The specific monitoring objectives, locations, and frequencies will be fully detailed in the Engineering Design Report (EDR).

Following implementation of the groundwater monitoring program, an additional round of on-site injections may be required if the EHC® is not performing as expected or does not appear to have the anticipated longevity in the system. If these conditions are observed GE will coordinate with Ecology to design a second on-site injection and monitoring program, or determine whether an alternative remedial technology should be evaluated (similar to the process described in Section 7 of the CAP.

The EHC® remedy can also be applied to downgradient soils and groundwater as necessary. The method of EHC® application is the same, but does require access to the contaminated media from the ground surface via Geoprobe™ unencumbered by buildings or utilities. Because there are no shallow groundwater cleanup level exceedances underneath buildings and therefore no vapor intrusion risk, the goal of off-site EHC® injections would be to prevent intermediate or deep groundwater exceeding groundwater to surface water cleanup levels from migrating toward the Duwamish River. A transect of injection points perpendicular to groundwater flow and targeting the interval of concern is sufficient to treat impacted groundwater as it flows through the treatment area and prevents migration toward the river. Figure 3 provides the approximate layout of off-site injection locations that could be used to treat and prevent migration of groundwater exceeding cleanup levels. The exact injection locations and treatment approach will be developed with Ecology based on the results of the on-site injection program.

Section 4 – Threshold Requirements and Other Criteria

As discussed at a high level in Section 2 and shown in Tables 1 and 2, an EHC® alternative remedy meets all of the threshold requirements and additional criteria. This section provides a more detailed description of how an EHC® remedy complies with each requirement/criteria.

Threshold Requirements

Protect Human Health and the Environment and Comply with Cleanup Standards

The EHC® remedy is protective of human health and the environment and complies with cleanup standards based on the following:

- Operation of the hydraulic control system reduces off-site migration of COC contaminated groundwater.
- Operation of the VIMS protects on-site properties from the risk of COC impacts to indoor air.
- The continued use of institutional controls for residual vadose zone soil contamination provides further protection by informing the current building owner of hazards and limiting activities that may result in exposures to COCs at the site.
- The use of EHC® will reduce COC concentrations in groundwater to below cleanup standards.

Comply with Applicable Laws

MTCA requires that all cleanup actions comply with applicable state and federal laws (WAC 173-340-360(2), WAC 173-340-710 and RCW 70.105D.090. In addition to the MTCA Cleanup Regulations, this project must also comply with the applicable state and federal laws provided in Table 4-2 of the CAP; this table is provided below for reference.

Table 4-2 Applicable State and Federal Laws

Law/Regulation	Requirements
Federal Water Pollution Control Act Clean Water Act (CWA) 40 CFR 100-149 Washington State Water Quality Standards for Surface Waters WAC 173-201A Washington State Underground Injection Program, Chapter 173-218 WAC	Establishes the basic structure for regulating discharges of pollutants into the waters of the United States and establishes standards for the protection of surface water quality. The cleanup action will comply with these regulations through the implementation of best management practices and a water quality monitoring program. The installation of the injection wells shall meet all applicable regulations of the UIC Program
National Pretreatment Standards (40 CFR 403) Metro District Wastewater Discharge Ordinance	Establishes pretreatment requirements for discharge to a municipal sewer. For water discharged to the Metro sanitary or combined sewer system, all conditions of the current permit must be met under future actions, or a new permit must be obtained.
Resource Conservation and Recovery Act (RCRA) (40 CFR 260 – 268) Washington Dangerous Waste Regulations (WAC 173-303)	Establishes requirements for identification of Dangerous Wastes based on whether or not the waste contains a listed waste, or if it displays a dangerous waste characteristic, for example by the Toxicity Characteristic Leaching Procedure. These regulations may be applicable for the storage, treatment, and disposal of the excavated/extracted material.
Solid Waste Handling Standards (RCW 70.95; WAC 173-350)	Establishes the requirements for solid waste management and disposal.
Clean Air Act, National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61) State Emission Standards for Hazardous Air Pollutants (WAC 173-400-075)	Establishes emission standards as well as ambient air quality standards. These requirements may be applicable to releases of hazardous air pollutants from remedial actions.

