Interim Action Plan
In Situ Enhanced Attenuation of Petroleum Hydrocarbons
Ken's Auto Wash
Ellensburg, Washington

Prepared for
Ken's Auto Wash

June 13, 2013
7168-11

HARTCROWSER

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Prepared by
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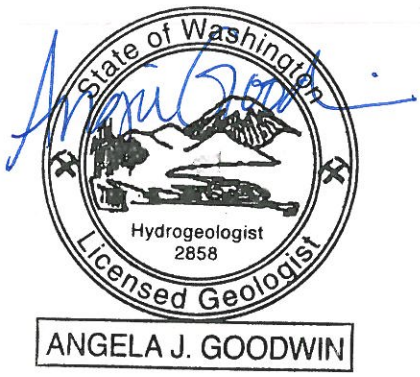

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KEN'S AUTO WASH
ELLENSBURG, WASHINGTON

1.0 INTRODUCTION

This Interim Action Plan (IAP) has been prepared to implement an *in situ* bioremediation injection program and groundwater response monitoring at the Ken's Auto Wash site, located at 1013 East University Way in Ellensburg, Washington (Figure 1). The Remedial Investigation/Feasibility Study (dated November 14, 2006) submitted under an Agreed Order with the Washington State Department of Ecology (Ecology) concluded that natural attenuation was the preferred remedy to address residual petroleum contamination. Subsequently, enhanced biodegradation was used to accelerate the cleanup process. In a letter dated June 20, 2012, Ecology requested that this IAP be prepared to document this approach.

The goal of this work is to assess applicability of anaerobic oxidation technologies to accelerate degradation of residual gasoline-range hydrocarbon (TPH-G) currently impacting the site. Results will be used to develop a Cleanup Action Plan for the site and achieve the ultimate goal of reducing contaminant concentrations below Washington State Model Toxics Control Act (MTCA) Method A cleanup levels (Chapter 173-340 WAC).

2.0 PROJECT BACKGROUND

Below is a summary of site information used to select and design this IAP.

2.1 Prior Environmental Work

The site is affected by a petroleum hydrocarbon release discovered during UST tightness testing in 1996 (Figure 2). Corrective actions were taken at that time, and the site USTs were subsequently removed in April 2005, as documented in the June 7, 2005, Gasoline UST Closure Report. Petroleum-impacted soil was removed downgradient of the UST area in October and November 2000, but a small volume of affected soil remained because of utilities and sidewalk at the site.

During the soil removal, oxygen-releasing compound (ORC) was added to the excavation backfill to promote biodegradation of residual petroleum

hydrocarbons. ORC was also injected in the downgradient area of petroleum hydrocarbon-affected groundwater in February 2005, as documented in the April 6, 2005, Supplemental Strataprobe Exploration Report. Although concentrations of TPH in groundwater continued to slowly decrease following UST removal, soil removal, and ORC injection, TPH-G concentrations in groundwater downgradient of the residual source area periodically exceed the MTCA Method A cleanup limit.

2.2 Geology and Hydrogeology

Shallow soils typically encountered at the site are near-surface fill of variable thickness and alluvial deposits consisting of silty, sandy gravel with occasional cobbles. These soils are consistent with shallow soils recorded on well logs and observed in the upper 32 feet of the municipal supply well southeast of the site. A clay aquitard underlies the shallow soils, and municipal supply well logs indicate that several aquitards separate shallow site groundwater from deeper water-bearing units, including units used for water supply.

Shallow site groundwater appears to be perched above the aquitard and is typically present between 4.3 and 9.8 feet below ground surface. Groundwater elevations at the site typically fluctuate 1 to 2 feet seasonally, reaching their peak in late spring and low point in late fall. The groundwater flow direction is toward the southwest. Calculated gradients are typically between 0.015 and 0.025 and do not change significantly with season. Extensive areas of imported gravel fill to depths of 13 feet below ground surface likely influence groundwater flow across the site (Figure 2). Recent groundwater elevation measurements and inferred groundwater flow direction are presented on Figure 3.

2.3 Areas of Residual Contamination

Petroleum-impacted soil remains downgradient of the former USTs beneath the adjacent sidewalk and portions of East University Way (Figure 2). Based on groundwater elevation and TPH-G concentration data, most of the residual contamination is located in two areas: in unexcavated soil between MW-4R and MW-1/MW-14 and near the top of the smear zone under the street and sidewalk north of MW-6. This remaining source material is likely contributing to periodic exceedances of MTCA Method A cleanup criteria for TPH-G in groundwater near wells MW-14 and MW-6. Gasoline-associated aromatics are also present, including toluene, ethyl benzene, and xylene. Benzene has not been detected since October 2008.

