FOCUSED FEASIBILITY STUDY

Morrell's Dry Cleaner

Prepared for: David Shaw, Successor to Walker Chevrolet

Project No. 080190-004-05 • March 26, 2012

Aspect CONSULTING

earth + water

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Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

This Focused Feasibility Study (FFS) develops and evaluates remedial alternatives for addressing subsurface contamination associated with the retail space currently occupied by Morrell's Dry Cleaners (Morrell's). The subject property (Property), owned by the former Walker Chevrolet Company, is defined by Pierce County tax parcel number 2030120030 and includes street addresses 608 and 610 North First Street in the City of Tacoma (Figures 1 and 2). The Morrell's Dry Cleaners Site (Site) includes the subject property and any off-property soil or groundwater confirmed or suspected of being impacted by chlorinated solvent releases at the Property.

Aspect Consulting, LLC (Aspect) submitted a Remedial Investigation (RI) Report (Aspect, 2011) to the Department of Ecology (Ecology). Ecology subsequently provided an opinion letter dated September 26, 2011 that identified data gaps and requested additional investigations before proceeding to a FFS. Aspect completed the additional investigations and prepared a Data Gaps Investigation (DGI) memorandum (Aspect, 2012). Combined, these reports identified soil, groundwater, and soil vapor contamination that exceeded recommended cleanup levels. The chemicals of concern (COCs) include tetrachloroethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloro-ethylene (cDCE), vinyl chloride, and naphthalene.

This FFS is intended as a decision-making tool for achieving compliance with environmental cleanup requirements under the Washington State Model Toxics Control Act (MTCA), 70.105D RCW, and its implementing regulations. Specifically, this FFS addresses source control interim actions and remedial actions for contamination in the soil and uppermost water bearing unit beneath the dry cleaners. It is being completed through the Voluntary Cleanup Program (VCP) administrated by Ecology. The Site was accepted into the VCP by Ecology on June 21, 2009, and assigned identification number SW1039.

1.1 Overview of Recommended Alternatives

This FFS presents cleanup alternatives that address accessible source contamination beneath the dry cleaner building. The cleanup alternatives are intended to address the on- and off-Property soil vapor intrusion, soil direct contact, and soil-to-groundwater leaching exposure pathways, and to remediate source contamination in the upper water bearing zone to the extent practicable. The recommended cleanup alternative would control the exposure pathways and mitigate the expansion of the chlorinated volatile organic compound (VOC) contaminated groundwater plume from the Property.

The preferred alternative (Alternative A4, discussed and evaluated in Sections 3 and 4) includes engineering controls for soil vapor intrusion, soil vapor extraction beneath the building and adjoining pedestrian alley, biostimulation to enhance degradation of contaminants in groundwater in the upper water bearing zone, monitored natural attenuation of residual groundwater contamination, and an environmental covenant requiring maintenance of engineering controls, restricting disturbance of contaminated soil, and restricting groundwater use.

Monitored natural attenuation to address residual groundwater contamination after application of active remediation measures is a component of the preferred alternative. This is often a cost-effective approach to remediate a diffuse, low-concentration plume of VOC-contaminated groundwater, but because it relies on the natural degradation of contaminants it can require long times to meet cleanup levels. Site closure would not be provided by Ecology until contaminants meet cleanup levels throughout the Site, or if a conditional point of compliance is approved, at the Property boundary. The time before cleanup levels would be met is uncertain and will depend in large part on the effectiveness of the biostimulation actions, but is expected to be on the order of 10 years.

If a shorter timeframe to reach closure is desired additional measures could be pursued to more aggressively treat contamination, including additional rounds of biostimulation treatment. A discussion of the conditions under which remediation contingencies would apply is provided in Section 3.3. Costs for these potential contingency actions are not included in the alternatives developed in this FFS.

The remainder of this introductory section summarizes information from the RI and DGI reports that are pertinent to the FFS. Section 2 discusses cleanup action objectives for the Site, Section 3 identifies and evaluates the cleanup action alternatives, Section 4 provides a detailed evaluation of the cleanup alternatives, and Section 5 provides the conclusions.

1.2 Property Description and History

The Property is an approximately 4,900 square-foot-parcel that contains one single-story, approximately 3,700 square foot building. Figure 2 shows the property boundaries and subject building location. The property outside the building footprint is paved with asphalt and concrete. The subject building contains Morrell's Dry Cleaners and office space for the nearby Thriftway grocery store.

The adjoining property to the southeast and southwest contains an auto body shop and a Thriftway grocery store (Figure 2), and was formerly the Walker Chevrolet automobile dealership. The adjoining properties and adjacent building to the northeast contain commercial and office space, including Tully's Coffee, Edward Jones Investments, and others. The adjacent building is separated from the Morrell's dry cleaning building by an approximate 5-foot wide, paved, gated alleyway.

According to reverse city directories, dry cleaning operations have been performed continuously on the property since 1929. Morrell Dry Cleaners began operations in 1972. According to a deposition of Linda Morrell (owner of the dry cleaners), PCE-based solvents were used in successive dry cleaning machines from the beginning of their tenancy in 1972 until early 2009, when Morrell's purchased the existing machine, which does not use PCE. The older cleaning machines used filter cartridges to separate lint and dirt accumulated during cleaning from the solvent. Approximately every six weeks, a waste disposal service would collect the used solvent and dirt "sludge." Prior to 1986, the used cartridges were placed on the pavement in the alley behind the building for storage until the trash was collected. In 1986, regulations governing handling and disposal of the filter cartridges changed and the cartridges were then stored in drums for pickup and disposal. The use of filter cartridges ceased with the purchase of a cleaning machine equipped with a solvent still in 1992. In addition to the dry cleaning machines, a 15-

gallon dip tank containing a mixture of PCE-based solvent and wax was used from 1972 until the early 2000s to waterproof clothes.

The Property is zoned by the City of Tacoma as Neighborhood Commercial Mixed-Use District (NCX), allowing for a mix of residential, office, retail, and commercial service uses. There are currently no firm plans for redeveloping the Property, but for the purpose of this FFS it is assumed that future land use will conform to the existing zoning.

1.3 Environmental Setting

The subject Property and adjacent properties are relatively flat, with a ground surface elevation of about 270 feet. Ground surface in the area slopes gradually to the northeast, before sloping steeply down to Commencement Bay approximately 1,200 feet northeast of the Property (Figure 1).

Figures 3 to 5 provide hydrogeologic cross sections beneath the Site (see Figures 1 and 2 for cross section locations). Site soils consist of approximately 35 feet of silty sand and gravel, interpreted as glacial till, overlying approximately 30 feet of sand, interpreted as advance outwash. Underlying the advance outwash sand is a sequence consisting primarily of interbedded silt, silty sand and gravel, and sand. This sequence extends to at least 146 feet below ground surface (bgs), the maximum depth drilled at the Site.

Groundwater at the Site occurs in perched, coarser-grained water bearing units within the finer-grained silts. An upper water bearing unit occurs in the outwash sand, and extends from approximately 53 feet bgs to the base of the outwash sequence at a depth of approximately 66 feet bgs. Eleven of the fifteen Site wells (Figure 2) are completed in the outwash sand. Deeper water bearing units were encountered in sand layers within the interbedded silt, silty sand and gravel, and sand sequence between depths of about 111 and 145 feet bgs. These typically showed saturated thicknesses of less than 10 feet.