Based on the similarity to the Ecology selected remedial alternative (ISCO) in the CAP, the recommended alternative remedy (EHC®) also complies with the MTCA Cleanup Regulations and other applicable state and federal laws. The project will also need to comply with any additional local government permits, such as the discharge authorization from King County for the hydraulic control system.

Provide for Compliance Monitoring

The recommended EHC® remedy provides for compliance monitoring through the continuation of quarterly groundwater sampling and monthly VIMS monitoring required by the CAP, plus the construction monitoring proposed during remedy implementation.

Additional Criteria

Use Permanent Solutions to the Maximum Extent Practicable

The recommended EHC® remedy uses permanent solutions to contain and remediate COCs from groundwater at the site. Because the recommended EHC® remedy was the only alternative screened against the threshold criteria (above), there is no need for a detailed disproportionate cost analysis to select the most "permanent to the maximum extent practicable" alternative from among two or more alternatives that meet threshold criteria. The use of EHC® results in a permanent remedy by directly reducing (destroying) site COCs. Because this remedy is fully permanent for the existing land use, with the exception of subsurface contaminated soil that remains underneath or near the 220 South Dawson Street building (for which costs of a fully permanent solution would be grossly disproportionate – see further discussion below), GE has determined that the recommended EHC® remedy uses permanent solutions to the maximum extent practicable.

Groundwater Contamination: For COC contaminated groundwater, the recommended EHC® remedy is permanent because it utilizes an active groundwater treatment that is designed to remediate (reduce) the organic contaminants in groundwater.

Contaminated Soils: EHC® treatments are expected to treat COC contaminated soil at or below the water table in order to meet groundwater cleanup standards. Residual subsurface vadose zone COC soil contamination near and under the building will not be removed, and areas of COC contaminated soils remaining underneath the footprint of the 220 South Dawson Street building will remain capped by a concrete floor.

Subject to the conditions described in Section 6.0, paragraph 13 of the CAP, Ecology has already determined that the incremental costs of removing this remaining contaminated soil are grossly disproportionate and far exceed the incremental degree of benefit achieved by removing those remaining contaminated soils. Institutional controls and groundwater monitoring shall be in place to protect human health and the environment.

Provide a Reasonable Restoration Time Frame

The expected restoration time frame for cleanup using the recommended EHC® remedy is expected to be 1 -5 years; this is based on remedy implementation at similar sites and previous experience. This is a reasonable time frame within which to complete the cleanup. A site-specific restoration time frame will be revised after the contaminant response to treatment can be better evaluated. Initial data will be collected to evaluate the performance of the cleanup action on groundwater, soil, and vapor concentrations after the initial treatment to revise the projected restoration time frame. GE and Ecology will continually evaluate whether the restoration time frame remains on schedule and reasonable.

Consider Public Concerns

Public review comments were received several times previously leading up to the approval of the CAP (for example, pertaining to the vapor intrusion exposures to building tenants and during Ecology review of the draft focused feasibility study). The EHC® alternative remedy addresses all of the previously submitted public comments. This memorandum is intended to be submitted as background information for public review of the alternative remedies for the site; additional public comments will be considered by GE and Ecology when finalizing the alternative remedy selection and preparation of the EDR.

Section 5 – Summary

The Phase I ISCO injection pilot study and subsequent slow release cylinder test did not provide the anticipated degradation of contaminants, indicating the implementation of a full ISCO remedy may not meet site cleanup goals within a reasonable time frame. Several site physical conditions influenced the poor performance of ISCO reagents, most significantly the lack of reagent residence time due to preferential pathways and high aquifer conductivity and the presence of COCs in soils just above groundwater elevations.

In re-evaluating technologies, in-situ chemical reduction (using EHC®) was selected as the best alternative to implement at the site given the lessons learned from the Phase 1 pilot study. Physically very similar to ISCO, the use of EHC® offers significantly improved persistence in the aquifer and supports currently active native dechlorination activities. EHC®, unlike persulfate (ISCO), will remain present within the vadose zone where residual soil contamination continues to impact groundwater quality. All of the other components (hydraulic control, the VIMS, and institutional controls) are the same as for the ISCO remedy selected in the CAP, including operation of the groundwater hydraulic control system until on-site cleanup levels are met. This combination will result in a successful treatment of COCs to below cleanup standards within a reasonable time frame, while concurrently protecting human health and the environment from further exposure. A schedule for implementing an EHC® remedy at the site and a list of deliverables is provided below in Table 3.