Residual contamination appears to be truncated south of University Way (Fairgrounds parking area) and west of the property (MW-5 area) because these

areas are not paved. Unpaved areas permit infiltration of natural oxidants dissolved in precipitation into the aquifer, including dissolved oxygen and nitrate. The rate of oxidant infiltration over time appears to exceed the flux of hydrocarbons and partially-degraded hydrocarbons, which are generically termed volatile fatty acids (VFAs). The resulting shift from reductive to oxidative conditions constitutes a redox-recovery zone and doesn't require any additional treatment.

2.4 Feasibility Study Recommendations

Remedial alternatives were presented and evaluated in the Remedial Investigation and Feasibility Study (RI/FS) completed in November 2006. The RI/FS addressed requirements of an Agreed Order issued by Ecology for site cleanup assessment following an MTCA site hazard ranking of 2. Remedial technologies evaluated in the RI/FS were based on results of site investigation, soil cleanup, and monitoring efforts through 2006.

Monitored natural attenuation (MNA) with free product removal was initially selected as the preferred remedial alternative. MNA is a process where hydrocarbon-degrading microbes that occur naturally in soil degrade petroleum hydrocarbons. Appreciable free product has not been identified at the site since 2004, so current remedial actions have not incorporated sorbent socks to remove free product. Site monitoring continues to be implemented in accordance with the selected FS alternative. Ecology has not required any additional actions besides the monitored natural attenuation.

Due to the slow progress of natural attenuation and the development of new treatment options since 2006, Hart Crowser has been evaluating options for accelerating the cleanup process. Implementation and performance findings from this IAP will be evaluated for possible inclusion and update of the preferred remedial alternative previously identified in the RI/FS.

3.0 REGULATORY AUTHORITY

According to the state cleanup regulation WAC 173-340-430(1), an "interim action" is distinguished from a "cleanup action" in that the interim action only partially addresses the cleanup of a site. The remediation conducted under an interim action may end up constituting the complete cleanup action for a site if the interim action subsequently is shown to meet requirements in the rule for a complete cleanup action.

The interim action proposed for the Ken's Auto site qualifies under WAC 173-340-430(1)(c). Data obtained as part of this IAP will be incorporated into the supplemental feasibility study and may be the basis for cleanup action design.

4.0 INTERIM ACTION ALTERNATIVES

Several new technologies have emerged since 2006 which may provide for a faster, more protective, and lower cost alternative compared to long-term MNA. These alternatives include:

- Direct Chemical/Biological Oxidant Injections – Direct injection of chemical and biological oxidants into areas of residual petroleum hydrocarbons to eliminate the ongoing source of TPH-G in groundwater;

- Closed-Loop Groundwater Recirculation – Groundwater recirculation containing dissolved ozone/oxygen and biological oxidants in areas north of University Way to assess achievable recirculation rates and develop an understanding of groundwater behavior at the highly disturbed site; and

- Enhanced Bioremediation Injections - A series of biological oxidant, surfactant, and bio-augmentation slug injections to more passively accelerate natural attenuation already occurring in site groundwater via anaerobic processes.

While there have been advancements in coupling chemical and biological processes to address TPH-G contamination, the direct injection interim action was eliminated from consideration at this site. As chemical oxidation requires direct contact with the contaminant, more extensive understanding of contaminant and natural soil oxidative demand distribution would have been required to develop a reliable and cost-effective remedy. Groundwater recirculation, while an effective technology for addressing petroleum, would have required substantial up-front capital cost and testing to assess applicability. Therefore, the most cost-effective and easiest to evaluate of the new technologies for this site is to improve existing natural attenuation through enhanced bioremediation injections.

5.0 DESCRIPTION OF THE INTERIM REMEDIAL ACTION

Enhanced bioremediation injections introduce several remediation amendments *in situ* in a series of quarterly injection events to accelerate the natural attenuation that is already occurring at the site. Petroleum is typically being

degraded through a process termed "anaerobic oxidation." As part of this process, native microbes use alternate electron acceptors (oxidants) instead of molecular oxygen for petroleum destruction, including nitrate, manganese, iron, sulfate and carbon dioxide. Residual petroleum is the targeted electron donor, and microbes gain energy for growth by using available oxidants to degrade available petroleum. Enhancing this process is termed Enhanced Anaerobic Oxidation (EAO).