The upper water bearing unit is potentially recharged by infiltration of irrigation water and precipitation in Wright Park, the northern edge of which is located approximately 500 feet south of the dry cleaners, and by leakage from stormwater and sanitary sewer utilities. Five wells completed in the upper outwash sand east, north, and west of the Property did not encounter water. On this basis, the upper water bearing unit is estimated to terminate along the approximate boundary shown on Figure 6. Water level measurements in the upper water bearing unit (Table A.2 and Figure 6) indicate the horizontal component of flow is to the northeast. Based on the perched nature and limited downgradient extent of this unit, a significant component of flow is expected to be vertically downward into the underlying fine-grained soils, ultimately recharging the lower water bearing units.

1.4 Conceptual Site Model

A conceptual site model (CSM) describing nature and extent of contaminants and identifying potentially complete exposure pathways at the Site is described in the RI Report. This section provides a summary of the CSM, incorporating additional data collected for the DGI Report (Aspect, 2012). The nature and extent of COCs was assessed based on results of soil and groundwater quality sampling and analysis, a Gore® Module survey of the relative concentrations of chlorinated VOCs in soil/soil vapor

beneath the building and adjacent paved areas, and analysis of soil vapor collected along the northern property boundary and indoor air quality samples collected from the Morrell's retail space and the Thriftway office.

1.4.1 Soil

The extent of soil contamination was assessed by sampling soil vapor in 29 discrete locations beneath the subject building and surrounding impervious surfaces using Gore-Sorber® passive diffusion sampling modules. Samples were collected after one week in February 2010 and submitted for analysis of chlorinated volatile organic compounds (VOCs). Although the sample results cannot be compared with soil cleanup levels, they were used qualitatively to identify the approximate extent of soil contamination (Figure 7) and guide the collection of soil samples for analysis of chlorinated VOCs. Soil contamination was primarily limited to beneath the building footprint in areas where PCE was handled or dry cleaning equipment was located, and in the adjacent pedestrian alley between the subject property and the adjoining building.

Soil samples beneath the building were collected using direct-push equipment following the evaluation of the Gore sampling modules (Figure 8). Table A.1 summarizes the soil sampling results. Because of direct-push refusal, no soil samples were collected deeper than 6 feet bgs beneath the building or alley. The highest concentration of PCE was 36 milligrams per kilogram (mg/kg) in DP-07, which is located outside of the storage room. Although TCE and cDCE were detected in DP-07, they were not detected in the remaining soil samples. Vinyl chloride was not detected in any soil sample. PCE was detected at concentrations ranging from 1.4 to 2.1 mg/kg in DP-01, DP-04, and DP-05, which were collected adjacent to the former dry cleaning machine and in the alley near the former filter cartridge staging locations.

Direct-push borings outside of the building extended to a maximum depth of 10 feet bgs. Outside of the building and alley, PCE was only detected in borings DP-09 and DP-10, adjacent to the southeast side of the building, with concentrations of 0.13 mg/kg in the 6-feet bgs interval of DP 09 and 0.24 mg/kg in the 8.5-feet bgs interval of DP-10. PCE was not detected in boring DP-08, located between DP-09 and DP-10, nor in borings DP-12 and DP-13, located about 10 to 15 feet further from the building than DP-09 and DP-10.

Naphthalene was detected in boring DP-08, with concentrations of 28 and 0.22 mg/kg in the 3 and 4.5 feet bgs intervals, respectively. The extent of naphthalene-impacted soil appears limited, based on the lack of other detections in soil.

Because of shallow refusal while drilling inside the building and in the alley, the maximum depth of impacted soil is uncertain. Based on the lateral extent of the Gore module survey and the presence of chlorinated VOC contamination in the upper water bearing unit, residual soil contamination may be present in a vertical plume beneath the dry cleaners that extends to the water table at approximately 53 feet bgs. The residual soil contamination in the glacial till from the surface to approximately 35 feet bgs and in the unsaturated advance outwash from approximately 35 to 53 feet bgs, where present, would provide a continuing source of contamination to groundwater. Additionally, contamination sorbed to soil beneath the water table likely provides a source of dissolved groundwater contamination.

1.4.2 Groundwater

Tables A.2 and A.3 summarize the groundwater levels and water quality results. Groundwater is encountered in an upper water bearing unit in the advance outwash from approximately 53 to 65 feet bgs and in deeper water bearing units between depths of about 110 and 145 feet bgs.

Upper Water Bearing Unit

In the upper water bearing unit, relatively high concentrations of chlorinated VOCs were detected in MW-2 and MW-8, which are approximately 12 and 45 feet east of the dry cleaner building, respectively. In February 2012, the concentrations of PCE were 1,600 and 960 micrograms per liter (µg/L) in MW-2 and MW-8, respectively, which exceed the 5 µg/L MTCA Method A groundwater cleanup level (Figure 9). Evidence of significant bioattenuation is observed in MW 2 and MW 8, where the concentrations of cDCE (a bioattenuation product of PCE and TCE) were 1,400 and 1,600 µg/L, respectively. Although vinyl chloride is detected in MW-2 and MW-8, the concentrations of vinyl chloride are approximately three orders of magnitude lower than the concentrations of cDCE, which likely indicates solvent bioattenuation in groundwater is stalling at cDCE.

Approximately 60 feet upgradient of the dry cleaners in MW-5, the concentration of PCE was 140 µg/L. Although PCE was detected at a concentration of 6.6 µg/L in MW-7 in January 2008, which is approximately 100 feet east-southeast of the dry cleaner building, the concentrations of chlorinated VOCs were less than 2 µg/L in five subsequent sampling events, and no other chlorinated VOCs were detected. The upper water bearing unit does not extend to the downgradient side of the adjacent building, where water has not been encountered in MW 4, MW-6, MW-9, and MW 10.

PCE has not been detected as a dense non-aqueous phase liquid (DNAPL) at this site. The maximum concentration of dissolved phase PCE measured in groundwater was 2,900 µg/L in MW-2 in August 2007, which is on the southeast side of the dry cleaner building. Sampled groundwater concentrations in excess of 1% of the effective solubility indicate that the groundwater may have come in contact with DNAPL (USEPA, 2009). Although some limited DNAPL may be present in soil and groundwater at this site, it would likely be bound to fine-grained soil or be dispersed in soil and/or groundwater beneath the building.

Lower Water Bearing Unit

The concentrations of chlorinated VOCs in wells completed in the lower water bearing units are relatively low, and did not exceed MTCA Method A cleanup levels when last sampled in early 2012. In wells MW-12D and MW-13D downgradient of the Property in the Tacoma Avenue North right-of-way, the concentrations of PCE were 6.1 and 14 µg/L in December 2010, slightly exceeding the 5 µg/L cleanup level. After the installation of MW-14D, Site wells were resampled in February 2012 and the concentrations of chlorinated VOCs were below applicable cleanup levels in all wells completed in the deeper water bearing unit.

1.4.3 Indoor Air/Soil Vapor

The presence of soil contamination has led to screening level exceedances for soil vapor and indoor air for the dry cleaning building and beneath the pedestrian alley between the dry cleaning building and the adjoining building. On February 9, 2012, three sub-slab soil

vapor samples (VP 1 through VP 3) were collected at a 20-foot interval along the pedestrian alley between Morrell's dry cleaners and the adjoining building to the northeast (Figure 9). Additionally, two 8-hour time-weighted average air samples were collected from inside the dry cleaning building, one in Morrell's dry cleaners and the other in the Thriftway office, and one 8-hour time-weighted average sample was collected as an ambient air sample above the parking lot on the opposing side of North First Avenue. Sample results were compared to MTCA Method B cleanup values for air, based on the 1 in one million excess cancer risk for a residential exposure scenario. For sub-slab samples, a conservatively low 10-fold attenuation factor was applied to account for the attenuation of vapors across the building slab, consistent with Ecology's draft vapor intrusion guidance (Ecology, 2009).

