ENVIRONMENTAL PARTNERS INC
1990 - 2015

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Interim Action Work Plan

Snohomish Square Cleaners
1419 Avenue D
Snohomish, Washington

Prepared For:

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October 9, 2015

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ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Definition
AMSL	Above mean sea level
AS	Air sparging
bgs	Below ground surface
cis-1,2-DCE	cis-1,2-Dichloroethene
COC	Contaminant of concern
DTW	Depth to water
Ecology	Washington State Department of Ecology
EPI	Environmental Partners, Inc.
ERD	Enhanced Reductive Dechlorination
ERH	Electrical resistance heating
IAWP	Interim Action Work Plan
MTCA	Model Toxics Control Act
mV	Millivolts
NFA	No Further Action
ORP	Oxidation-reduction potential
PCE	Tetrachloroethene
psi	Pounds per square inch
PVC	Polyvinyl chloride
RCW	Revised Code of Washington
SVE	Soil vapor extraction
TCE	Trichloroethene
TCH	Thermal conductive heating
TOC	Total organic carbon
trans-1,2-DCE	trans-1,2-Dichloroethene
UIC	Underground injection control
VCP	Voluntary Cleanup Program
VOCs	Volatile organic compounds
WAC	Washington Administrative Code

1.0 INTRODUCTION

Environmental Partners, Inc. (EPI) completed this *Interim Action Work Plan* (IAWP) for the Snohomish Cleaners property located at 1419 Avenue D in Snohomish, Washington, which will be referred to as the "subject property." The location of the subject property is indicated on Figure 1, General Vicinity Map.

The work documented in this IAWP was conducted on behalf of Skotdal Enterprises, Inc. in an ongoing effort to comply with the Model Toxics Control Act (MTCA; Revised Code of Washington [RCW] Chapter 70.105D) and its implementing regulations (Washington Administrative Code [WAC] 173-340; collectively referred to as MTCA).

The Site, as defined in Section 1.1, is enrolled in the Washington State Department of Ecology's (Ecology's) Voluntary Cleanup Program (VCP). The VCP ID No. for the Site is NW2740 and the Ecology-assigned project manager is Mr. John Guenther.

1.1 Background

Based on a review of available data, tetrachloroethene (PCE) was released at the subject property, which has resulted in impacts to soil and groundwater. The groundwater impacts have migrated downgradient (to the southwest) to a property owned by Snohomish County. The "Site," as defined by MTCA, includes portions of the subject property as well as the "upper terrace" of the downgradient Snohomish County–owned property to the southwest (Snohomish property).

The Site is depicted on Figure 2, Site Representation with Existing Monitoring Wells and Groundwater Plume.

1.1.1 Previous Environmental Investigations

To prepare this IAWP, EPI reviewed the following environmental investigation documents that documented the previous environmental investigations that were conducted at the Site:

- *Source Area Removal and Remedial Action Pilot Study* prepared by ERM-West, Inc. (ERM) dated November 2007 (ERM Report).

- *Phase II Environmental Site Assessment Data* letter report prepared by CDM Smith Inc. (CDM Smith, previously Camp Dresser & McKee Inc.) dated August 30, 2010 (CDM Smith Phase II Report).

- *Remedial Investigation and Focused Feasibility Study* prepared by CDM Smith dated April 30, 2013 (CDM Smith RI Report).

- *Preliminary Remedial Investigation and Cleanup Action Plan* prepared by Associated Earth Sciences, Inc. (AES) dated August 12, 2014 (AES Report).

- *Additional Subsurface Investigation and Preliminary Groundwater Interim Action Plan* prepared by EPI dated May 21, 2015.

1.1.2 Piezometric Conditions

On January 20, 2015, EPI measured static depth to water (DTW) below top of casing in wells that were measured at the Site. The DTW measurements levels ranged from 1.68 to 21.70 feet; these values are converted to groundwater elevations by subtracting the DTW from the surveyed measuring point elevations for each well. The resulting groundwater elevation data indicate that groundwater flow direction at the subject property is generally in a south-southwest direction with a horizontal hydraulic gradient of 0.017 foot/foot. Figure 3 depicts the groundwater elevations during the January 20, 2015 work.

1.1.3 Environmental Setting

The Snohomish Square Shopping Center is located in a commercially developed area within the City of Snohomish city limits. The property is currently zoned as COM for commercial development and is approximately 12 acres in size with multiple commercial buildings. The Snohomish Square Cleaners was located in the northwest corner of the main building at the subject property. The location of Snohomish Square Cleaners relative to the property boundary and the Snohomish County property is depicted on Figure 2. It should be noted that Snohomish Square Cleaners has been closed and there is no known current PCE use at the subject property or within the Site.

According to the ERM Report, the release of PCE to soil and groundwater was identified at the subject property in 2003. The likely source of impact was identified as improper disposal of cleaning solvent into a planter box located to the north of the cleaners.

Based on a review of the ERM Report, PCE impacts to soil appear to have been limited to the area surrounding the planter box. As part of a pilot study performed at the subject property, in 2006 ERM conducted soil remediation in the source area by excavation with off-Site disposal. Excavation activities occurred during four phases over an area of approximately 945 square feet to a depth of 8.5 to 9 feet below ground surface (bgs), which resulted in the removal and off-Site disposal of approximately 415 tons of PCE-impacted soil. Based on EPI's review of the analytical data for soil samples from the excavation bottom and sidewalls, the majority of PCE-impacted soil source material has been excavated and removed from the Site and only residual soil impacts remain.

Additional investigations performed by ERM and CDM Smith identified PCE impacts to groundwater. The impacted groundwater extends from Snohomish Square Cleaners to approximately 950 feet downgradient in a south to southwesterly direction. PCE impacts to groundwater have migrated off-property and have impacted the upper terrace portion of the Snohomish property to the southwest of the subject property.

CDM Smith performed investigations at the Snohomish property in 2009 and 2010 in support of a planned redevelopment of that property. According to the CDM Smith RI Report, the Snohomish property is divided into two distinct geographic areas: upper (eastern) and lower (western) terraces. A discontinuous perched layer of groundwater was encountered on the upper terrace, which is where the PCE impacts to groundwater were encountered. Data in the CDM Smith RI Report demonstrated that the perched groundwater is laterally discontinuous and is limited to the upper terrace. Therefore, the groundwater impacts migrating onto the Snohomish property are limited to the perched layer in the upper terrace and do not extend onto the lower terrace.

Based on a review of the available data, the only contaminants of concern (COCs) for the Site are PCE and its associated breakdown products:

- PCE;
- Trichloroethene (TCE);
- cis-1,2-Dichloroethene (cis-1,2-DCE);
- trans-1,2-Dichlroroethene (trans-1,2-DCE); and
- Vinyl chloride.

No other COCs have been identified for the Site.

1.2 Objectives of Planned Interim Measure

The initial objective of this IAWP is to facilitate obtaining a property-specific No Further Action (NFA) determination for the adjacent Snohomish property, with a longer-term objective of obtaining an NFA determination for the remainder of the Site. The proposed treatment described herein is based on input received from Ecology's VCP project manager and is intended to be responsive to Ecology comments and expectations to facilitate issuance of a property-specific NFA determination for the upper terrace of the Snohomish property.