The bioremediation injections were formulated based on site-specific conditions. These conditions include the nature of the contaminant (TPH-G and aromatic hydrocarbons); the estimated mass of residual petroleum; the target soil matrix (silty sand to sandy gravel with large areas of gravel backfill); contaminant distribution (localized to shallow source area); monitoring well locations; estimated groundwater flow direction and velocity, and the relatively short distance between areas of residual contamination on the site and rapid redox recovery occurring south of University Way. Recent groundwater elevation and inferred groundwater flow direction is provided on Figure 3.

5.1 Amendment Details

There are four categories of amendments selected for bioremediation injections. These include supplemental oxidants/nutrients, surfactants, microbes, and conservative tracer. The first two categories augment the bioavailability of electron acceptors and electron donors to control the EAO process based on site-specific conditions. The introduction of microbes is termed bio-augmentation, which helps to quickly populate soil and groundwater in impacted areas with non-pathogenic bacteria specifically selected for their ability to use provided oxidants to degrade petroleum contamination. Added nutrients help to propagate both native and introduced microbes and maximize EAO utilization and performance. Conservative tracers improve understanding of the movement of groundwater at the site.

Supplemental Oxidants/Nutrients. Hart Crowser has chosen to use AnoxEA-aq™ (formerly OxEA-aq™), manufactured by Bioremediation Specialists, LLC, to serve as the source of oxidants and nutrients for EAO at this site. The product contains a patent-pending blend of nitrate and sulfate salts (oxidants), a dose of macro- and micro-nutrients, and pH buffers. AnoxEA-aq is fully water soluble and can be injected as a solution into existing monitoring wells.

Surfactants. To improve bio-availability of petroleum for subsequent oxidation and destruction, surfactants will be injected to promote desorption of soil-bound hydrocarbons. Selected surfactants include EA™ (provided by ETEC, LLC) and Ivey-Sol® 103 (provided by Ivey International, Inc). EA is a blend of

biodegradable rhamnolipids that enhance desorption of weathered and heavy-end petroleum hydrocarbons and is bundled with microbes in ETEC's PetroBac™ product bundle. Ivey Sol is a biodegradable, non-ionic surfactant which promotes desorption of gasoline-range hydrocarbons. Both products are provided as highly concentrated liquids.

Bio-Augmentation. Because of the relatively short distance between contaminated areas and the redox-recovery zone south of University Way, bio-augmentation will be necessary to ensure rapid consumption of injected oxidants and desorbed hydrocarbons. A2™ (provided by ETEC, LLC) was selected and consists of a blend of non-pathogenic, hydrocarbon-degrading bacteria including *Pseudomonas putida*, *Pseudomonas fluorescens*, and *Rhodococcus sp*. A2 is provided in liquid form and is packaged along with EA in ETEC's PetroBac product bundle.

5.2 UIC Registration

Introduction of bioremediation enhancing materials to the subsurface requires registration under Washington State's Underground Injection Control (UIC) program. The UIC program was created to protect groundwater quality by regulating discharges to wells, including remediation. Remediation wells will be designated "5X26" injection features. Ecology must approve and complete UIC registration before we can initiate the proposed bioremediation injection. The registration seeks approval for injection up to 2,800 pounds of AnoxEA-aq, 25 gallons of PetroBac, 25 pounds each of chloride and bromide tracer, and 9.2 gallons of Ivey-Sol amendments.

5.3 Amendment Injection Summary

Amendment distribution will be achieved by using multiple amendment injections into multiple locations on quarterly basis. Table 1 summarizes the scope of the up to four injection events, which will ultimately be used to assess applicability of the EAO program. Injection locations are within areas of current or recent contamination. In summary, this IAP will inject up to a total of 25 gallons of PetroBac, 2,800 pounds of AnoxEA-aq, and 9.2 gallons of Ivey Sol. Conservative tracers will be introduced into MW-4R (sodium bromide) and MW-3 (sodium chloride) during the first injection to track groundwater movement, flux, and amendment use. Up to 25 pounds of each tracer will be introduced. Actual amendment application may be reduced based on field screening results, as described in Section 6.0 (below). If elevated levels of nitrate are detected in an injection well, less amendment may be added to prevent over-treatment and amendment migration into the redox-recovery zone.