Table 3. Contingent Remedy Schedule and Deliverables

Milestone/Deliverable	Due/End Date	Duration
Draft Engineering Design Report (EDR/CPS/OMP)	GE shall submit within 90 days following completion of the public comment process.	Per EDR schedule
Final EDR/CPS/OMP which addresses Ecology's comments	GE shall submit within 45 days following receipt of Ecology comments on the draft EDR/CPS/OMP.	
Construction and implementation per detailed EDR schedule (on-site EHC® treatment)	GE shall initiate construction and implement the EDR/CPS/OMP within 60 days following approval of Final EDR/CPS/OMP.	Per EDR schedule
Institutional controls per the approved EDR and its schedule	GE shall complete implementation of institutional controls within one year following finalization of the EDR.	Until Ecology determines institutional controls are no longer needed at the Site.
Draft on-site EHC® treatment and performance monitoring report	GE shall submit within 45 days after Ecology determines that on-site work is complete.	
Draft off-site EHC® treatment and performance monitoring plan (EDR addendum)	GE shall submit within 60 days after Ecology written approval of the on-site EHC® treatment and performance monitoring report.	
Implement off-site EHC® treatment and performance monitoring work plan	GE shall initiate implementation within 60 days after Ecology written approval of the off-site EHC® treatment and performance monitoring work plan.	Per EDR schedule
Draft off-site EHC® treatment and performance monitoring report	GE shall submit within 45 days after Ecology determines that off-site work is complete.	
Additional EHC® treatment and performance monitoring plans (EDR addendum)	GE shall submit within 60 days after Ecology written notice if Ecology determines that cleanup standards are not sufficiently met.	

Implement additional phase EHC® treatment and performance monitoring work plan	GE shall initiate implementation within 60 days after Ecology written approval of the additional phase EHC® treatment and performance	Per EDR schedule
Draft EHC® treatment and performance monitoring reports	GE shall submit within 45 days after Ecology determines that each applicable phase of EHC® work is completed.	
Revised phased EHC® treatment and performance monitoring work plans and reports.	GE shall submit within 45 days following receipt of Ecology comments on each respective draft work plan and report. GE shall revise the work plans and reports per Ecology comments.	
Draft As-built Report	GE shall submit per the schedule in the Ecology approved EDR.	
Revised Final As-Built Report	GE shall submit within 45 days following receipt of Ecology's comments on the draft As-built Report.	
Protection Monitoring	GE shall initiate implementation of protection monitoring within 60 days after monitoring plan in the EDR is approved by Ecology.	Until Ecology determines that protection monitoring is no longer required.
Performance Monitoring	GE shall implement immediately after phased EHC® injections are complete. Each phase of the EHC® treatment will have a specified performance monitoring plan.	Until Ecology determines that performance monitoring is complete.
Draft Confirmation Monitoring Work Plan	GE shall submit within 60 days after Ecology written request.	
Revised Confirmation Monitoring Work Plan	GE shall submit within 45 days following receipt of Ecology comments on the draft work plan.	
Confirmation Monitoring	GE shall initiate implementation of approved Confirmation Monitoring Work Plan within 30 days after Ecology determines that performance monitoring is complete.	Until Ecology determines that residual hazardous substance concentrations no longer exceed site cleanup levels.
Other Deliverables	Unless otherwise stated, GE shall resubmit revised deliverables per all Ecology comments within 45 days.	