1.3 Work Plan Organization

This IAWP is organized as follows:

- Section 1.0 Introduction
- Section 2.0 Selected Technology
- Section 3.0 Interim Measure Implementation
- Section 4.0 Reporting
- Section 5.0 Schedule
- Section 6.0 Limitations

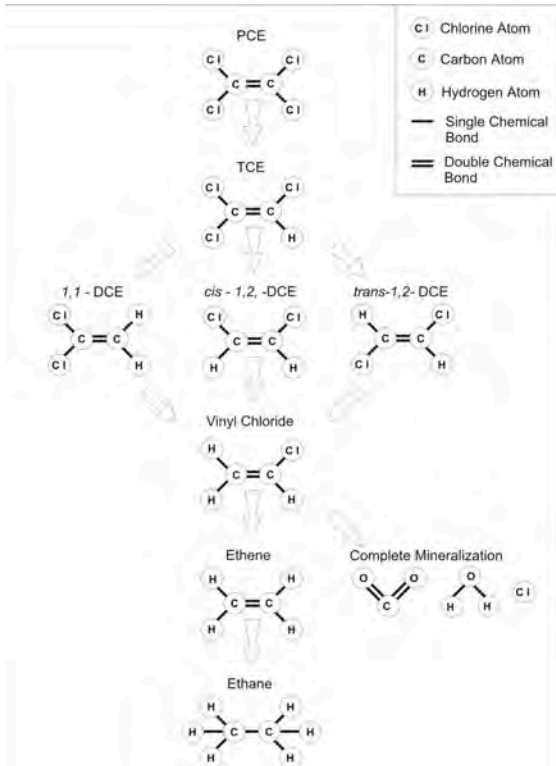
2.0 SELECTED TECHNOLOGY

ERM performed a pilot study at the subject using enhanced reductive dechlorination (ERD), which is an in situ bio augmentation remediation technology. Pilot study results are presented in the ERM document titled *Source Area Removal and Remedial Action Pilot Study*, dated November, 2007. As empirically demonstrated through ERM's pilot study described above, ERD has been shown to be an effective remedial strategy at the subject property in consideration of the site-specific goals and Site uses. Therefore, ERD is the remediation technology that has been selected to bring the Snohomish property into regulatory compliance. A more thorough explanation of the ERD process and the suitability to the subject property is presented below.

2.1 Enhanced Reductive Dechlorination Process

ERD is an *in situ* remediation technology that directly provides nutrients to the subsurface to enhance anaerobic geochemical conditions and promote the growth of specific bacterial populations that are effective in the biologically mediated step-wise transformation of chlorinated volatile organic compounds (VOCs) to their lesser chlorinated daughter products until only ethene or ethane gas remains. This process involves the addition of an electron donor, commonly a carbon-based nutrient substrate which when metabolized, provides a source of hydrogen for the sequential substitution of chlorine atoms for hydrogen atoms. In these redox reactions, hydrogen is created during the metabolism and fermentation of the nutrient substrate, whereby the electron donor, hydrogen (becomes oxidized) and the electron acceptor (chlorinated compound) becomes reduced. Diagram 1 presented below, uses PCE as a model example and depicts the biological breakdown pathway that occurs during reductive dechlorination.

Diagram 1
Reductive Dechlorination Breakdown Pathway



2.2 Site Applicability and Other Remedial Alternatives Considered

In addition to ERD, several other applicable remedial alternatives were considered for the Site. Those remedial alternatives are:

- Excavation and monitored natural attenuation (MNA);
- Soil vapor extraction and air sparging;
- *In situ* chemical oxidation;
- Thermal remediation;
- Pump and treat; and
- Permeable reactive barriers.

The remedial alternatives listed above were considered as potential candidates for implementation at the subject property, and while these remedial alternatives could potentially meet compliance goals for the subject property and Snohomish property, they were not selected as the remedial alternative for one or more reasons.

The remedial alternatives that were evaluated are discussed in greater detail below. The selection of the preferred remedial alternative, ERD, is based on multiple Site-specific factors and are evaluated and screened by comparing the following minimum screening criteria found in WAC 173-340-360:

As defined in WAC 173-340-360, the selected remedial alternative must meet the minimum ‘threshold” requirements listed below.

- Protect human health and the environment;
- Comply with cleanup standards (WAC 173-340-700 through 760);
- Comply with applicable local, state, and federal laws; and
- Provide for compliance monitoring (WAC 173-340-410 and 1730340-720 through 760).

In addition, the selected remedial alternative shall:

- Use permanent solutions to the maximum extent practicable (as defined in WAC 173-340-360, subsection 3);
- Provide for a reasonable restoration time frame (as defined in WAC 173-340-360, subsection 4); and
- Consider public concerns (per WAC 173-340-600).

Brief evaluations for each of the remedial alternatives with regard to the screening criteria listed above are provided below.

Excavation and Monitored Natural Attenuation (MNA)

In consideration of the remedial efforts conducted to date, there appears to be little benefit to performing additional soil removal activities. Targeted excavations have already been conducted in the source area to remove the highest concentrations of PCE in soil. As the PCE concentrations decrease with distance from the source area, the cost to dig, transport, and dispose of soils with lower concentrations become disproportionately cost prohibitive relative to the benefit achieved.

Excavation and offsite disposal simply transfers the PCE-impacted soil from the Site to a landfill where it will continue to be a potential liability. This outcome is less desirable as a long term solution than destruction or detoxification of the PCE, which are achievable outcomes by other remedial alternatives evaluated for the Site.

Because there will continue to be residual concentrations of chlorinated VOCs sorbed to soil particles near the source area, it is expected that MNA alone would not bring the subject property into regulatory compliance with a reasonable restoration time frame and therefore, the alternative will not be implemented as a remedial strategy. In addition, the lack of detectable lesser chlorinated breakdown products in groundwater samples indicates that reductive dechlorination, a component of natural attenuation, is not occurring to a measurable degree under current geochemical conditions in the aquifer at the Site.

Based on an evaluation relative to the screening criteria, excavation to remove the residual concentrations of PCE in soils on the subject property, followed by MNA for groundwater remediation has been ruled out as an effective remedial alternative for the Site.

Soil Vapor Extraction and Air Sparging (SVE and AS)

SVE and AS are proven as effective methods for treating chlorinated VOCs in soil and groundwater, are generally cost-effective, however, the shallow water conditions, geological features and plume dimensions render this option very technically challenging and potentially cost prohibitive.

The shallow soil layer at the subject property appears to contain the majority of the impacted groundwater. In order for SVE and AS to work effectively, there needs to be available vadose zone soil from which to recover the impacted vapors. In addition, the heterogeneous geology found in the vadose zone and upper aquifer will result in air movement through more permeable preferential pathways. The permeable layers will appear to reach cleanup goals while the bulk of PCE-impacts in finer-grained, less permeable layers will be less affected resulting in "rebound" of PCE concentrations when the system is shut down.

The groundwater table at the subject property has reportedly been detected at approximately 4 feet below ground surface (bgs), and the soils are comprised of dense lodgment till. If AS were introduced to the groundwater, localized mounding of the groundwater table would occur leaving even less available vadose zone soil to extract vapors from and potentially even cause bubbling in the parking lot during wet months. In consideration of these factors and the large areal extent of the plume, which would require costly infrastructure, this remedial alternative is not considered a viable option at this Site.

***In Situ* Chemical Oxidation**

Shallow groundwater conditions and extensive subsurface infrastructure at the subject property make this option unsuitable. Chemicals used for in situ chemical oxidation can corrode metals and cause damage to subsurface utilities, potentially escape to the surface, be driven into stormwater collection systems during pressure injections, and can have exothermic reactions which could degrade or melt plastic utilities or become unsafe in the shallow groundwater conditions at the Site.

In situ chemical oxidation relies on contact between the injected oxidant and the target contaminant(s). Because the subsurface geology is heterogeneous the chemical oxidant would preferentially flow into more permeable layers but would not be effectively introduced into fine-grained, less permeable layers where the bulk of the PCE mass tends to reside. This remedial alternative has a considerable risk of contaminant concentration rebound when the chemical oxidant is spent and PCE diffuses out of the low permeability layers.

In situ chemical oxidation is not preferred at the subject property mainly for health and safety reasons primarily due to the potential for uncontrolled releases during chemical injections. In addition, *in situ* chemical oxidation will not remediate residual PCE impacts in vadose zone soils due to lack of contact.

Thermal Remediation

Thermal remediation mainly consists of two different methods. Both methods require the installation of a network of steel-cased wells into the groundwater plume and areas of residual soil contamination. One method, called electrical resistance heating (ERH), works by inducing an electrical current between the steel-cased wells (electrodes), which causes the water to heat up allowing the volatile contaminants to reach their boiling points whereby they are volatilized into vapor phase and then captured by SVE wells. Another thermal technology called thermal conduction heating (TCH) also uses electricity, but creates heat at the wells causing the soils and water around them to heat up until they volatilize the nearby contaminants. TCH can achieve higher temperatures than ERH and can also be used to volatilize semi-volatile compounds.

The SVE portion of this technology, transfers contaminants from soil and groundwater to activated carbon, which when spent, will require special handling and disposal.