Table A.4 provides the sub-slab vapor sample results and screening levels, which are adjusted to provide a 10-fold attenuation factor. In VP-2, which was collected adjacent to the door to the alley in the previously identified "hot spot" from the Gore® module survey, PCE was detected at a concentration of 150,000 micrograms per cubic meter (µg/m3), which exceeds the screening level by more than three orders of magnitude. Twenty feet from the hot spot, the sub-slab vapor concentrations in the alley decreased to 270 and 380 $\mu g/m^3$. Although the detection limit for TCE exceeded the screening level by almost two orders of magnitude in VP-2, the concentrations of TCE were less than the screening level in the two samples (VP-1 and VP-3) collected adjacent to the hot spot. Toluene, ethylbenzene, and xylene were also detected beneath the alley pavement, but with concentrations well below the associated screening levels. Naphthalene was not detected in the sub-slab vapor samples.

Table A.5 provides the indoor air sample results and cleanup levels. The cleanup levels are the most stringent MTCA Method B air cleanup levels, based on the residential exposure scenario. The cleanup levels for PCE and TCE were calculated using equations 750-1 and 750-2 from WAC 173-340-750(3) with updated toxicity values (September 2012) from Ecology's CLARC database, whereas the remaining cleanup levels were identified from Table B-1 in Ecology's guidance for evaluating indoor air (Ecology, 2009). The indoor air sample results indicate that the highest concentrations PCE and TCE exceed the cleanup levels by factors of 2.3 and 24 in the two samples collected inside the dry cleaner building, although it should be noted that background indoor air levels for these constituents were not determined. Benzene, toluene, ethylbenzene, and total xylenes (BTEX) compounds were detected in all three samples, but after subtracting the background concentrations (outside ambient air), the concentrations of the BTEX compounds inside the building were below the cleanup levels. Naphthalene was not detected in the indoor air samples.

2 Cleanup Action Objectives

This FFS is developed to evaluate cleanup alternatives to address the release of source contamination from the soil and upper water bearing unit and to mitigate and/or control the exposure pathways at the site.

2.1 Soil Cleanup

2.1.1 Chemicals of Concern

The COCs in soil include the chlorinated VOCs PCE and TCE and the non-chlorinated VOC naphthalene. PCE, TCE, and naphthalene were detected in soil samples above their respective Method A cleanup levels. Although chlorinated VOC bioattenuation daughter products cDCE and vinyl chloride are considered COCs in groundwater, they are not an indicator hazardous substance in soil (WAC 173-340-703) and are not retained as COCs in soil. cDCE was only detected at one location (DP-07) and is collocated with the highest detected concentration of PCE in soil. Based on the limited extent and relatively low concentration of cDCE in soil (0.11 mg/kg), this compound does not add significantly to the overall threat to human health or the environment at the Site. Vinyl chloride was not detected in any of the soil samples collected at the site. Furthermore, remedial actions that address PCE-contaminated soil would also address the collocated bioattenuation daughter products in soil.

The BTEX compounds are not retained as COCs, as these were either not detected or were detected at concentrations well below MTCA Method A soil cleanup levels. Although toluene, ethylbenzene, and total xylene were detected in the sub-slab vapor samples beneath the alley, the concentrations were at least a factor of 50 below the screening levels (Table A.4). Similarly, although BTEX compounds were detected in indoor air within the dry cleaning building, these concentrations were only marginally higher than the concentrations measured in the ambient air background sample that was collected above the parking lot on the opposite side of North First Avenue, and the marginal increased concentrations within the building are below the screening levels (Table A.5).

2.1.2 Exposure Pathways

Potential exposure pathways and receptors include:

- Workers contacting contaminated soils in the future (skin contact or incidental ingestion) during excavation or other construction-related activities, if no worker protection controls are in place. This pathway is applicable to all COCs in soil;
- Humans in buildings inhaling indoor air contaminated – via vapor intrusion – by the volatilization of contaminated soils. This pathway is limited to volatile COCs in soil (i.e., PCE and TCE);
- Leaching of soil contamination to the upper water bearing unit from surface infiltration, condensate, and plumbing leaks; and

- Terrestrial ecological receptors contacting contaminated soils in the future, if no controls are in place.

Areas of the Property with COCs in soil are paved with asphalt or covered with buildings, limiting the potential for the human or ecological receptor direct contact pathways under current conditions. Any future construction activities in these areas that disturb the overlying pavement could result in completion of the human direct contact pathway, but could be effectively managed with suitable soil handling protocols. Soil vapor and indoor air monitoring results indicate that the vapor intrusion pathway may currently be complete at the dry cleaner building, although the measured concentrations of chlorinated solvents in indoor air may be attributed to an operating dry cleaner with a long history of chlorinated solvent usage.

2.1.3 Points of Compliance and Cleanup Levels

The points of compliance include the upper 15 feet of soil beneath the dry cleaning building and the alley for direct contact, inhalation, and ingestion exposure pathways. The point of compliance for the leaching exposure pathway extends from the surface to the groundwater table at approximately 53 feet bgs. The point of compliance for the indoor air exposure pathway is all occupied spaces within the building.

The cleanup levels are the MTCA Method A soil cleanup levels for unrestricted land use. Table 2.1 provides the designated soil cleanup levels.

Table 2.1 – Soil Cleanup Levels

	MTCA Method A (mg/kg)	Cleanup Level (mg/kg)
PCE	0.05	0.05
TCE	0.03	0.03
Naphthalene	5.0	5

2.1.4 Exceedance Areas

The soil exceedance area is generally under the dry cleaning building and the approximate 5-foot wide pedestrian alley on the northeast side of the cleaners. The only detections of PCE outside of the building footprint were adjacent to the building in the southeast sidewalk, where PCE was detected at a concentration of 0.13 mg/kg in the 6 feet bgs interval of DP-09 and 0.24 mg/kg in the 8.5 feet bgs interval of DP-08.

The depth of contamination potentially extends to the water table at approximately 53 feet bgs in the upper water bearing unit, however, the depth of the soil investigation was limited within the building, where the direct-push probe was unable to penetrate more than 2.5 feet bgs. The highest soil concentration was 36 mg/kg in the moist, dark brown, organic silt in the 2.5 feet bgs interval of DP-07 beneath the building near the storage room. The concentration of PCE ranged from 0.54 to 3 mg/kg in the remaining seven samples collected beneath the building and alley. These samples were collected from predominantly sand and gravel, and the concentrations of PCE appear highly correlated with the amount of fines in the soil. The glacial till extends from the surface to approximately 35 feet bgs, and is underlain by sandy advance outwash from approximately 35 to 65 feet bgs. Given the long history of PCE at the site, PCE is

anticipated to be predominantly associated with fine-grain glacial till deposits beneath the dry cleaners.

2.1.5 Areas/Volumes Requiring Cleanup

The volumes of soil exceeding the MTCA Method A cleanup levels are beneath the building and alley and extend to the water table at approximately 53 feet bgs. Because the soil contamination is generally inaccessible, controls will be needed to mitigate the exposure pathways.