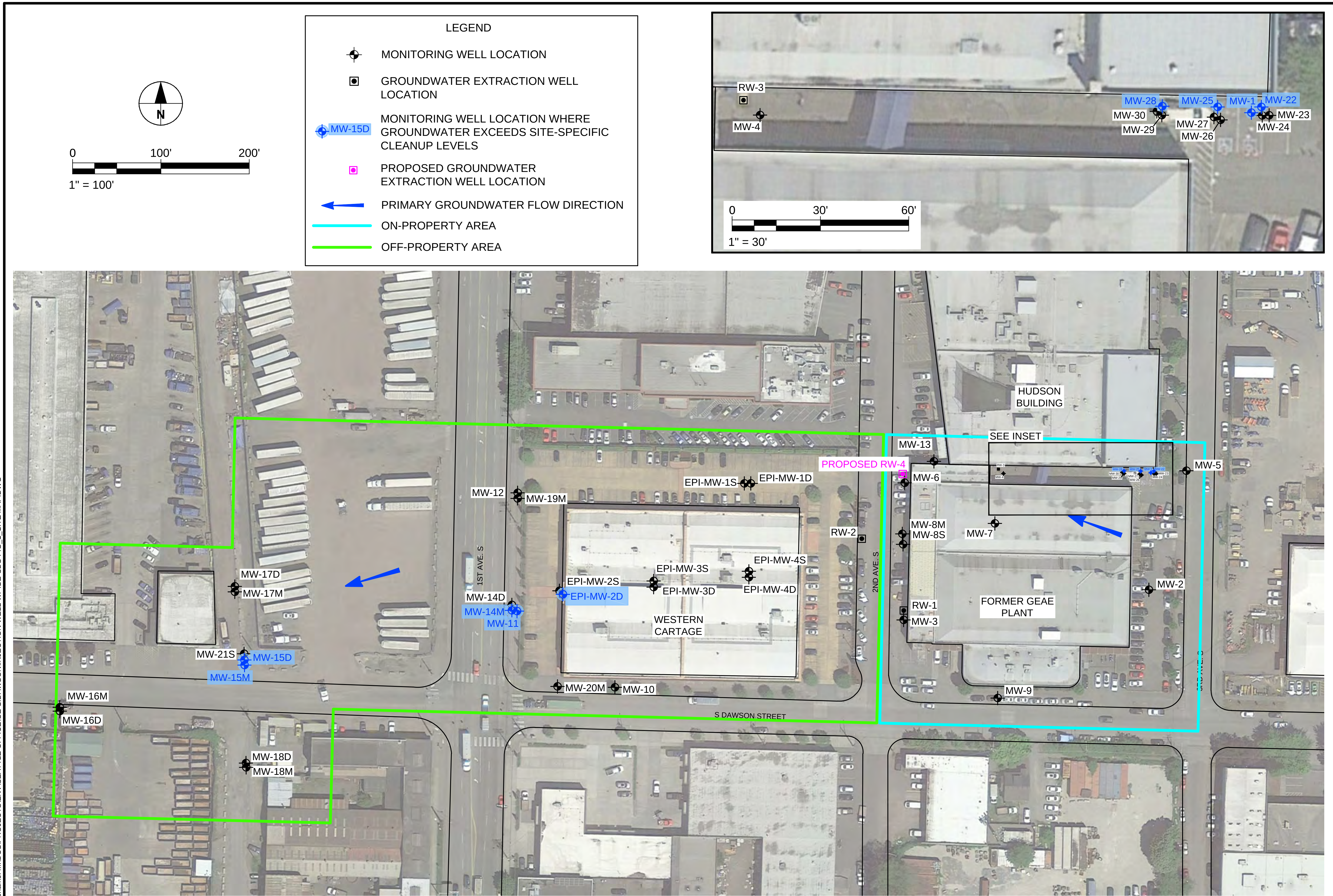

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