Amendment injections occur in a prescribed sequence to achieve the goals of treatment traceability and amendment contact with residual petroleum contamination. All injections use municipal tap water for dissolving and distributing amendments. Pressures will be monitored in-line near the well head and will be limited to 15 pounds per square inch. This pressure preserves well seal integrity while pushing amendment into less accessible pore spaces. Injectate will be conveyed to each injection location using a flexible hose and secured high-pressure Furnco compression fitting. In-line valving located up-flow of the pressure gauge will be used to control flow rates and injection pressures. A flow meter will be used to monitor overall injection volumes at each location.

Tracers. During the initial injection, conservative tracer solutions are introduced first. Twenty-five pounds of sodium chloride dissolved in tap water will be introduced into MW-3, followed by a 25-gallon tap water chase to flush the tracer out of the well. Up to 25 pounds of sodium bromide dissolved in tap water will be introduced into MW-4R and followed by a tap water chase. These tracer injections will help confirm groundwater flow directions and diffusion time frames over the course of the IAP.

Bio-Augmentation. Following the initial tracer injection, PetroBac will be diluted to a 1:20 ratio in tap water and injected into MW-4R, MW-6, and MW-14.

Oxidants/Nutrients. Wells MW-2, MW-3, MW-4R, MW-5, MW-6, and MW-14, will receive the prescribed AnoxEA-aq mass by dissolving the amendment at a rate of approximately one pound of AnoxEA-aq to 1 gallon of tap water to make a master working solution. Master working solutions are prepared in batches up to 55 gallons. This master solution is then injected into each location and chased with 9 gallons of tap water for each gallon of master working solution.

Subsequent injection events will introduce AnoxEA-aq and Ivey Sol only. The AnoxEA-aq injection methodology for subsequent injection events will follow the same master working solution method. For wells receiving Ivey Sol, the Ivey Sol is added full-strength to the first master working solution batch prepared. Subsequent master working solutions will then be injected (as required) and followed by the same 9 gallons of tap water per gallon of master working solution.

6.0 SAMPLING AND ANALYSIS PLAN

IAP performance groundwater monitoring events will be completed before the first injection (baseline) and during four quarterly events thereafter. The monitoring program is presented in Table 2. The monitoring program is

designed to evaluate oxidant distribution, amendment use, groundwater flow paths and travel times, and petroleum hydrocarbon concentration responses. Groundwater monitoring will include both depth to groundwater measurements and sample collection for subsequent analysis, as described below.

6.1 Monitoring Equipment

Equipment to be used for the collection of groundwater samples include:

- pH, specific conductivity, redox potential, and temperature meters;
- Solinst or equivalent water level indicator;
- Peristaltic pump with disposable polyethylene tubing;
- Laboratory-supplied, pre-cleaned and preserved sample containers;
- Coolers with cubed or "blue" ice;
- Hach color disk and colorimetric strips for field testing; and
- Hart Crowser Sample Custody Record and Groundwater Sampling Data forms.

6.2 Sampling Procedures

Depth to groundwater will be measured in all monitoring wells before each quarterly monitoring and injection event to confirm groundwater flow direction and gradient across the site. After measuring the depth to groundwater, samples will be collected from the wells using standard low-flow sampling techniques. Each well will be purged until the field parameters of pH, temperature, and specific conductivity met the stability criteria (i.e., specific conductivity ±10 percent, pH ±0.1 pH units, and temperature ±0.1° C).

After field parameters stabilize, wells will be field tested for ferrous iron, nitrate, nitrite, and ammonia. Groundwater samples will be collected for laboratory testing by directly filling pre-cleaned sample containers provided by the laboratory with disposable polyethylene tubing. The labeled sample containers will be immediately placed in coolers with ice. Samples will be transferred under chain of custody protocol to Analytical Resources, Inc. (ARI) in Tukwila, Washington, for laboratory analysis.

Monitoring includes sampling groundwater from up to nine monitoring wells (Figure 2) for analysis of one or more of the following:

- TPH-G via Ecology Method NWTPH-G;

- Benzene, toluene, ethylbenzene, and total xylenes (BTEX) via EPA Method 8021B;
- Nitrogen as nitrate, sulfate, bromide, and chloride via EPA Method 300.0; and/or
- Total lead via EPA Method 6020.