In general, thermal remediation is the most expensive remedial option and while it provides a quick restoration time frame and works effectively to remove contaminants from the subsurface, it requires extensive infrastructures consisting of large-diameter specially constructed wells, piping, and electrical networks, and has a disproportionately high capital and operational costs compared to the selected remedial option.

Pump and Treat

Pumping groundwater and treating it above ground using pumps, filters, strippers, and other equipment was evaluated as a remedial option. This technology also requires significant upfront capital costs and significant operational costs. The design of groundwater pumping and treatment systems requires multiple complex considerations to maintain hydraulic control provide adequate instrumentation and control. Hydraulic control at this Site with an intrinsically shallow water table is a concern and requires the de-watering and treatment of very large quantities of contaminated water, all manipulated through piping, instrumentation, valves, pumps, and control logic. In addition, long-term operation and maintenance costs for complex integrated remedial systems can easily cost in excess of $100,000 per year and requires the disposal or regeneration of treatment media such as granular activated carbon.

In addition, the heterogeneous geology found in the upper aquifer will result in the majority of the groundwater extracted coming from more permeable preferential pathways. The permeable layers will appear to reach cleanup goals while the bulk of PCE-impacts in finer-grained, less permeable layers will remain, resulting in “rebound” of PCE concentrations when the system is shut down.

Permeable Reactive Barriers (PRBs)

A PRB also works on the principal of reductive chlorination and was considered as a remedial alternative at the Site. PRB systems consist of an underground "wall" of reactive media installed within a matrix of engineered permeable material that treats dissolved contaminants as they passively migrate through the PRB with the flow of groundwater. For the Site, a series of trenches would be installed perpendicular to groundwater flow vectors in a downgradient location and a material such as nano-scale zero-valent iron (ZVI) would be placed below ground in the trenches to serve as an electron donor where the chlorine molecule becomes reduced.

PRBs again rely on hydraulic control and in aquifers with multiple geological and hydrogeological conditions, PRBs become difficult to hydraulically control. With already shallow water conditions, this potential lack of hydraulic control could be technically challenging and difficult to control. In addition, PRBs commonly don't treat the source area resulting in a long restoration timeframe.

2.3 Technology Limitations

While each of the remedial alternatives evaluated above meet some of the selection criteria, ERD meets all of the selection criteria and is a low-cost, low maintenance, proven technology with limited up-front capital cost and relatively no permanent infrastructure required to implement.

The primary limitation of ERD is monitoring and maintaining the specific required geochemical conditions in the aquifer that promote the growth of anaerobic bacteria populations. Groundwater monitoring for indicator constituents will be conducted prior to and following the nutrient injections to ensure favorable geochemical conditions are maintained for ERD to be successfully implemented.

Other limiting factors may include:

- The presence of preferential pathways, such as utility corridors that can negatively affect the dispersion and coverage of the injected nutrient substrate;
- Increased solubility resulting in the mobilization of some metals due to reducing geochemical conditions and lowered pH; and
- Insufficient dispersion throughout the treatment zone, which may render portions of the plume inadequately reducing and unfavorable for reductive dechlorination.

2.4 Permitting

An Underground Injection Control (UIC) permit will be required by Ecology prior to initiation of the injection process. EPI will coordinate the submittal, payment, and receipt of the UIC permit.

In addition, the wells installed along Avenue D will likely be located within the City of Snohomish (COS) right-of-way. Therefore, it will be necessary to obtain a COS Right-of-Way permit for well installation.

Other than drilling start cards no other permits are expected for this work.

3.0 INTERIM MEASURE IMPLEMENTATION

Implementation of the selected remedial alternative as an interim measure is intended to promote increased anaerobic bacteria populations that are capable of reductively dechlorinating the chlorinated contaminants in groundwater. This process relies on several key factors including maintaining the following geo-chemical groundwater conditions to promote reductive dechlorination:

- No presence of dense non-aqueous phase liquids (DNAPL, or free product).
- Moderate to high soil hydraulic conductivity. Hydraulic conductivities of 10^{-4} centimeters per second (cm/sec) or greater typically ensures that the injection substrate will effectively disperse and diffuse in the groundwater under natural flow conditions.
- Low dissolved oxygen. In general, an initial dissolved oxygen concentration of less than 3 milligrams per liter (mg/L) in groundwater is acceptable to promote an anaerobic environment, and a target concentration of less than 0.5 mg/L is preferred during ERD implementation.
- Negative oxidation-reduction potential (ORP). ORP values of -100 millivolts (mV) or lower are desired to ensure sufficiently reducing conditions are maintained.
- Neutral or slightly basic pH.

3.1 Interim Measure Overview and Design Considerations

3.1.1 Interim Measure Overview

ERD will be initiated by injection of a liquid nutrient substrate to the groundwater plume at the source area (Treatment Area 1), in wells downgradient of the source area (Treatment Area 2), and in linear treatment area parallel to Avenue D (Treatment Area 3) as shown in Figure 4. Geochemically reducing conditions will be established through the stimulation of indigenous microbial populations in response to a food source. Therefore, it is essential that the nutrient substrate be injected in appropriate concentrations and sufficient quantities to create those conditions.

The former remedial excavations in the source area (Treatment Area 1) were backfilled with pea gravel and the high permeability of the pea gravel will allow for the rapid introduction of large volumes of nutrient substrate to the groundwater with minimal resistance from the naturally tight native soils present in the rest of the Site. EPI expects that some residual concentrations of PCE remain sorbed onto soil particles in the saturated zone within the region around the previous soil remediation areas (the source area). It is critical that strong geochemically reducing conditions are maintained within this area of the plume.

Nutrient substrate will also be injected into groundwater monitoring wells located downgradient of the source area (Treatment Area 2) to enhance geochemically reducing conditions throughout the dissolved-phase groundwater plume on the subject property as shown in Figure 4.

Treatment Area 3 is a linear array of injection wells installed across the plume on the east side of Avenue D as shown in Figure 4. The injection well alignment in Treatment Area 3 is relatively perpendicular to the groundwater flow direction. This injection well alignment and spacing is intended to create a groundwater treatment zone whose effects will be transported downgradient by groundwater flow to remediate the chlorinated VOC plume on the Snohomish property.

3.1.2 Design Considerations

Results of the pilot study performed by ERM empirically demonstrated that ERD is an effective remedial alternative at the subject property. ERM performed bench-scale tests that compared the use of soybean oil and sodium lactate to demonstrate the effectiveness ERD.

In consideration of the successes demonstrated during the pilot study, ERD will be used as the remedial alternative, but the injected substrate will consist of 3-D Microemulsion®, a Regenesis product. While the introduction of an electron donor is the primary goal, other design considerations are factored into the selection of the appropriate substrate. 3-D Microemulsion® is a slightly viscous liquid composed of lactic acid, polylactate esters, and free fatty acids esterified to a glycerin molecule. In short, this combination of compounds provides both short-term and long-term electron donors. The lactic acid quickly and strongly initiates the dechlorination process by rapidly fermenting, while the polylactate esters are metabolized more slowly serving as a mid-term electron donor. The free fatty acids and fatty acid esters are converted to hydrogen over a longer time period and serve as a slower-releasing electron donor to provide a long-term hydrogen supply.

3-D Microemulsion® is a product that has become a standard by which many ERD solutions are compared. This product has a proven record with hundreds of case studies in which ERD has been successfully implemented at chlorinated solvent sites and is considered an industry standard for enhancing ERD as a remedial technique.

3.2 Well Types

3.2.1 Injection Points

Following the phased excavations within the former source area, two sections of 2-inch diameter 20-ft long polyvinyl chloride (PVC) slotted well screens were installed horizontally along the bottom of the former excavation prior to backfilling. These pipes were completed approximately 7 to 8 feet bgs and are connected to vertical riser pipes that are stubbed near the ground surface in a traffic-rated well box. From this well box, one pipe is angled to the southeast and the other pipe is angled to the southwest. These injection points will be identified as:

- EIW-E (Excavation Injection Well-East); and

- EIW-W (Excavation Injection Well-West).

As discussed above, these approximately 20-foot-long horizontal well screens are completed within the washed pea-gravel that was used as excavation backfill and will be suitable for use as substrate injection points. These injection points are depicted on Figure 4. A well-construction diagram for these injection points is provided in Attachment A.