2.2 Groundwater Cleanup

2.2.1 Chemicals of Concern

The COCs in groundwater include the chlorinated VOCs PCE, TCE, cDCE, and vinyl chloride. Naphthalene has not been detected in groundwater. Carbon tetrachloride (CT) has been detected in the upper water bearing unit in MW-5, MW-7, and MW-11 and in the lower water bearing unit in MW-8D. The highest detected concentration of CT was 3.3 µg/L in MW-5, which is below the federal Maximum Contaminant Level (MCL) of 5 µg/L (there is no established MTCA Method A groundwater cleanup level for CT, but the MCL is an Applicable, Relevant, and Appropriate Requirements [ARAR] and applies as a cleanup level when numerical values under Method A are not available).

The BTEX compounds are not retained as COCs. Benzene was the only detected BTEX compound in groundwater. BTEX was detected at a concentration of 2.2 µg/L in MW-1 in August 2007, which is below the 5 µg/L MTCA Method A cleanup level, and benzene was below the 1 µg/L detection limit in the four subsequent sampling events.

2.2.2 Exposure Pathways

Potential groundwater exposure pathways and receptors include:

- Humans who drink contaminated groundwater in the future, if groundwater is brought to the surface for this purpose;
- Direct exposure for aquatic ecological receptors in Commencement Bay, if contaminants in groundwater discharge to surface water; and
- Humans consuming aquatic ecological receptors contaminated by discharges to surface water.

Based on the perched nature and limited lateral extent of the upper water bearing unit, the more than two order of magnitude decrease in PCE concentrations between the upper water bearing unit and the deeper, downgradient water bearing unit, the 1,200 foot distance from the Property to surface water of Commencement Bay, and the apparent biodegradation of chlorinated VOCs it is unlikely that contaminants in groundwater from the upper water bearing unit are discharging to surface water. As a result, the human consumption and direct exposure for aquatic ecological receptor pathways are likely not complete at this Site.

Groundwater from the perched water bearing units is not currently used as a drinking water source. Based on the limited saturated thickness and lateral extent of this unit, it is unlikely to be used for drinking water purposes in the future. However, potential migration of contaminated water from the upper water bearing unit to deeper units that

could support future drinking water use cannot be ruled out and the human drinking water pathway could potentially be complete in the future.

2.2.3 Points of Compliance and Cleanup Levels

The groundwater point of compliance is established throughout the Site from the uppermost level of the saturated zone extending vertically to the lowest most depth that could potentially be affected by the Site. The cleanup levels are designated at the MTCA Method A cleanup levels and the federal MCLs for COCs where the MTCA Method A cleanup level is not defined. The designated cleanup levels are defined in Table 2.2.

Table 2.2 – Groundwater Cleanup Levels

	MTCA Method A (µg/L)	MCL (µg/L)	Cleanup Level (µg/L)
PCE	5	5	5
TCE	5	5	5
cDCE	-	70	70
Vinyl chloride	0.2	2	0.2

2.2.4 Exceedance Areas

The groundwater exceedance area is generally beneath the dry cleaning and adjacent building, and the chlorinated VOC plume appears to have diffused laterally to wells MW-2, MW-8, and MW-5, where the concentrations of PCE were 1,600, 960, and 140 µg/L, respectively, in February 2012. MW-2 and MW-8 are located approximately 20 and 50 feet east and cross-gradient of the dry cleaners and MW-5 is located approximately 70 feet south-southwest and upgradient of the dry cleaners. The upper water bearing unit becomes dry on the west and north sides of the dry cleaner and adjoining building. Chlorinated VOC contamination is suspected to accumulate and disperse in the upper water bearing unit within the advance outwash, and to seep downward into the Olympia Bed glacial deposits towards lower water bearing units.

Four wells, MW-8D, MW-12D, MW-13D, and MW-14D, are installed in the lower water bearing units with screened intervals between 113 and 145 feet bgs. The concentrations of chlorinated VOCs are currently below the cleanup levels. In February 2012, PCE was detected at concentrations of 4.2 µg/L in MW-13D and MW 14D, but were below the 1 µg/L detection limit in MW 8D and MW 12D. Evidence of reductive dechlorination is observed in the wells, and the concentrations of cDCE ranged from 17 to 28 µg/L in MW-8D and MW-12D to MW 14D in February 2012.

2.2.5 Areas/Volumes Requiring Cleanup

Although chlorinated VOC contamination in the upper water bearing unit exceeds the cleanup levels, none of the exposure pathways are currently complete. The Olympia Bed glacial deposits have provided an effective attenuation barrier between the upper water bearing unit and the lower water bearing units for releases of PCE. Nevertheless, contamination in the upper water bearing unit may be amenable to remediation, which could be done to mitigate the further release of contamination to deeper water bearing units that could support future drinking water use.

3 Description and Evaluation of Cleanup Alternatives

This FFS presents five cleanup alternatives that address source contamination in the soil and upper water bearing zone. Table 3.1 summarizes the components and costs of the cleanup alternatives, which are described in Section 3.1. Although comprehensive cleanup alternatives are developed, residual contamination may remain onsite following active treatment. Natural attenuation processes are expected to be effective at addressing residual contamination; however, Section 5 describes additional active treatment contingencies to address residual contamination, if performance monitoring after implementation of the selected alternative indicates natural attenuation will not achieve cleanup.

3.1 – Summary of Cleanup Alternative Components and Cost

Development Scenarios/ Cleanup Alternatives:	Alternatives:				
	A1	A2	A3	A4	A5
Building Remains in Place	X	X	X	X	
Building Demolition					X
Excavation with shoring					X
Onsite vapor intrusion controls		X	X	X	NA
Soil vapor extraction (SVE) (vertical and horizontal wells)			X	X	
Biostimulation on edge of source area				X	
In situ chemical oxidation (ISCO) in soil and groundwater					X
Monitored natural or enhanced attenuation in groundwater		X	X	X	X
Environmental covenant for cap, prohibiting groundwater use, and stipulating performance and confirmation groundwater monitoring		X	X	X	X
Present value cost	$25,000[1]	$245,000	$445,000	$545,000	$1,200,000

3.1 Cleanup Alternatives

Under alternatives A1 through A4, the dry cleaning building is retained and cleanup relies on containment, institutional controls, and *in situ* treatment methods for soil and

[1] No action costs include consulting, negotiation, and reporting costs for continued interaction with Ecology.

groundwater. Under alternative A5 the building would be removed, allowing excavation of soil followed by *in situ* treatment of groundwater and residual soil contamination. The alternatives include:

- **Alternative A1** – No action.
- **Alternative A2** – Engineering controls to mitigate the release of soil vapor to the dry cleaning building and an environmental covenant to maintain a cap in event of redevelopment, to restrict groundwater use, and to monitor contaminant attenuation in groundwater.
- **Alternative A3** – Soil vapor extraction (SVE) performed for six months to reduce the concentrations of VOCs in impacted soil beneath the dry cleaner and adjacent pedestrian alley. Engineering controls to mitigate the release of soil vapor to the dry cleaning building and an environmental covenant to maintain a cap in event of redevelopment, to restrict groundwater use, and to monitor contaminant attenuation in groundwater.
- **Alternative A4** – SVE performed for six months to reduce the concentrations of VOCs in impacted soil beneath the dry cleaners and adjacent pedestrian alley. Biostimulation to enhance natural bioattenuation in the upper water bearing unit near monitoring wells and through leachate application. Engineering controls to mitigate the release of soil vapor to the dry cleaning building and an environmental covenant to maintain a cap in event of redevelopment, to restrict groundwater use, and to monitor contaminant attenuation in groundwater.
- **Alternative A5** – Demolition of the dry cleaning building to allow soil excavation. Excavation of contaminated soils to 15 feet bgs beneath dry cleaner lease space and pedestrian alley by installing sheet pile shoring. *In situ* mixing of soil and permanganate beneath excavation area. Construction of an impermeable cap to prevent surface water infiltration through residual soil contamination and leaching of contamination to groundwater. Construction of horizontal leach pipes in aggregate fill and six injection wells through source area, followed by permanganate injection in aggregate fill and in the upper water bearing unit. Conversion of leachate system to passive ventilation system beneath impermeable cap. Repeat permanganate application performed after two to three years. Environmental covenant to maintain impermeable cap, to restrict groundwater use, and to require long-term groundwater monitoring.