In addition, ferrous iron will be measured in the field using a Hach color disc and nitrate, nitrite, and ammonia will be measured in the field using colorimetric strips. These field measurements will be used to evaluate and potentially modify the injection schedule during the bioremediation program.

6.3 Investigation-Derived Waste Storage and Disposal

The purge water produced from groundwater sampling will be drummed on site pending receipt of chemical analysis results from the laboratory to determine appropriate disposal procedures. Drum disposition forms will be filled out to record the number, contents, and location of the drums generated during implementation of the IAP.

6.4 Reporting

Quarterly groundwater sampling results will be summarized in a table and electronically transmitted to the project team. A technical groundwater monitoring report will be prepared after the annual (Fall) event and a draft will be submitted to the project team for review and comments. Following incorporation of review comments and document edits, we will submit a revised report to Ecology.

7.0 LIMITATIONS

Work for this project was performed, and this report prepared, in accordance with generally accepted professional practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Ken's Auto Wash for specific application to the referenced property. This report is not meant to represent a legal opinion. No other warranty, express or implied, is made.

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Table 1 - Enhanced Bioremediation IAP Injection Schedule
Ken's Auto Wash
Ellensburg, Washington

Injection Location	Event 1			Event 2		Event 3		Event 4		**AnoxEA-aq Total**
	AnoxEA-aq	PetroBac	Tracer	AnoxEA-aq	Ivey-sol	AnoxEA-aq	Ivey-sol	AnoxEA-aq	Ivey-sol	
MW-2	75 lbs				1.6 gal		0.8 gal		2.0 gal	**75** lbs
MW-3	275 lbs		Cl 25 lbs	250 lbs		150 lbs		300 lbs		**975** lbs
MW-4R	275 lbs	10 gal	Br 25 lbs	175 lbs	1.0 gal	75 lbs	0.2 gal	250 lbs	1.6 gal	**775** lbs
MW-5	75 lbs									**75** lbs
MW-6	100 lbs	5 gal		75 lbs	0.2 gal			100 lbs	0.2 gal	**275** lbs
MW-14	250 lbs	10 gal		150 lbs	0.8 gal	75 lbs	0.2 gal	150 lbs	0.6 gal	**625** lbs
Event Total	1,050 lbs	25 gal	50 lbs	650 lbs	3.6 gal	300 lbs	1.2 gal	800 lbs	4.40 gal	**2,800** lbs

Notes:
Table presents the planned series of up to four quarterly injection events as part of the Interim Action Plan technology evaluation.
PetroBac contains biodegradable surface-active agents and petroleum-degrading microbes to enhance amendment consumption and petroleum destruction.
AnoxEA-aq is a soluble blend of oxidants with macro- and micro-nutrients to enhance petroleum degradation.
Ivey-sol is a biodegradable, non-ionic surfactant formulated to improve bioremediation of petroleum hydrocarbons.
Table presents maximum quarterly injection masses. Actual mass may be modified based on performance and monitoring results.