3.2.2 Groundwater Monitoring/Injection Wells

Four of the existing vertical groundwater monitoring wells immediately downgradient of the source area will be used for 3-D Microemulsion® injection. These four wells are completed along the general downgradient flowpath from the source area and samples from these wells contain some of the highest concentrations of chlorinated VOCs observed at the subject property. Establishing reducing geochemical conditions within this area will be critical in the overall success of the remedial objectives.

The following existing groundwater monitoring wells will be used as injection points:

- MW-3;
- MW-4;
- MW-10; and
- MW-11.

Figure 4 depicts the locations of the vertical injection wells listed above. Attachment B provides the well-construction drawings for these wells.

In addition to the existing monitoring wells that will serve as injection wells, 12 new monitoring/injection wells will be installed in Treatment Area 2 and Treatment Area 3 as a part of the proposed interim actions. The proposed locations of these new injection wells are depicted on Figure 4.

Four additional monitoring/injection wells will be installed in Treatment Area 2 within the highest concentration areas of the plume. These wells will be sufficiently spaced from one another and the existing monitoring wells to ensure adequate spatial coverage of the nutrient substrate in this area when it is injected. Wells within the regions of the subject property around MW-3, MW-4, MW-10 and MW-11 will be installed to 25 feet bgs or refusal if it is encountered between 20 and 25 feet bgs. The approximate elevation of the well screens will be elevation 145 feet to 155 feet above mean sea level (AMSL). Wells in this area will be screened with 10 feet of 0.020-inch slotted PVC well screen. Figure 4 depicts the locations of the proposed vertical injection and monitoring wells.

Eight additional monitoring/injection wells will be installed along the subject property side of Avenue D across the width of the plume. The findings of the previous pilot study indicate that the radius of influence during injections will be approximately 10 feet. Therefore, a spatial separation of approximately 20 feet between wells will ensure that the injected nutrient substrate will disperse as it moves downgradient and sufficiently mix within the plume as it migrates. The width of the plume as it passes beneath Avenue D is approximately 160 feet wide. Spacing wells approximately every 20 feet apart will require the installation of seven additional injection wells in this location. Existing monitoring well GW-10 will additionally be used as one of these injection wells.

Wells will be completed using standard hollow-stem auger drilling techniques with 12-inch diameter auger flights. Wells will be installed to a maximum depth of 30 feet bgs, or if refusal is encountered between 25 feet and 30 feet bgs. These wells will be completed with 15 feet of 0.020-inch slotted PVC well screen set in an appropriate sand filter pack. The approximate elevation of the well screens will be elevation 135 feet to 150 feet AMSL.

Newly installed injection wells will be comprised of 6-inch diameter Schedule 40 PVC. The large diameter well will enable a large reservoir for gravity feeding in the event that injection rates are slow. The large diameter of the borehole and sand pack will also provide more surface area for substrate to flow into the native formation.

Each well will be fitted on the top with 2-inch diameter male polyethylene cam fittings to allow for quick assembly of injection piping. Other existing injection well heads may necessarily be modified in a similar fashion for ease in the injection process.

Each newly installed well shall be developed to remove as much fine material as possible. Each well will be developed using a surge and pump technique until NTU values are less than 0.5.

In addition to the injection and treatment wells, one additional monitoring well (MW-15) will be installed in the middle of the groundwater plume for geochemical monitoring purposes. This well will be 2-inch in diameter and will be installed to a depth of 30 feet below grade with 15 feet of 0.010-inch slotted PVC well screen. The location of this monitoring well is depicted on Figure 4.

3.3 Substrate Injection Process

3.3.1 Pre-Injection Procedures

Nutrient substrate injections will be conducted at each of the injection points listed above during injection events. In order to be able to use MW-10 as a gauge for temporary groundwater mounding during injections in the horizontal wells, the former excavation points will be injected into first while MW-10 is monitored for groundwater levels. It will be important to gauge the water level in MW-10 during this process to ensure that water levels affected by temporary mounding at the injection points do not pose a threat of entering the stormwater or other utility systems. Close attention will be paid to the utility corridors and nearby groundwater monitoring wells to ensure that the injections do not cause water and injected substrate to daylight at the ground surface or follow preferential pathways of the utility lines. Elevation measurements from the ground surface to the bottom of the catch basin outlets and the stormwater retention system (if possible) will be obtained prior to injections.

3.3.1.1 Geochemical Testing

A round of groundwater levels will be collected from all Site wells prior to injecting substrate. In addition to water levels, a round of geochemical data will be collected from upgradient wells MW-3 and MW-9, injection wells, and downgradient monitoring locations MW-1, MW-2, MW-7, MW-8, MW-15, GW-4, and GW-11 to serve as control wells establishing background conditions.

Geochemical parameters will be collected using a low-flow peristaltic pump and passing groundwater through a flow-through cell where the following parameters can be collected using a handheld meter:

- Temperature in degrees Fahrenheit (°F);
- pH (unitless);
- Dissolved oxygen (DO) in milligrams per liter (mg/L);
- ORP in mV; and
- Conductivity in millisiemens (mS).

3.3.1.2 Laboratory Analysis

Prior to the collection of groundwater samples, the field parameter data above will be collected approximately every 3 minutes until sufficiently stabilized. Stabilization is indicated by, at a minimum, one of the following criteria: the static water level in the well will not drop more than 1/10 of the wetted length of the exposed well screen in the aquifer, a minimum of three well volumes have been removed, or each specific parameter does not change more than a certain amount over the duration of the purging.

In addition to geochemical parameters, laboratory chemical analysis of the baseline groundwater samples will be collected prior to injection and analyzed for the following:

- Chlorinated VOCs by EPA Method 8260B;
- Total organic carbon (TOC) by EPA Method 415.1;
- Chemical oxygen demand (COD) by EPA 410.4;
- Biological oxygen demand (BOD; 5-Day) by EPA Method 5210B;
- Total and dissolved iron and manganese by EPA Method 6010b;
- Chloride by EPA Method 325.1;
- Sulfate/sulfide and nitrate/nitrite by EPA Method 300.0; and

- Methane, ethane, and ethane, and carbon dioxide by Method RSK-175.

3.3.2 Injection Procedures

Substrate injection into the injection points described above and shown in Figure 4 will occur following the collection of the baseline data described above. The non-hazardous and non-toxic 3-D Microemulsion® solution will be shipped to the Site in sealed 3.7-gallon plastic buckets and staged in an appropriate location prior to the beginning of field work.

3.3.2.1 Mixing Ratio

Injections of 3-D Microemulsion® will be performed in approximately 244-gallon batches. A 330-gallon clear polyethylene tank will be used as a mixing, storage, and delivery tank for the nutrient substrate. The tank will be placed inside the back of a 1-ton pickup truck for ease of transportation between injection locations.

A ratio of 10 parts water by volume will be mixed with 1 part 3-D Microemulsion®. Mixing 6 buckets of 3-D Microemulsion® product, (22.2 gallons total) with 222 gallons of water will yield a total tank volume of 244 gallons of nutrient substrate. The water will be metered into the top of the tank using a flow totalizer on the fire hydrant located on the northwest corner of the former excavation. Product will be added to the tank manually.

Mixing of the factory-emulsified product with water will be performed using a positive displacement water pump with recirculation valving on the tank. When thoroughly mixed to the correct concentration, the substrate will be injected into the formation. Additional valves and pressure gauges will be added to the injection hoses to allow for operators of the injection process to control the flow.

A flow totalizer will be installed on the discharge side of the piping system to allow for an accurate measurement of the injection volumes at each location. In addition, the mixing and injection tank will be marked on the side to visually determine the volumes in the tank before and after injections.

Injection pressures may be regulated by either opening the recirculation valve on the discharge side of the pump to allow some amount of the pump discharge to return to the tank. In addition, the end of the injection hose will be fitted with a valve to allow the operator to control the flow and pressure at the well. Injections will be performed slowly by allowing the pressures to slowly develop until flow occurs into the wells.

In consideration of the weight of the soil and water above the bottom of the well screens, it is expected that a minimum of 0.86 psi will be required for every submerged foot of the well, and approximately 0.7 psi will be required for every unsubmerged foot. As an example, if an injection well is 15 feet submerged and 15 feet unsubmerged, a minimum pressure of 23.4 psi will be required to initiate flow. Some amount of additional pressure will be required to overcome the hydrodynamic force necessary to push the water through the pore spaces. Beyond the hydrostatic pressures mentioned above it may be possible to fracture or lift the soils and therefore, close attention will be paid to injection pressures at which flow is initiated, how it rises or falls as flow is initiated, and will be recorded in a daily field log at each location. Injection pressures of greater than 40 psi were necessary during previous injection work.