The following subsections provide a description, evaluation, and conceptual design for the current use cleanup alternatives. Appendix B provides a summary of the cleanup action components and present value cost estimates, along with detailed cost estimates and assumptions for each alternative.

3.1.1 Alternative A1 – No Action

Under this “no action” alternative, no remediation or long-term monitoring would take place, and no property covenants would be developed to restrict future Site activities or to require the maintenance of the existing pavement and building to cap impacted soil. The purpose of this alternative is to provide a baseline against which the other alternatives are compared. The Site would remain in the VCP and on Ecology’s Hazardous Site List;

nominal costs are included in Table 3.1 for continued consultation and interaction with Ecology.

3.1.2 Alternative A2 – Engineering and Institutional Controls

This alternative includes the construction of engineering controls to control or mitigate the intrusion of soil vapor into the dry cleaning and adjacent building; repair of a leaking sanitary sewer line leading from the dry cleaners; institutional controls (environmental covenant) restricting groundwater use, restricting disturbance of soil, requiring maintaining the building and paved areas as a cap to reduce groundwater recharge through impacted soils, and requiring maintenance of the engineering controls; and monitored natural attenuation of VOC-contaminated groundwater. Engineering controls can include the construction of vapor barriers and ventilation systems (EPA, 2008, EPA/600/R-08/115). Engineering control options are limited for existing construction, but may include one or more of the following options:

- Indoor ventilation: Increase the air exchange rate within the building(s) using the heating, ventilation, and air conditioning (HVAC) system, while maintaining positive pressure in the building. Negative pressures may induce additional soil vapor intrusion.
- Vapor barrier: For existing slab foundations, vapor barriers would be applied above the existing slab by either an epoxy paint or a sprayed-on membrane (e.g., Liquid Boot™). Because spray-on membranes may be asphaltic, additional flooring would need to be installed on top of the membrane.
- Sealing: Seal penetrations, expansion joints, and cracks in the foundation, particularly plumbing penetrations.
- Sub-slab depressurization or ventilation: Involves the installation of subsurface piping or ventilation. Building codes often require the installation of a coarse fill as a capillary break and a thin, 5-mil, moisture barrier beneath slab foundations. Boring logs DP-01, DP-02, and DP-07 indicate moist gravelly, very silty sand; moist silty, sandy gravel; and moist, slightly sandy, gravelly silt; with no obvious capillary breaks beneath the foundation. Because of the lack of a dry, coarse-grained capillary break, the radius of influence of ventilation piping or extraction points would be limited under the foundation. Nevertheless, it may be possible to remove the concrete surface in the alley and install ventilation pipe, coarse-grained backfill, and an overlying impervious membrane barrier to facilitate depressurization or ventilation. Ventilation pipe would extend to the outside, typically to the roof, and may be connected to plumbing chases.

  Passive ventilation occurs due to barometric pressure changes that results in air flow beneath the structure and due to the mixing of warm and cool air from the soil, foundation, and ventilation pipe. Active sub-slab depressurization or ventilation may be performed by installing a ventilation fan or wind turbine to induce a flow. Although similar, depressurization is performed to reverse the pressure gradient for subsurface vapor intrusion, whereas ventilation is performed to exchange the air beneath the foundation.

No active groundwater treatment is proposed under this alternative. Instead, VOCs in groundwater in the upper water bearing zone would be allowed to degrade by natural

processes (e.g., biodegradation), with long-term monitoring to demonstrate contaminant removal and confirm that contaminants do not migrate from the upper water bearing zone to deeper units. Leaching of VOCs from soils under the building would continue to act as a source of contamination to groundwater, replacing contaminants in groundwater removed through degradation and resulting in a long time before groundwater may meet cleanup levels. It is assumed that annual monitoring and reporting of 7 Site wells would be required for 30 years.

This alternative would also provide institutional controls. These controls would include an environmental covenant to require cap maintenance in the event of building decommissioning and to prohibit groundwater use, and to require performance and confirmational sampling for groundwater.

3.1.3 Alternative A3 – Soil Vapor Extraction and Engineering and Institutional Controls

Soil vapor extraction (SVE) may be performed under the dry cleaner building to volatilize and remove soil vapor and sorbed contamination in the soil beneath the building and pedestrian alley. SVE is effective for the removal of chlorinated VOCs from accessible, permeable soils. SVE would be anticipated to have a number of limitations at this site.

SVE is effective in soils with a permeability of greater than 10^{-8} centimeters squared (cm^2), which is equivalent to a hydraulic conductivity of approximately 10^{-2} feet per day (ft/day), and may be effective in soils with permeability greater than 10^{-10} cm^2, which is equivalent to a hydraulic conductivity of approximately 10^{-4} ft/day. The radius of influence for SVE decreases in the presence of silts, clays, and moisture. Although the glacial till beneath the building contains a high percentage of sands and gravels, the soil is compacted, contains fine grained material, and is moist. SVE may also be performed in the unsaturated interval of the advance outwash, from approximately 35 to 53 feet bgs. Pilot testing would be needed to evaluate the radius of influence, however, based on our experience in similar soils, the radius of influence at this site is estimated to range from 5 feet in finer grained soils up to 15 feet in coarser soils.

The presence of the building limits the installation of SVE wells. SVE wells could include one or more of the following:

- Construction of horizontal well near the surface under the pedestrian alley. This would consist of the concrete demolition, excavation, installation of perforated pipe with aggregate backfill, installation of an impermeable geomembrane and low permeability fill, and concrete cover. This well would be installed over sources of contamination and could be converted for later application for indoor vapor control.
- Installation of one or more vertical wells adjacent to the southeast side of the dry cleaners. Although limited by the radius of influence, shallow wells may be used to address contamination under the building. Deeper wells may be used to remove soil contamination that extends to the water table at 53 feet bgs. If the well is continuously screened, most of the air would be extracted for higher permeable

intervals closer to the water table, and insufficient vacuum pressure may be applied under the building.

- Installation of horizontal wells using specialized drilling equipment. Horizontal drilling equipment can be used to emplace one or more wells under the building at multiple depths, and along curved paths. Ideally, these wells would be installed in the areas of highest contamination.

SVE would be performed using a blower or vacuum pump to extract soil vapor, which would be treated with activated carbon and released. The presence of impervious surfaces near the SVE wells would decrease surface leakage and thereby increase system performance. Although SVE system performance can be increased by air sparging beneath the water table or by blowing air into the subsurface to increase the flow, these measures would not be performed under occupied buildings. Depending on the scale, SVE equipment may create noise nuisance and vapor treatment requirements that would inhibit its long-term application.

SVE response actions typically have diminishing returns as soil vapor is removed from more permeable soil intervals. After cessation of active treatment, soil vapors increase as contamination diffuses from lower permeability soils. For this reason, periodic active remediation may be appropriate. Although the end-point of active remediation is uncertain, SVE is effective at mitigating source contamination in soil that leaches to groundwater and potentially infiltrates to indoor air.