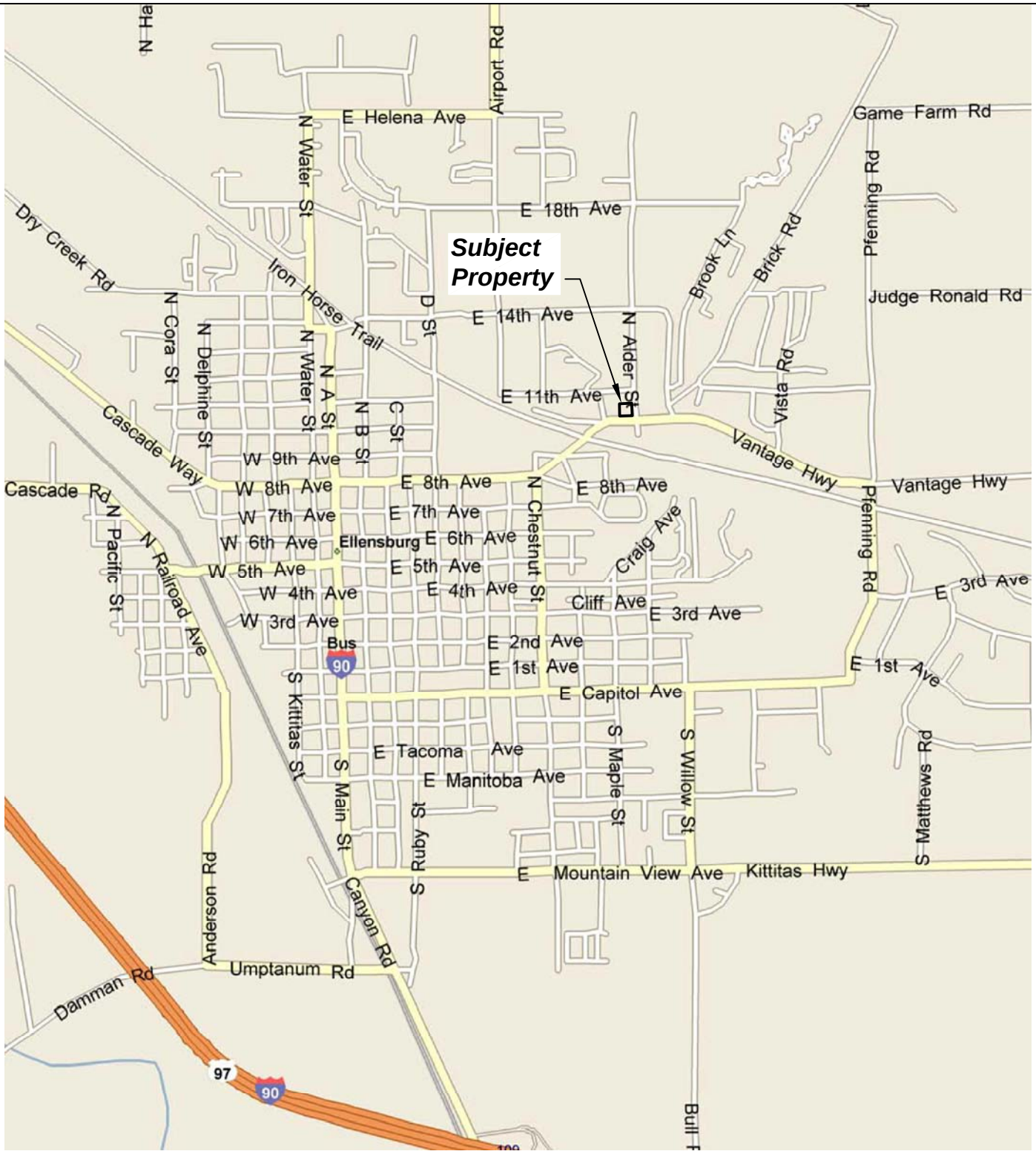
Abreviations:
IAP = Interim Action Plan.
Br = Food-grade sodium bromide salt.
Cl = Food-grade sodium chloride salt.
lbs = pounds.
gal = gallons.

Table 2 - Enhanced Bioremediation IAP Groundwater Monitoring Schedule
Ken's Auto Wash
Ellensburg, Washington

Monitoring Well	Baseline				Event 2				Event 3				Event 4				Non-Injection Event			
	G	V	Ions	F	G	V	Ions	F	G	V	Ions	F	G	V	Ions	F	G	V	Ions	F
Injection Wells																				
MW-2	X	X											X	X						
MW-3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MW-4R	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MW-5	X	X											X	X						
MW-6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MW-14	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Downgradient Wells																				
MW-12	X	X											X	X						
MW-13	X	X	X	X			X	X			X	X	X	X	X	X			X	X
MW-15	X	X											X	X						

Notes:
Quarterly monitoring will be performed before any injection activities.
Water level elevations will be measured quarterly, before well purging and sampling.
Samples will be collected using low-flow techniques and a flow-through cell, consistent with recent monitoring events.

Abreviations:
IAP = Interim Action Plan.
G = Total petroleum hydrocarbons by Ecology Method NWTPH-G.
V = Volatile organic compounds benzene, toluene, ethylbenzene, and xylene by EPA Method 8021B.
Ions = Nitrate as nitrogen, sulfate, bromide, and chloride by EPA Method 300.0.
F = Field kit testing of nitrate, nitrite, ammonium, and ferrous iron.



Note: Base map prepared from Microsoft Streets and Trips 2005.