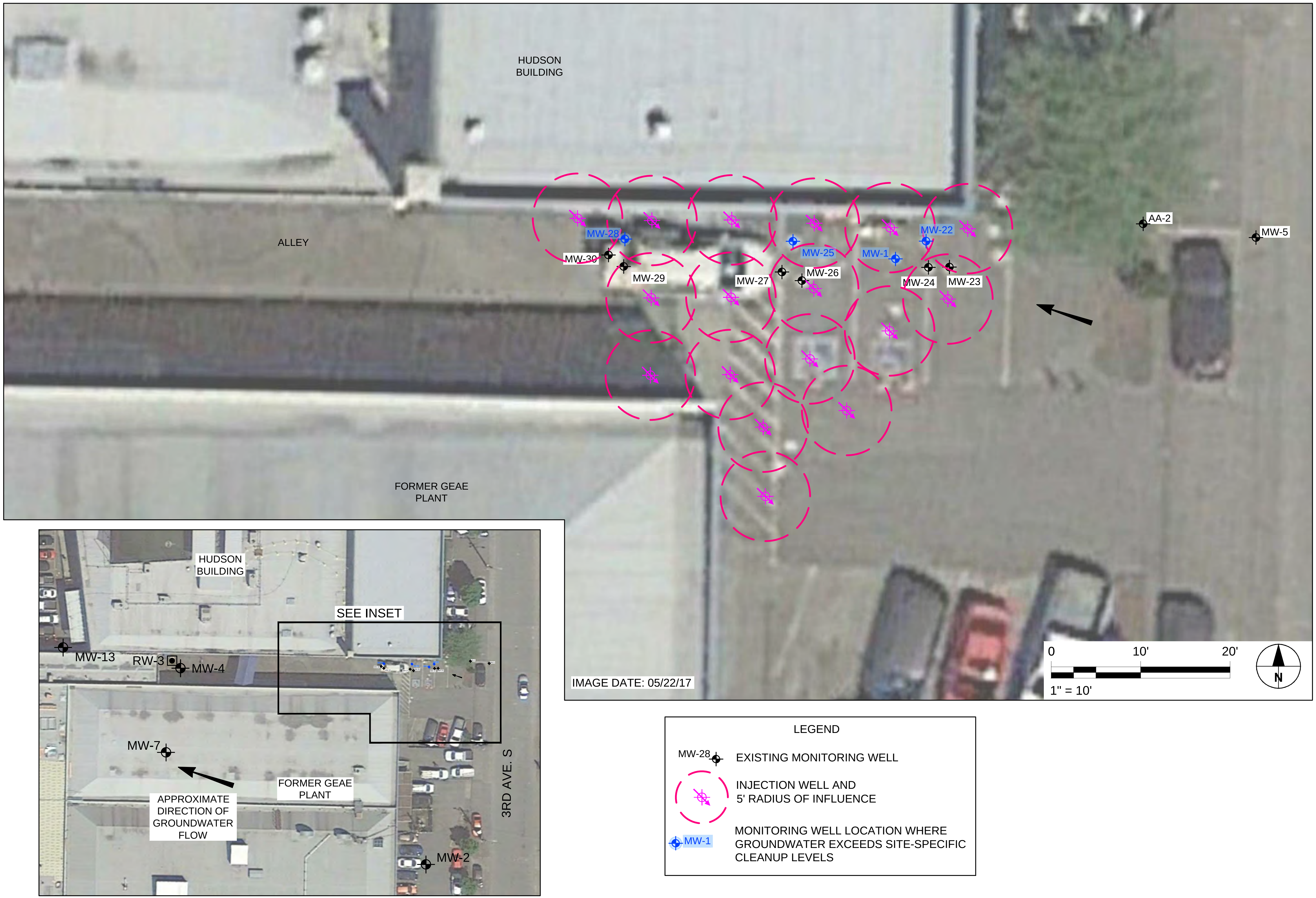
Figure: 1