SVE differs from sub-slab ventilation in the objective and end points, the air flow rates and equipment, and the vapor treatment requirements. Nevertheless, SVE wells may be converted to sub-slab ventilation systems, provided that the wells are not manifolded in a manner that disperses contamination such that the indoor air exposure risk increases.

This alternative does not actively address groundwater contamination in the upper water bearing unit. However, source contamination would be removed above the groundwater, which would reduce additional contamination from migrating to groundwater. Contamination would be allowed to attenuate through natural processes with long-term monitoring to demonstrate contaminant removal and confirm that contaminants do not migrate from the upper water bearing zone to deeper units. It is assumed that annual monitoring and reporting of 7 Site wells would be required for 15 years.

This alternative would also provide engineering controls to control or mitigate the intrusion of soil vapor into the dry cleaning and adjacent building, repair of the sanitary sewer line leading from the dry cleaner, and institutional controls, as described in Alternative A2.

3.1.4 Alternative A4 – Soil Vapor Extraction, Biostimulation, and Engineering and Institutional Controls

This alternative is identical to Alternative A3, but includes the injection of biostimulants into the SVE well(s) following active SVE treatment to enhance the natural degradation of chlorinated VOCs in groundwater. *In situ* treatment of groundwater is limited at this site because the chlorinated VOC plume extends vertically beneath the building. However, biostimulation reagents can be applied by using the horizontal SVE well(s) as leachate well(s) above the main sources of contamination. Alternately or additionally,

biostimulation reagents can be injected through vertical injection wells east (cross gradient) and south (upgradient) of the dry cleaners to stimulate bioattenuation along the periphery of the plume in the upper water bearing unit.

PCE and TCE typically biodegrade by reductive dechlorination, where chlorine atoms are sequentially removed such that PCE degrades to TCE, which degrades to DCE isomers, which degrade to vinyl chloride. Reductive dechlorination occurs when PCE and TCE are used as electron acceptors, not as a source of carbon, in microbial reactions. Natural attenuation may be feasible when the groundwater parameters (e.g., pH, temperature, and alkalinity) are favorable, sufficient sources of carbon are available, and the concentrations of competing electron acceptors are low. PCE and TCE degrade once the preferential electron acceptors are reduced in groundwater, including dissolved oxygen, nitrate, ferric iron, and sulfate. Reductive dechlorination reactions are optimized under iron- and sulfate-reducing conditions. DCE and vinyl chloride may also bioattenuate through reductive dechlorination, or may be consumed as carbon source under aerobic conditions.

Evidence of very limited reductive dechlorination was observed in the soil samples collected between 1 and 8.5 feet bgs. Reductive dechlorination daughter products were only detected in the 2.5 feet bgs interval of DP-07, where the concentrations of PCE, TCE, and cDCE were respectively 36, 0.14, and 0.11 mg/kg. The presence of reductive dechlorination daughter products in this sample is apparently related to the higher concentration of PCE, the presence of moist, fine grained soil, and the higher retention of contamination in the silty soil.

Evidence of bioattenuation is much more pronounced in the upper and lower water bearing units. The concentrations of cDCE generally equal the concentrations of PCE in MW-2 and exceed the concentrations of PCE in MW-8, and the concentrations of cDCE are generally three orders of magnitude greater than the concentrations of vinyl chloride. Although PCE was detected below the 5 µg/L cleanup level in MW-13D and MW-14D, cDCE is the predominant species of chlorinated VOC in MW-12D to MW-14D, where the concentrations are below the 70 µg/L cleanup level.

Bioremediation of chlorinated VOCs is normally accomplished under anaerobic conditions using either a biostimulation or bioaugmentation process. Biostimulation involves the injection of available carbon and nutrients to enhance microbial growth and reduce the concentrations of competing electron acceptors for anaerobic degradation. Under anaerobic conditions, biostimulation often results in the rapid depletion of PCE and TCE and the accumulation of cDCE and vinyl chloride, which may readily bioattenuate under aerobic conditions where the compounds are used as a source of carbon. Sometimes, groundwater is bioaugmented with *dehalococcoides ethenogenes* to promote the anaerobic degradation of vinyl chloride.

In this alternative, an initial round of biostimulation would be performed at the start of remediation and a second round would be performed after the cessation of active SVE operations and conversion of the SVE wells for biostimulation reagent injection. Biostimulation could be performed by periodically injecting large batches of commercially-produced biostimulants that have a prolonged release of lactate and fatty acids. Engineered biostimulants can release carbon for one to three years per application.

The migration of the biostimulants toward the groundwater would need to be evaluated, however, to assess the effectiveness of this approach. Alternatively, carbon and nutrients (e.g., sodium acetate and ammonium phosphate) could be metered into a potable-water drip irrigation system, and biostimulated water could flush through the soil contamination. Acetate is readily available for microbial consumption and must be continually replenished. This approach may lead to additional leaching, but would enhance biostimulation in the soil and groundwater and reduce the total treatment time. The introduction of water would reduce the air permeability of the soil, reducing the exposure risk from vapor intrusion. The injection of biostimulants into the SVE well(s) would reduce the permeability of the well screen, which would reduce the effectiveness of SVE if pursued again.

This alternative includes engineering controls to control or mitigate the intrusion of soil vapor into the dry cleaning and adjacent building, repair of the sanitary sewer line leading from the dry cleaner, and an environmental covenant to require cap maintenance in the event of building decommissioning, to prohibit groundwater use, and to require performance and confirmational sampling for groundwater. It is assumed that annual monitoring and reporting of 7 Site wells would be required for 10 years.

3.1.5 Alternative A5 – Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and In Situ Chemical Oxidation

Under this alternative the building would be demolished and the foundation broken and removed. The piers for the foundation would be cut below grade level and left in place. The concrete pavement in the approximately 5-foot wide pedestrian alley between the dry cleaner and adjacent retail building would be removed and replaced. The building materials would be removed from the site and disposed as construction and demolition waste.

Contaminated soils would be further characterized at depth and then excavated beneath the dry cleaner building and the adjoining pedestrian alley. Steel sheet pile shoring would be installed near, but not adjacent, to the off-property building and street. The placement of the shoring would be limited by property boundaries and utility easements. The shoring would be installed to below the target excavation depth so that impacted soil could be excavated to a depth of 15 feet bgs. The estimated excavation volume is 2,000 bank cubic yards (BCY), based on removing all soils under the current building foot print to a depth of 15 feet bgs.

Any remaining contaminated subsurface soils beneath the depth of excavation in the source area can be treated by *in situ* soil mixing using a backhoe and potentially with a rotary mixer. Granular potassium permanganate would be added to the bottom of the excavation and hydrated, and the purple permanganate solution would be mixed in place to distribute and blend the permanganate. Physical mixing may be limited to 2 to 5 feet beneath the bottom of the excavation. The glacial till is composed of compacted gravels, silts, and sands, which have limited expansion potential when wet. Nevertheless, the treated soils would need to be sufficiently compacted for the normal load-bearing capacity of future uses of the property.

The excavation would be backfilled with coarse aggregate. Horizontal slotted PVC pipe would be installed approximately one foot beneath the surface and placed above remaining VOC-impacted soils within the footprint of the building and pedestrian alley; one or more PVC risers would be extended vertically to allow the injection of permanganate and the passive ventilation of the fill. Six vertical *In situ* chemical oxidation (ISCO) injection wells would be installed through the source area and would extend to the bottom of the advance outwash zone at approximately 65 feet bgs. The injection wells would be continuously screened across the unsaturated and saturated intervals of the advance outwash from approximately 35 to 65 feet bgs. Bedding material and a flexible membrane liner would be constructed on top of the fill material and the liner would be keyed in the backfill vertically along the perimeter. The flexible membrane liner seams and the pipe penetrations would be sealed to prevent the infiltration of surface water. The impermeable barrier would significantly inhibit the infiltration of surface water through residual soil contamination in the glacial till and unsaturated intervals of the advance outwash. Thus, the impermeable cap would be protective of the leaching-to-groundwater exposure pathway. The surface would be paved with asphalt following the installation of the flexible membrane liner, and the site drainage would be directed away from the impermeable barrier.