Injections at each location will terminate if the minimum target volume of substrate is injected, or if unsafe or potentially damaging pressures are experienced.

The injections will begin in the former excavation cavity through the injection points EIW-E and EIW-W. It is possible that these two points may take the substrate by gravity draining it from the tank. The piping on the injection piping system will allow for the pump to be bypassed if pressure injection is not required at any of the locations.

The following injection areas and volumes will be segregated as follows:

- **Area 1:** includes the two horizontal injection wells (EIW-E and EIW-W) and MW-3
  - Approximately 240 gallons in MW-3
  - Approximately 1,080 gallons in each horizontal well
- **Area 2:** includes the four new vertical wells installed immediately downgradient of the source area and existing wells MW-4 and MW-11
  - Approximately 375 gallons in each well
- **Area 3:** includes the row of eight new vertical wells along Avenue D and existing well GW-10.
  - Approximately 400 gallons in each well

3.4 Performance Monitoring

Following injections, performance monitoring will be performed to measure the progress of the injections and whether or not adequate groundwater conditions have been met to support the ERD process.

3.4.1 Groundwater Sampling and Analyses

Performance groundwater samples will be collected from all injection and observation wells. All samples will be collected following similar techniques as those used during the baseline analysis.

Geochemical parameters will be field collected from all wells as described in Section 3.3.1.1.

Monitoring wells MW-1, MW-2, MW-3, MW-7, MW-8, MW-9, MW-15, GW-4, and GW-11 will be submitted for the laboratory analysis detailed in Section 3.3.1.2.

Samples from the remaining monitoring wells will be submitted for chlorinated VOC analysis using EPA Method 8260B.

3.4.2 Monitoring Schedule

Groundwater samples will be collected and analyzed on a quarterly basis. Baseline sampling can be performed following approval of this IAWP and upon receipt of the UIC permit. The quarterly sampling program will be initiated 30 days after the first treatment injection. The monitoring schedule might be adjusted after the first injection event is conducted, and depending on Site-specific conditions.

3.5 Re-Treatment Criteria

Additional applications of nutrient substrate will be evaluated following analysis of the quarterly groundwater sampling program. It is expected that concentrations of PCE will decline and concentration of daughter products will rapidly increase during the reductive dechlorination process as the lactic acid is quickly consumed by the anaerobes. It is also expected that additional breakdown will continue as the fatty acid esters begin to ferment. Temporary increases in cis-1,2-DCE concentrations followed by temporary increased in vinyl chloride concentrations are expected following the injection.

We cannot accurately predict how long the groundwater remediation process will take; however, the previous injection at the Site resulted in an order of magnitude decrease in PCE concentrations in the non-injection wells within 2 months of the injection. Similar results are anticipated for the proposed remedial action.

Concentrations of 20 mg/L of TOC will continue to be a target concentration within any wells within the injection areas. If injection well TOC concentrations fall below 20 mg/L and there are little to no measured declines in chlorinated VOC concentrations in the next quarterly sampling event, another round of injections may be warranted.

4.0 REPORTING

Following the baseline sampling event, the first injection, and a follow-up performance groundwater monitoring event, an Interim Remedial Action Report will be completed to document to following:

- Newly installed injection wells and associated boring logs;
- Substrate injection procedures, pressures and volumes injected and spatial coverage;
- Geochemical and environmental aquifer response and laboratory data;
- Off-property and sentinel well conditions; and
- Potential re-treatment criteria and/or next steps.

After the initial treatment, an interim progress memorandum will be prepared following the first notable change in either contaminant concentrations or to geochemical parameters indicating that the injected substrate is performing as designed.

Annual groundwater monitoring reports will be submitted at the end of each January to document groundwater conditions for the previous year. Annual groundwater monitoring reports will be comprehensive evaluations of the remedial progress achieved at the Site. The annual reporting schedule will allow data evaluations to be performed in the context of seasonal groundwater fluctuations and is intended to allow sufficient time for the ERD process to become established and produce sufficient data to prepare meaningful conclusions and recommendation for the Site.

5.0 SCHEDULE

EPI anticipates starting the permitting for this project within 30 days from submitting this document to Ecology. Well installation and initial treatment will be implemented within 30 days of receiving all appropriate permits, dependent on driller availability. The first round of groundwater sampling will occur after well installation and development, prior to initial treatment. This data will serve as the “baseline” conditions for the Site. Quarterly monitoring will be initiated 30 days after the initial treatment. EPI will perform a total of two years of quarterly monitoring (eight sampling events) and then evaluate future sampling frequencies.

Assuming a submittal date of October 12, 2015, permit applications will be submitted by November 9, 2015. Assuming approval within 7 to 10 work days, well installation, initial sampling, and initial treatment would be started by December 14, 2015. Following well installation, the first quarterly sampling event will be implemented in January 2016. In the event that Ecology delays the start of the project, the schedule outlined above will be implemented according to this relative schedule.

6.0 LIMITATIONS

To the extent that preparation of this IAWP has required the application of best professional judgment and the application of scientific principles, certain results of this work have been based on subjective interpretation. EPI makes no warranties express or implied, including and without limitation, warranties as to merchantability or fitness for a particular purpose. The information provided in this IAWP is not to be construed as legal advice.

This IAWP was prepared solely for Skotdal Enterprises, Inc., and the contents herein may not be used or relied upon by any other person without the express written consent and authorization of EPI.