SITE LAYOUT

GE, Seattle, WA

Project No.: 60563407 Date: 06/21/18



AECOM

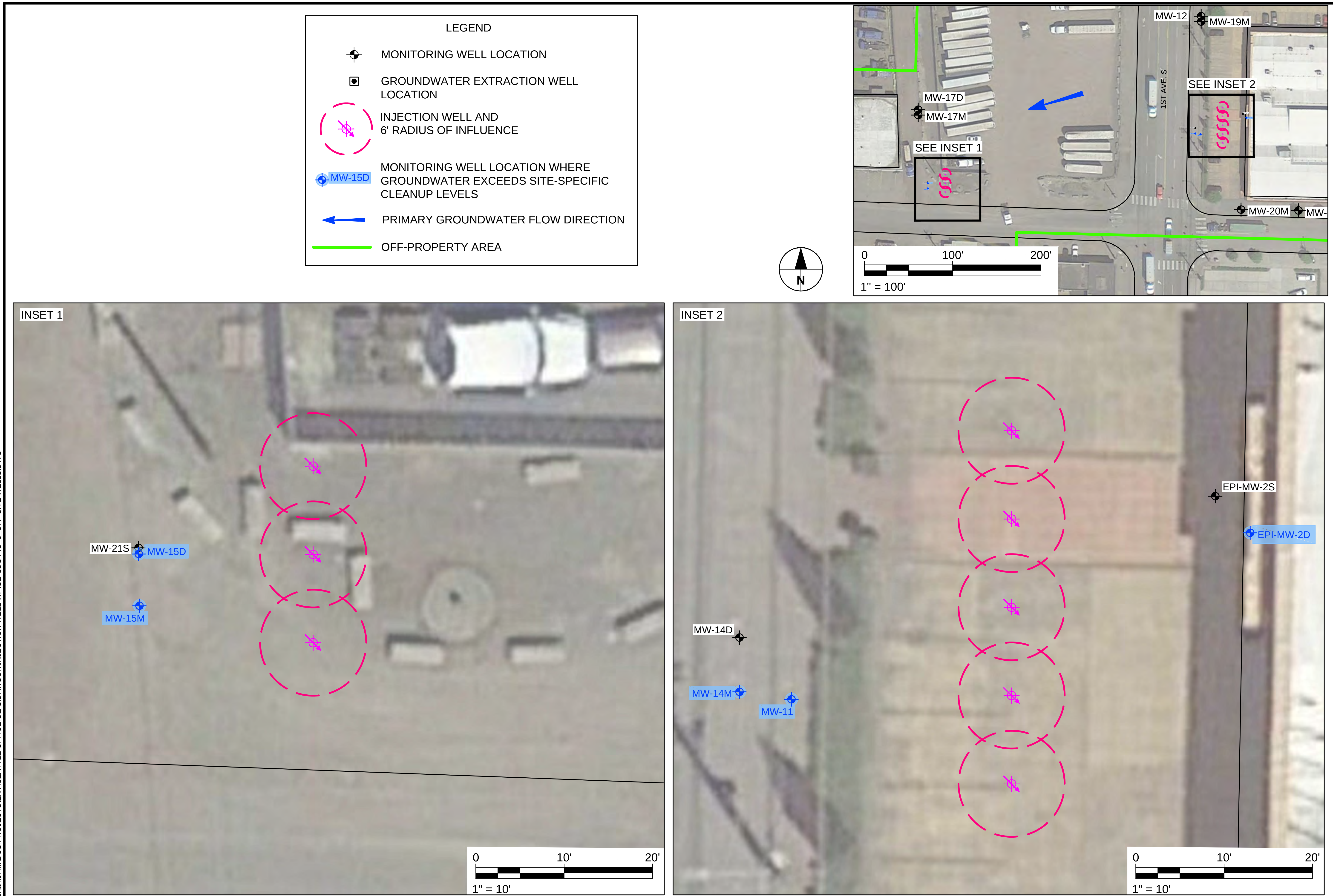
Figure: 2

CONCEPTUAL ON-SITE EHC® REMEDY

GE, Seattle, WA
Project No.: 60563407 Date: 06/21/18

Project Management Initials: Designer: e.s.s. Checked: D.C. Approved: ____ ANSI B 11" x 17"

Last saved by: SCHWARTZE(2018-06-21) Last Plotted: 2018-06-21
Filename: M:\DCS\PROJECTS\ENV\SEATTLE OFFICE\GE-S.DAWSON\INJECTION WELL WP\GE-SDS-FIG_2_ON-SITE WELLS.DWG



AECOM

Figure: 3

CONCEPTUAL OFF-SITE EHC® REMEDY

GE, Seattle, WA
Project No.: 60563407 Date: 06/21/18

ANSI B 11" x 17"
Approved:____
Checked: D.C.
Designer: e.s.s.
Project Management Initials:

Last saved by: SCHWARTZE(2018-06-21) Last Plotted: 2018-06-21
Filename: M:\DCS\PROJECTS\ENV\SEATTLE OFFICE\GE-S.DAWSON\INJECTION WELL WP\GE-SDS-FIG_3_OFF-SITE WELLS.DWG