0 2000 4000

Scale in Feet

N

Ken's Auto Wash
Ellensburg, Washington

Vicinity Map

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Figure **1**

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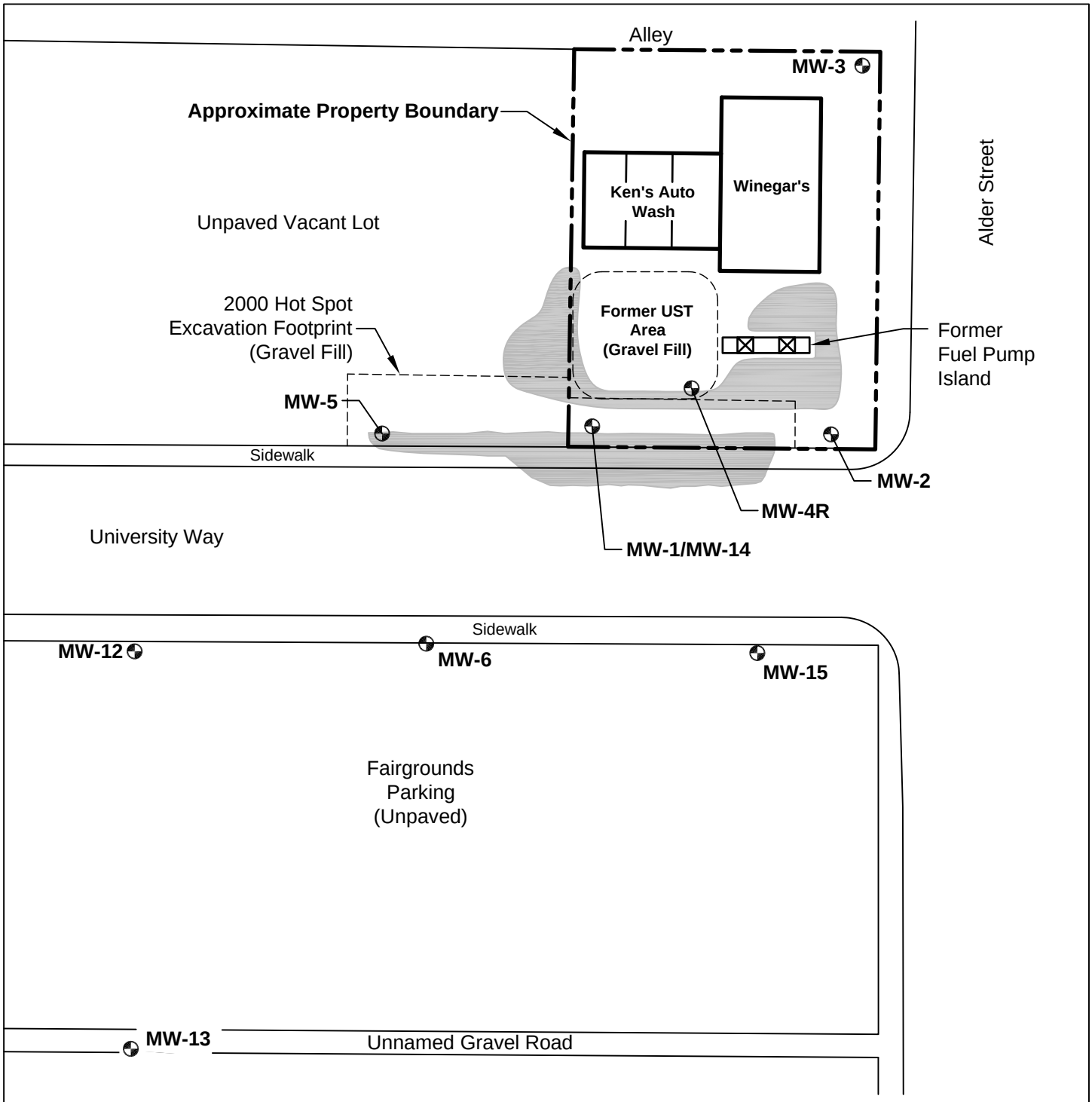

Note: Base map prepared from drawing provided by Sage Earth Sciences titled "Proposed Addtional Monitoring Well and ORC Injections Locations," dated January 1998.