Figures

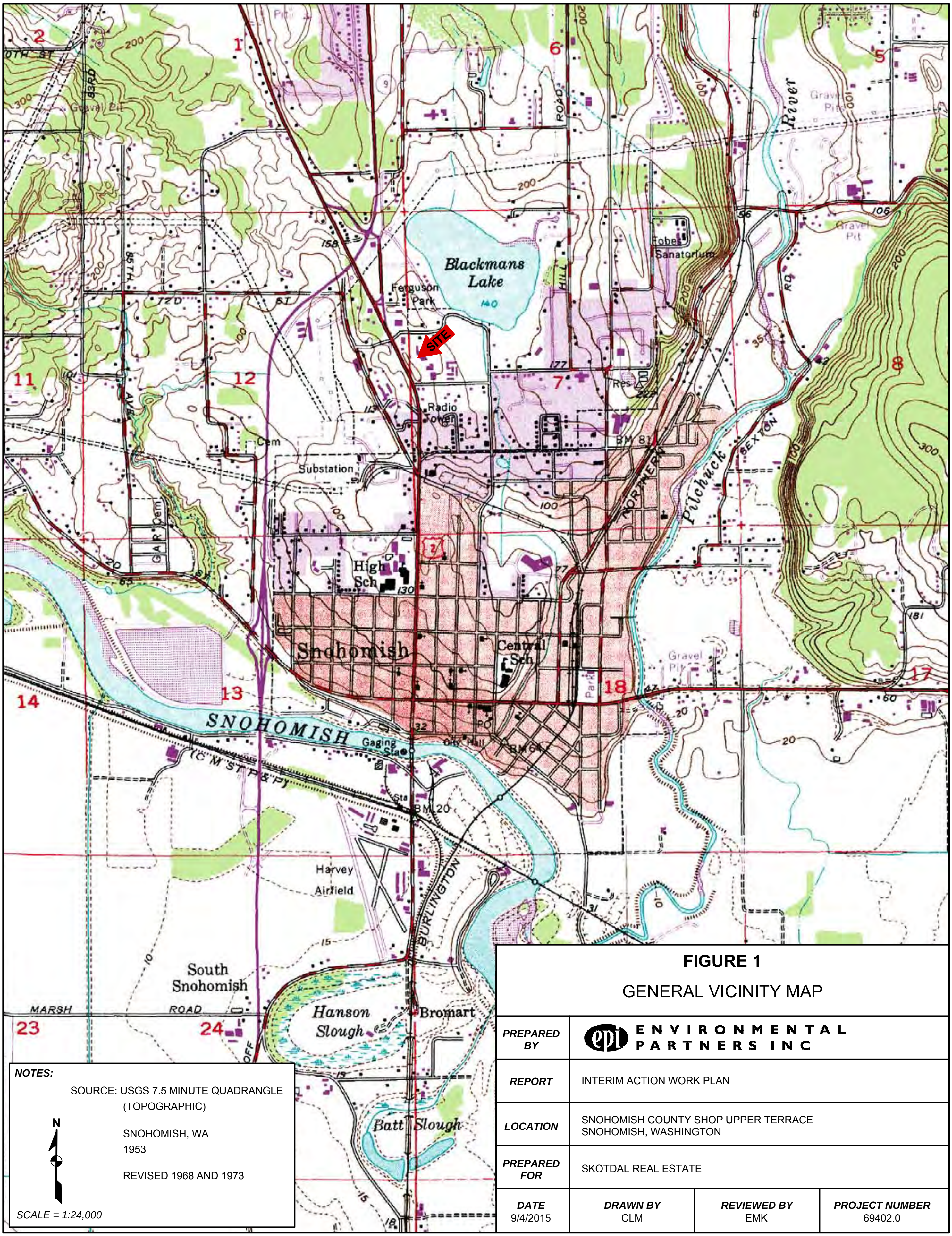


FIGURE 1

GENERAL VICINITY MAP

PREPARED BY	EPI ENVIRONMENTAL PARTNERS INC
REPORT	INTERIM ACTION WORK PLAN
LOCATION	SNOHOMISH COUNTY SHOP UPPER TERRACE SNOHOMISH, WASHINGTON
PREPARED FOR	SKOTDAL REAL ESTATE

DATE	***DRAWN BY***	***REVIEWED BY***	***PROJECT NUMBER***
9/4/2015	CLM	EMK	69402.0

NOTES:

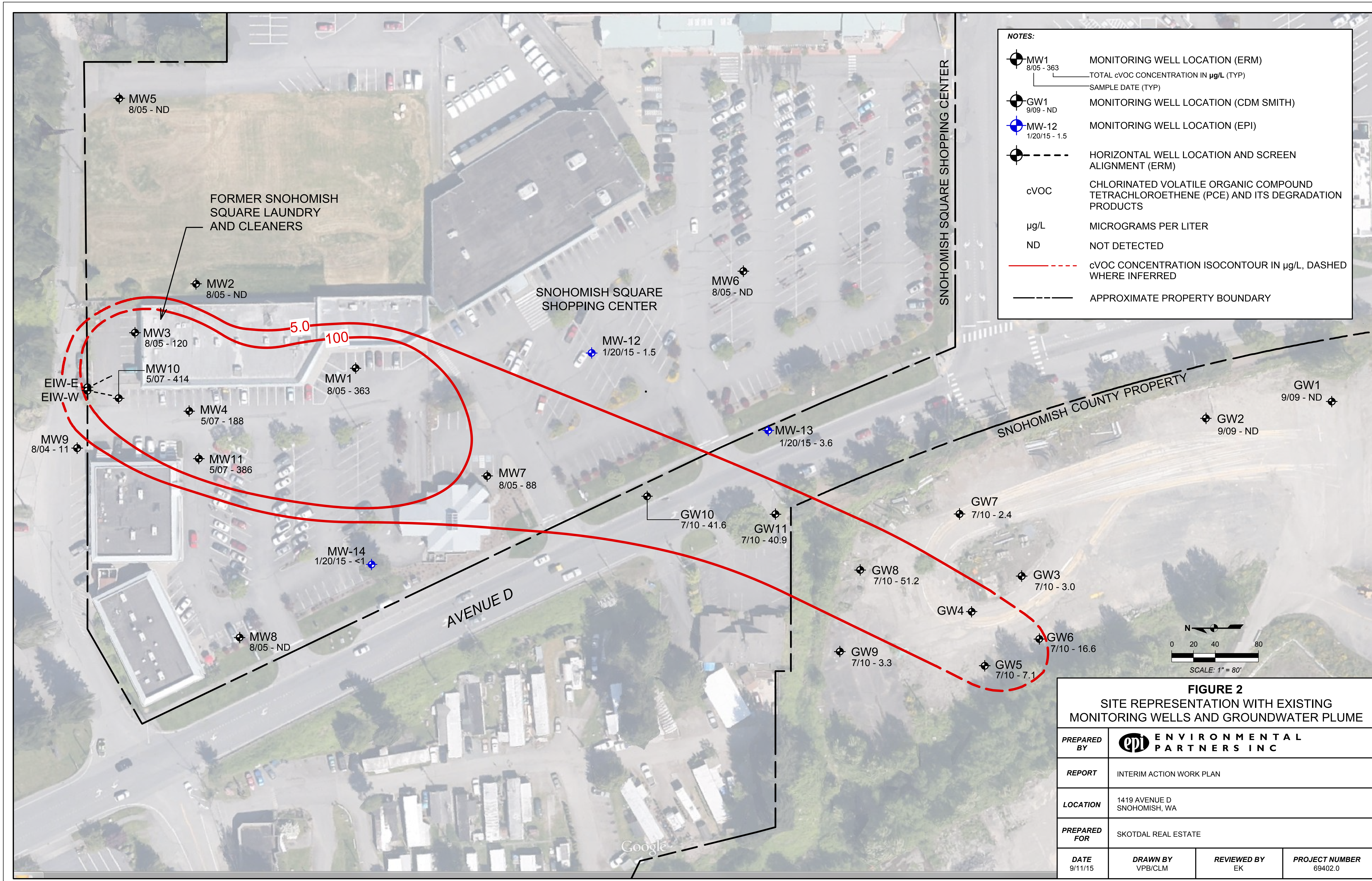
SOURCE: USGS 7.5 MINUTE QUADRANGLE (TOPOGRAPHIC)

SNOHOMISH, WA
1953

REVISED 1968 AND 1973

N

SCALE = 1:24,000


NOTES:
MW1
8/05 - 363
MONITORING WELL LOCATION (ERM)
TOTAL cVOC CONCENTRATION IN µg/L (TYP)
SAMPLE DATE (TYP)
GW1
9/09 - ND
MONITORING WELL LOCATION (CDM SMITH)
MW-12
1/20/15 - 1.5
MONITORING WELL LOCATION (EPI)
HORIZONTAL WELL LOCATION AND SCREEN ALIGNMENT (ERM)
cVOC
CHLORINATED VOLATILE ORGANIC COMPOUND TETRACHLOROETHENE (PCE) AND ITS DEGRADATION PRODUCTS
µg/L
MICROGRAMS PER LITER
ND
NOT DETECTED
cVOC CONCENTRATION ISOCONTOUR IN µg/L, DASHED WHERE INFERRED
APPROXIMATE PROPERTY BOUNDARY
MW5
8/05 - ND
FORMER SNOHOMISH SQUARE LAUNDRY AND CLEANERS
MW2
8/05 - ND
SNOHOMISH SQUARE SHOPPING CENTER
MW6
8/05 - ND
SNOHOMISH SQUARE SHOPPING CENTER
MW3
8/05 - 120
5.0
100
MW-12
1/20/15 - 1.5
MW10
5/07 - 414
EIW-E
EIW-W
MW1
8/05 - 363
MW4
5/07 - 188
MW-13
1/20/15 - 3.6
SNOHOMISH COUNTY PROPERTY
GW1
9/09 - ND
GW2
9/09 - ND
MW9
8/04 - 11
MW11
5/07 - 386
MW7
8/05 - 88
GW10
7/10 - 41.6
GW11
7/10 - 40.9
GW7
7/10 - 2.4
MW-14
1/20/15 - <1
GW8
7/10 - 51.2
GW3
7/10 - 3.0
AVENUE D
GW4
GW6
7/10 - 16.6
MW8
8/05 - ND
GW9
7/10 - 3.3
GW5
7/10 - 7.1
N
0 20 40 80
SCALE: 1" = 80'
Google
FIGURE 2
SITE REPRESENTATION WITH EXISTING MONITORING WELLS AND GROUNDWATER PLUME
PREPARED BY
ENVIRONMENTAL PARTNERS INC
REPORT
INTERIM ACTION WORK PLAN
LOCATION
1419 AVENUE D
SNOHOMISH, WA
PREPARED FOR
SKOTDAL REAL ESTATE
DATE
9/11/15
DRAWN BY
VPB/CLM
REVIEWED BY
EK
PROJECT NUMBER
69402.0