Large volumes of low dosage (e.g., 2 to 3 percent) permanganate would be injected into the injection wells and into the horizontal leachate pipe in the aggregate fill. The permanganate in the aggregate fill would be allowed to seep downward through the glacial till to treat residual contamination. This may be an effective means to treat chlorinated VOCs in the lower permeable intervals in the glacial till. Large volumes of low dosage permanganate would also be injected into the source area in the unsaturated and saturated intervals of the advance outwash from approximately 35 to 65 feet bgs. Because the advance outwash is composed of slightly silty sand and is fairly homogeneous, the permanganate would be well distributed beneath the source areas.

Because of the desorption, dissolution, and leaching of VOCs from lower permeable intervals, the initial permanganate concentrations should be high enough to remain above 50 mg/L for an extended period to oxidize additional dissolved phase contamination. Permanganate is a stable oxidant, and would remain in the subsurface until reduced by the natural oxidative demand of the aquifer. The low pore water exchange rate and presumed low concentration of organics in the advance outwash may extend the presence of high concentrations of permanganate for a year or more. Typically, two or more ISCO treatments are required to permanently reduce the concentrations of chlorinated VOCs to below cleanup levels. However, two rounds of ISCO treatment in the advance outwash may be sufficient because ISCO would be applied across the source area and additional contaminant leaching would be reduced by the impermeable barrier.

ISCO would not address all contaminated groundwater outside of the source area in the advance outwash. In MW-5, which is about 70 feet upgradient of the source area, the concentration of PCE was 140 µg/L in February 2012, which exceeds the 5 µg/L cleanup level. Chlorinated VOC contamination has migrated up- and cross-gradient from the source area beyond MW-2 and MW-5 potentially by lateral dispersion, spreading, and diffusion as it migrates downward through discontinuous, unsaturated coarse- and fine-grained soil layers. The injected permanganate solution would be expected to spread laterally in a fashion similar to the observed PCE release, likely delivering permanganate

to impacted groundwater outside the soil source area; however, relatively low concentrations of chlorinated VOCs in groundwater further from the source area would not be directly treated. With the highly oxidizing conditions produced by ISCO natural attenuation processes relying open more reducing conditions would be inhibited, although other processes such as dispersion would remain active. Areas not directly treated by ISCO would retain the ambient reducing conditions and residual VOCs in groundwater in these areas would be allowed to naturally attenuate through biodegradation.

The use of sheet pile shoring would allow excavation sufficient to eliminate the onsite soil direct contact exposure pathway, which would eliminate the need for institutional controls restricting direct contact exposure. Nevertheless, the excavation would be backfilled and covered with a combination hydraulic cap and passive ventilation system to eliminate the soil-to-groundwater leaching exposure pathway and the offsite soil vapor intrusion exposure pathway. An environmental covenant would be implemented to maintain the impermeable cap, to prohibit groundwater use, and to require performance and confirmational monitoring for groundwater.

4 Detailed Evaluation of Cleanup Alternatives

This section provides a comparative evaluation of the five alternatives (A1 to A5). The cleanup alternatives must meet minimum threshold requirements to be accepted by Ecology. The cleanup alternatives that meet the threshold requirements are then comparatively evaluated based on permanence, restoration time frame, and public concerns. Appendix C provides evaluation tables for the cleanup alternatives, using criteria from the Washington Administrative Code (WAC), 173 340 360.

4.1 Threshold Requirements

Threshold requirements are identified in WAC 173 340 360, and include:

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

Table C.1 describes the degree that each cleanup alternative meets the threshold requirements. With the exception of the no action alternative, each cleanup alternative provides a degree of protection and each establishes a compliance monitoring plan.

Because the contaminant source possibly extends vertically beneath the dry cleaner building to the water table at approximately 53 feet bgs, the alternatives are limited to institutional and engineering controls and the *in situ* treatment of accessible contamination, except for Alternative A5, which includes demolition and replacement of the building to allow more aggressive remediation. Alternatives A2 to A4 build on each other, progressively adding engineered controls for soil vapor intrusion for existing construction, SVE for the remediation of accessible soils beneath the source areas, and biostimulation to enhance natural bioattenuation in the upper water bearing unit. Alternatives A2 to A5 meet the threshold requirements, and are carried forward for further consideration.

WAC 173-340-360 has additional requirements for soil, groundwater, and institutional controls. For properties with a current or potential future residential use, the soil must be treated, removed, or contained. An environmental covenant would require that impacted soils be capped by a building or other impervious structure.

For nonpermanent groundwater cleanup actions, cleanup actions should be performed to remove free product and prevent expansion, and should to not be reliant on dilution and dispersion alone. Although some DNAPL may be present in soil and groundwater at this site, it would likely be bound to fine-grained soil, be dispersed in soil and/or groundwater beneath the building, and be inaccessible by conventional remediation technologies. Nevertheless, conventional remediation methods can be performed to treat contamination in the upper water bearing unit.

4.2 Permanence Requirements and Disproportionate Cost Analysis

WAC 173-340-360 requires that the cleanup action uses permanent solutions to the maximum extent practicable, based on the development of a disproportionate cost analysis that compares the costs and benefits for the following criteria:

- Protectiveness (30%)
- Permanence (20%)
- Cost
- Long-term effectiveness (20%)
- Short-term risks (10%)
- Implementability (10%)
- Public concerns (10%)

These criteria include the discretionary weighting factors (percentages) listed above to facilitate the calculation of an environmental benefit. Table C.2 provides the permanence criteria and disproportionate cost analysis for Alternatives A2 to A5. As described in the footnotes in Table C.2, a numerical ranking of 1 to 5 is assigned to each criterion for each alternative based on the relative degree that the cleanup alternative satisfies the criterion. The environmental benefit for each cleanup alternative is calculated as the sum of the products of the weighting factor and numerical ranking for each criterion. Figure 10 provides a graphical comparison of costs and environmental benefit rankings for the alternatives.

As shown in Table C.2, at a cost of $545,000 Alternative A4 (SVE and biostimulation) will be protective of all potential exposure pathways, is implementable, and presents very limited short-term risks or public concerns. The weighted score of this alternative considering the criteria listed above is 3.9.

Alternative A2 (institutional and engineering controls) has a lower cost ($255,000) than Alternative A4, ranks significantly lower overall (score of 2.0) due to low protectiveness, permanence, and long-term effectiveness rankings. The incremental costs between Alternatives A2 and Alternative A4 are not disproportionate, based on the appreciably greater protectiveness, permanence, and long-term effectiveness of Alternative A4.

Alternative A3 (SVE and institutional and engineering controls) has similar costs ($445,000) to Alternative A4, but ranks lower overall (score of 3.0), due primarily to low permanence and long-term effectiveness rankings. Given the similar costs and higher ranking of Alternative A4, the incremental costs relative to Alternative A3 are not disproportionate.