0 50 100
Scale in Feet

MW-6 Hart Crowser Monitoring Well Location and Number

Estimated Remaining Area with TPH-G and/or BTEX Concentrations above MTCA Method A Soil Cleanup Levels (2000-2005 Data)

N

Ken's Auto Wash
Ellensburg, Washington

Site and Well Location Plan

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Figure
2

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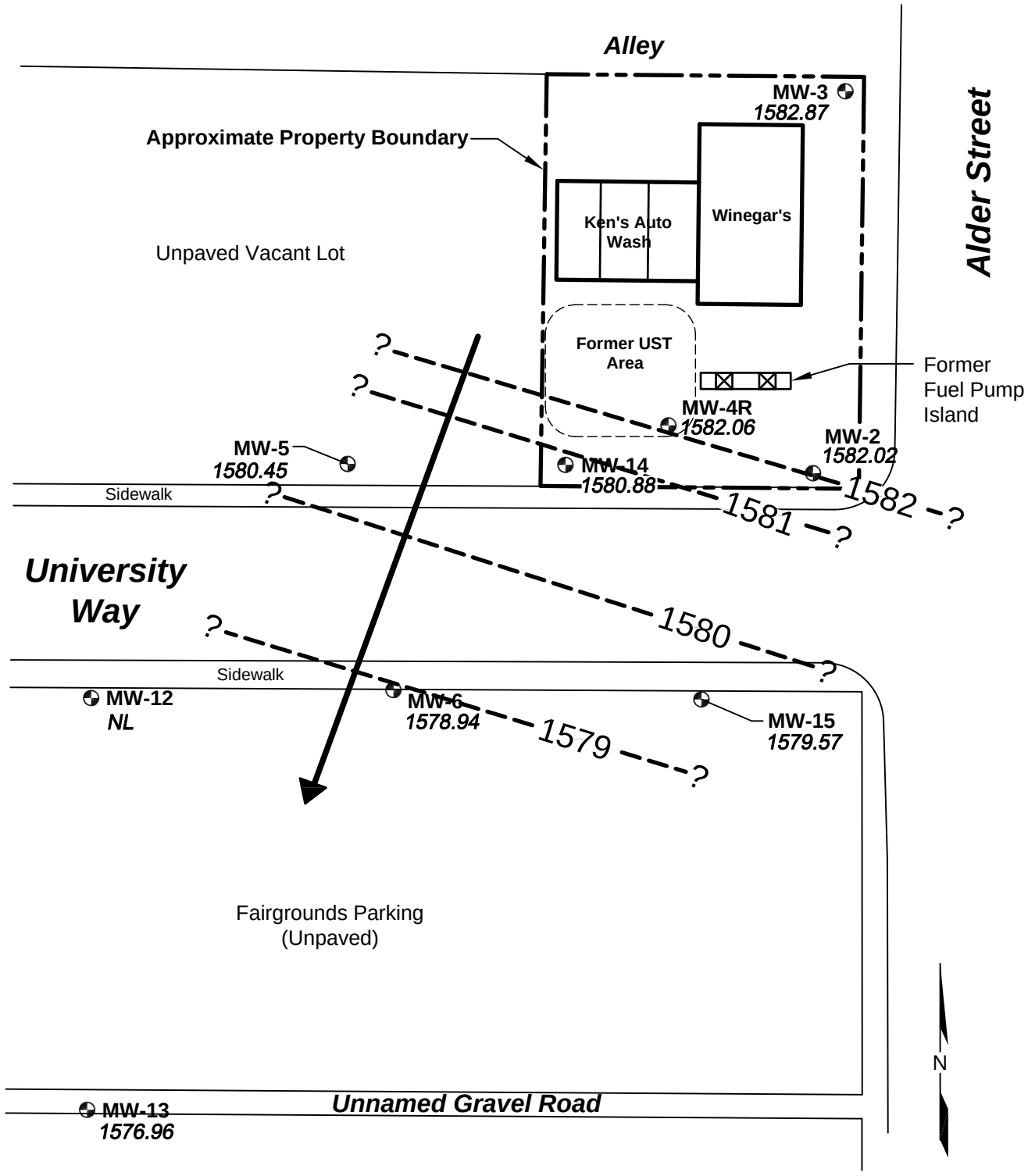

Note: Elevation shown are in feet above Mean Sea Level.

0 50 100

Scale in Feet

MW-6	Monitoring Well Location and Number
1578.94	Groundwater Elevation in Feet
NL	Not Located
1580	Groundwater Elevation Contour in Feet
	Inferred Groundwater Flow Direction

Ken's Auto Wash
Ellensburg, Washington

Groundwater Elevation Contour Map
November 2012

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Figure
3

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