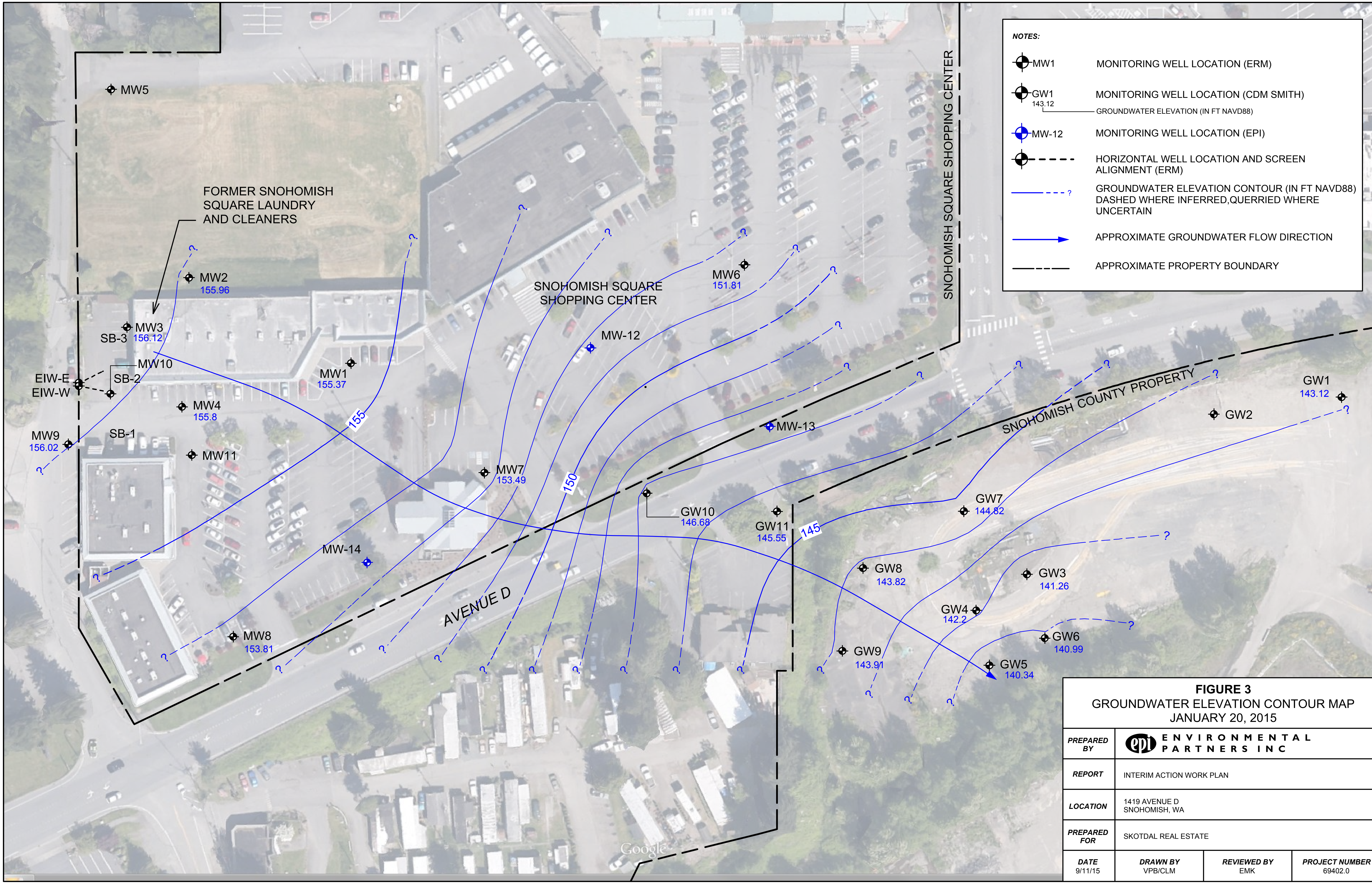


FIGURE 3 GROUNDWATER ELEVATION CONTOUR MAP JANUARY 20, 2015	
PREPARED BY	ENVIRONMENTAL PARTNERS INC
REPORT	INTERIM ACTION WORK PLAN
LOCATION	1419 AVENUE D SNOHOMISH, WA
PREPARED FOR	SKOTDAL REAL ESTATE

DATE	DRAWN BY	REVIEWED BY	PROJECT NUMBER
9/11/15	VPB/CLM	EMK	69402.0

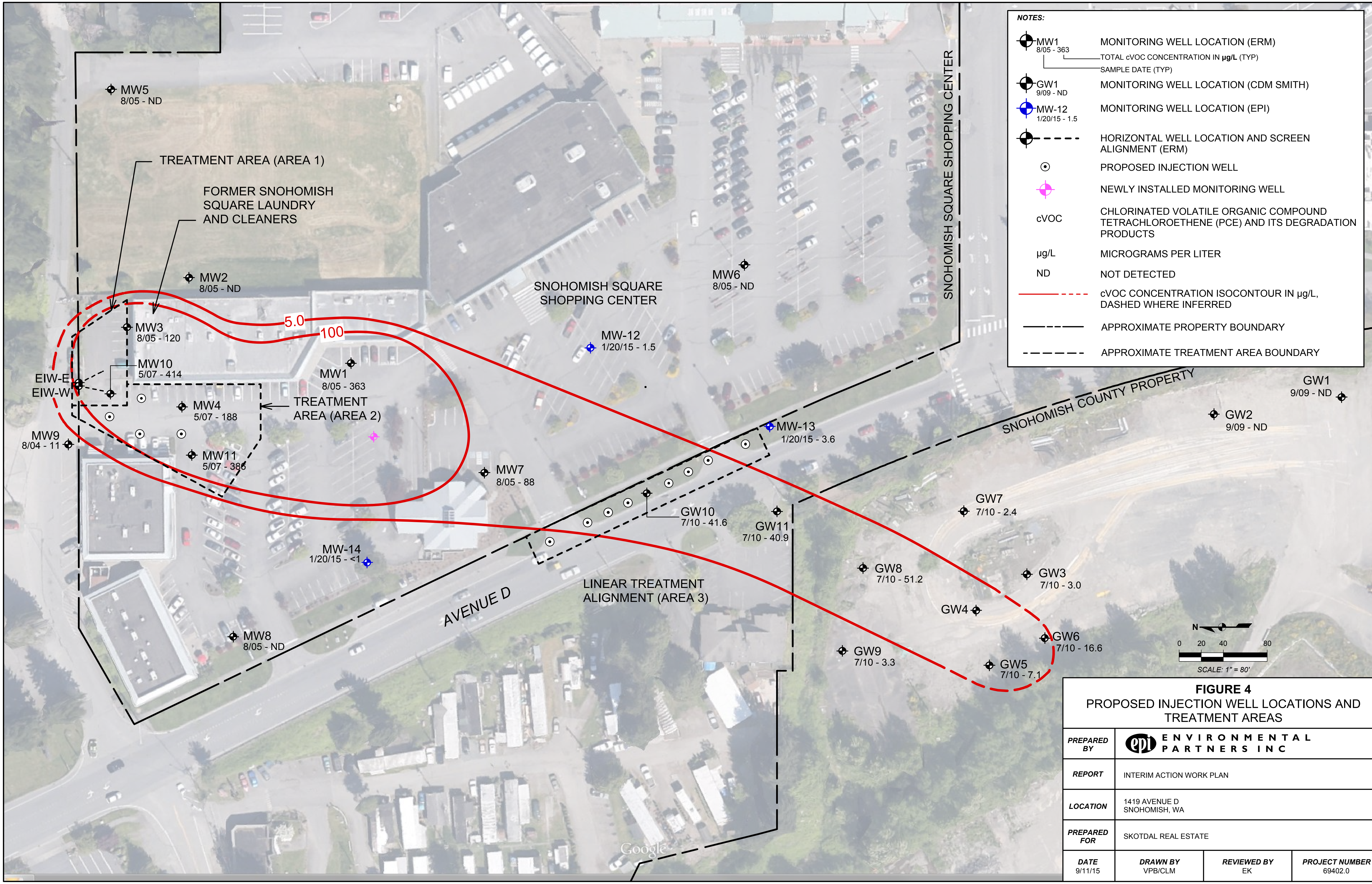


FIGURE 4
PROPOSED INJECTION WELL LOCATIONS AND TREATMENT AREAS

PREPARED BY	ENVIRONMENTAL PARTNERS INC
REPORT	INTERIM ACTION WORK PLAN
LOCATION	1419 AVENUE D SNOHOMISH, WA
PREPARED FOR	SKOTDAL REAL ESTATE

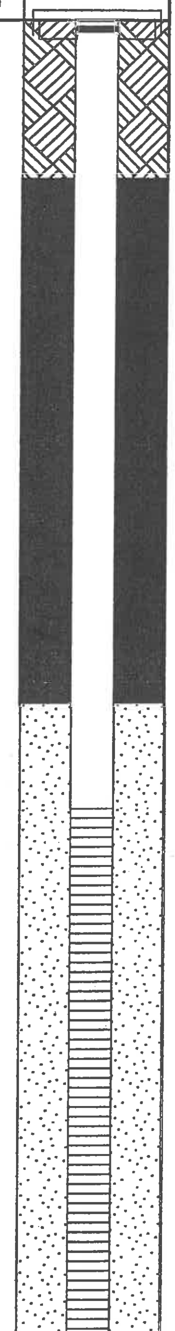
DATE	DRAWN BY	REVIEWED BY	PROJECT NUMBER
9/11/15	VPB/CLM	EK	69402.0

Attachment A
Boring Logs

Boring Log GW-10

Other Tests	Sample No.	Moisture Content (%)	Dry Density (pcf)	OVM (ppm)	Penetration Resistance (blows / foot)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
						0–7		SM		0 to 7 ft bgs cleared with vac truck. Gravelly, Silty SAND (SM), brown, poorly graded medium sand, fine, rounded gravel (1/4-1/-1/2" dia.), loose, wet. Old tree stump present from 5 to 7 ft bgs.	
				1.3	23/6" 50/5"	7–10		SM		Silty SAND (SM), brown, poorly graded, fine sand, trace fine to coarse gravel (1/4-1" dia.), dense, moist, root present in sample.	
				1.3	33/6" 50/6"	10–15.5		SM		Slightly Silty, Gravelly SAND (SM), olive-gray, well graded, fine to coarse sand, fine to coarse, rounded gravel (1/4-1" dia.), dense, moist.	
				2.7		15				Becomes wet.	
						15.5–17		SP-SM		Slightly Silty SAND (SP), brown, poorly graded, fine sand, dense, wet.	
				5.4		17–20		SM		Gravelly, Silty SAND (SM), brown to olive-gray, poorly graded, fine sand and rounded gravel (1/4-1/2" dia.), dense, wet, till-like texture.	
				1.3	100/4"	20–25		SM		Gravelly, Silty SAND (SM), olive-gray, well graded, fine to coarse sand, fine to coarse, rounded gravel (1/4->2" dia.), very dense, wet.	
				1.3	100/4"	25–26		SM		Silty SAND (SM), brown, poorly graded, coarse sand, some fine, subangular gravel, very dense, saturated.	
										Boring terminated at 26 ft bgs. Groundwater appeared to be encountered at 15.5 ft bgs during drilling.	

Well or Piezometer Completion



Location:
Surface Elevation:
Logged By: AW

Drill Rig: LAR Hollow-stem Auger
Equipment/Hammer: Split Spoon/140 lb/30"
Date Completed: 6-18-10

Snohomish County
Contaminant Assessment, Snohomish County Shop-Upper Terrace
Snohomish, Washington

Boring Log GW-10
Project No: 19947.71366

Figure: C48
1 of 1

CDM

LOG OF BORING WITH WELL 19947-71366-JUNE 2010 GP7-GP11.GPJ CDM BLLV.GDT 8/24/10 REV.

ERM
915 118th Avenue SE
Suite 130
Bellevue, WA 98005
ERM (425) 462-8591

BOREHOLE LOG

Project Number: 0048167.03

Project Name: Snohomish Square

Location: Snohomish, Washington

Contractor: Holt Drilling

Drilling Method: Hollow Stem Auger

Logged By: B. Magee

Date(s): 11/20/06

Initial Water Level: 10.00'

Static Water Level: NA

Total Depth: 21.50'

Completed Depth: 20.50'

Borehole Dia.: 8.25in

Blank Casing:			
type: Sch. 40 PVC	dia: 2.00in	fm: 0.0'	to: 10.00'
type: Well Cap	dia: 2.00in	fm: 20.00'	to: 20.50'

Screens:				
type: Slotted	size: 0.010in	dia: 2.00in	fm: 10.00'	to: 20.00'

Annular Fill:		
type: Concrete	fm: 0.50'	to: 2.50'
type: Bentonite Chips	fm: 2.50'	to: 9.00'
type: 10–20 Colorado Silica	fm: 9.00'	to: 21.50'

Depth (ft)	USCS Code	Blow Count	PID (ppm)	Description/Soil Classification
0				Asphalt.
	ML			SILT (ML): tan orange gray, some fine sand, firm, moist.
		2 5 8		GRAVELLY SILT (ML): brown.
5				
	SM	15	5.0	SILTY SAND (SM): brown, cohesive, moist.
	GP	27 30		GRAVEL (GP): gray, shattered.
10	SM	50 27 50	8.1	SILTY SAND (SM): medium to coarse grained, some gravel, subrounded, saturated.
	SP	50		SAND (SP): tan, little to no silt, medium to coarse grained.
	GP	50 50–5		Shattered rock.
15	SP			SAND (SP): gray, coarse grained, saturated.
	GP	38 54 –		Shattered rock.
	ML	43 54 –		SILT (ML): tan, some gravel and sand, very hard.
20		49 50–2		
				Total Depth – 21.5' bgs

ERM
915 118th Avenue SE
Suite 130
Bellevue, WA 98005
(425) 462-8591

BOREHOLE LOG

Site Id: MW-11

Project Number: 0048167.03
Project Name: Snohomish Square
Location: Snohomish, Washington
Contractor: Holt Drilling
Drilling Method: Hollow Stem Auger
Logged By: B. Magee
Date(s): 11/20/06
Initial Water Level: 10.00'
Static Water Level: NA

Total Depth: 21.50'
Completed Depth: 21.25'
Borehole Dia.: 8.25in

Blank Casing:				
type: Sch. 40 PVC		dia: 2.00in	fm: 0.0'	to: 11.00'
type: Well Cap		dia: 2.00in	fm: 21.00'	to: 21.25'
Screens:				
type: Slotted	size: 0.010in	dia: 2.00in	fm: 11.00'	to: 21.00'
Annular Fill:				
type: Concrete			fm: 0.50'	to: 3.00'
type: Bentonite Chips			fm: 3.00'	to: 9.00'
type: 10-20 Colorado Silica			fm: 9.00'	to: 21.50'

Depth (ft)	Graphic Log	USCS Code	Well Construction	Sample Recovery	Blow Count	PID (ppm)	Description/Soil Classification
		FILL					Asphalt, 4.0". Sand and gravel.
		ML					SILT (ML): brown, plastic, wet.
5		SM					SILTY SAND (SM): brown, some cobbles(?), based on rig behavior.
					2, 1, 2		SILTY SAND (SM): tan, with gravel, slightly cohesive, wet.
		ML					SILT (ML): tan and orange, firm, cohesive, sligthly moist. No recovery.
10		SM			7, 11, 20		SILTY SAND (SM): tan, with gravel, saturated. No recovery.
		SP			26		SAND (SP): tan, medium to coarse grained, some silt, saturated.
		GP			30, 39		SANDY GRAVEL (SP): tan gray, large gravel, saturated.
							Cobbles(?), based on rig chatter.
15		SM/GM			41, 45, 55		SILTY SAND/GRAVEL (SM/GM): tan silt, gray sand and shattered gravel.
					48		SILTY SANDY GRAVEL (GM): gray, very hard, cohesive, saturated.
		ML			52, –		SANDY SILT (ML): tan gray, with gravel, hard, cohesive. No recovery.
20		SM/GM			54, –, –		SILTY SAND/GRAVEL (SM/GM): tan, saturated. No recovery. Total Depth – 21.5' bgs