Alternative A5 (building demolition, excavation, Capping, and ISCO) ranks higher than Alternative A4 overall (score of 4.4), ranking higher in terms of protectiveness, permanence, and long-term effectiveness. However, incremental cost (estimated as $1,200,000 or about $650,000 more than Alternative A4) is disproportionate to the modest incremental benefits of this alternative.

4.3 Restoration Time Frame Requirements

WAC 173-340-360 requires that the cleanup action provides a reasonable restoration time frame by evaluating the following criteria:

- Potential risks posed to human health and the environment;
- Practicality of achieving a shorter restoration time frame;
- Current use of the site and surrounding properties;
- Potential future use of the site and surrounding areas;
- Availability of alternative water supplies;
- Likely effectiveness and reliability of institutional controls;
- Ability to control and monitor migration of hazardous substances;
- Toxicity of hazardous substances; and
- Natural attenuation processes.

The presented cleanup alternatives address source areas in the surface and subsurface soil beneath the dry cleaner building and adjoining pedestrian alley and in the upper water bearing zone. The advance outwash becomes dry in the bounding wells along North First Street and Tacoma Avenue North, including MW-3, MW-6, MW-4, MW-9, and MW-10, and groundwater is not accessible for sampling underneath the on- and off-site structures.

The presented cleanup alternatives are developed to control the exposure pathways and to remove source contamination to the extent practicable to reduce or eliminate the migration of contamination. Residual contamination may remain in groundwater at concentrations above the cleanup levels following active remediation, and would ultimately be addressed through natural attenuation.

Table C.3 summarizes how Alternatives A2 to A5 address the restoration time frame criteria. Alternatives A2 to A4 provide controls and limited treatment for accessible source areas, while Alternative A5 provides more extensive soil source area removal and treatment following demolition of the building. Because of the controls and likely recontamination of the treated source areas, the alternatives that retain the existing building have longer restoration time frames than Alternative A5.

Alternative A2 provides controls only, and the effectiveness of the engineering controls for soil vapor intrusion would diminish in time. Alternative A3 provides for removal of accessible soil contamination by SVE, and would decrease the subsurface vapor intrusion and leaching exposure risks. Alternative A4 also includes biostimulation of the upper water bearing unit to enhance the natural bioattenuation observed at the site. Although biostimulation will lead to increased concentrations of vinyl chloride, which is more toxic than its parent compounds, the total mass of contamination will be significantly reduced, and vinyl chloride poses less risk to subsurface vapor intrusion than does PCE. Alternative A5 provides remediation of the currently non-accessible surface and subsurface soil contamination, which can accelerate restoration and mitigate the need for the engineering controls.

5 Cleanup Action Contingencies

This FFS develops cleanup alternatives to address source contamination in soil and the upper water bearing unit beneath the dry cleaner building. The remediation of these source areas reduces risk for the indoor air, soil, and groundwater exposure pathways and reduces the potential migration of contamination to inaccessible treatment areas in the discontinuous lower water bearing units. However, the cleanup alternatives considered would not immediately reduce the concentrations of all COCs to below the cleanup levels on the Property and must rely on long-term monitoring to demonstrate that natural attenuation processes are effectively removing residual contamination remaining after active remediation measures are complete.

The preferred cleanup alternative A4 provides for up to six injection wells for biostimulation treatment, which would focus active remediation primarily on the higher concentrations of PCE in soil and groundwater located beneath the building and accessible areas to the east and south. This alternative would leave a diffuse plume of lower-concentration chlorinated VOCs in deeper groundwater above the cleanup levels at the Site. As described in the alternatives discussion, the residual contamination would be allowed to naturally attenuate over time, with provisions for long-term monitoring to demonstrate the effectiveness of bioattenuation. Site closure would not be provided by Ecology until contaminants meet cleanup levels throughout the Site, or if a conditional point of compliance is approved, at the Property boundary. The time before cleanup levels would be met is uncertain and will depend in large part on the effectiveness of the biostimulation actions, but is expected to be on the order of 10 years.

The following sections provide general contingencies that could be applied:

- If a more aggressive schedule for Site closure is required, or
- If after implementing the selected alternative, results of performance monitoring indicate the timeframe to achieve cleanup is longer than anticipated.

The selection of any contingency would depend upon the observed effectiveness of the biostimulation treatment and the nature of any residual contamination.

The biostimulation action would be anticipated to decrease the concentrations of dissolved-phase PCE and TCE in groundwater to below cleanup levels. Although biostimulation would reduce the concentrations of cDCE and vinyl chloride bioattenuation daughter products, these compounds would be generated relatively quickly and degraded relatively slowly with diminishing returns for the more reduced vinyl chloride compound. The total mass of chlorinated VOCs would be significantly reduced and the groundwater would retain its natural or enhanced ability to reductively dechlorinate PCE that migrates from upgradient or partitions from lower permeability soil or vadose zone soil. Performance monitoring would be used to assess the effectiveness of biostimulation, the attenuation of the carbon source, and the recovery of the competing electron acceptors. Several years after application, the influence of biostimulation would be negligible, and several treatment approaches may be pursued.

Depending on the degree of contamination and the effectiveness and resilience of the biostimulants, an additional biostimulation response action may be warranted to achieve compliance. If vinyl chloride persists, the residual contamination could be treated by bioaugmentation with *dehalococcoides ethenogenes* to enhance the anaerobic degradation of vinyl chloride. Alternately, the groundwater could be biovented to transition the groundwater to aerobic conditions. cDCE and vinyl chloride bioattenuate relatively quickly under aerobic conditions, but aerobic conditions inhibit the bioattenuation of PCE and TCE.

6 Conclusions

The site has a long history of dry cleaning operations, which began in 1929 and continue today. Numerous small releases were likely during these operations, and most of the contamination appears to be below the building and adjoining pedestrian alley. Although soil characterization was limited by shallow direct-push refusal beneath the building, PCE contamination is assumed to extend from below identified source areas in the building and alley to the upper water bearing unit. PCE contamination has dispersed laterally in the upper water bearing unit and evidence of bioattenuation is observed. Although the upper water bearing unit becomes dry on the downgradient side of the adjoining buildings, chlorinated VOCs are detected in discontinuous lower water bearing units at concentrations below the cleanup levels, with significant bioattenuation. Although the exposure risk for soil and groundwater is limited, there are indications that subsurface soil vapor may pose a risk to indoor air.

This FFS identified and evaluated several feasible remediation alternatives for this Site. The recommended cleanup alternative is a comprehensive approach that controls the exposure pathways and remediates the accessible source contamination to the extent practicable.

The preferred cleanup alternative, Alternative A4, includes the following components:

- Engineering controls to mitigate soil vapor intrusion for existing construction;
- Construction of three vertical SVE wells and pilot testing to determine SVE design parameters;
- Soil vapor extraction to volatilize and remove accessible contamination beneath the building using pilot test and horizontal well(s);
- Two rounds of biostimulation of soil and groundwater using horizontal SVE well(s), new injection wells, and/or existing monitoring wells;
- Performance monitoring for two years after each biostimulation injection to evaluate the effectiveness of treatment, the maintenance of favorable reducing conditions, and the attenuation of available carbon for bioattenuation;
- Natural attenuation monitoring to demonstrate continued removal of residual groundwater contamination; and
- Environmental covenant to require a building or cap over the source areas, to restrict groundwater use, and to require performance and confirmation monitoring of groundwater plume stability for an estimated 10 years.

The estimated cost of Alternative A4 is $545,000. The actual costs for Alternative A4 are more uncertain and may ultimately be higher because of the long-term maintenance requirements for the vapor intrusion controls and the potential for additional treatment of impacted groundwater.

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Limitations

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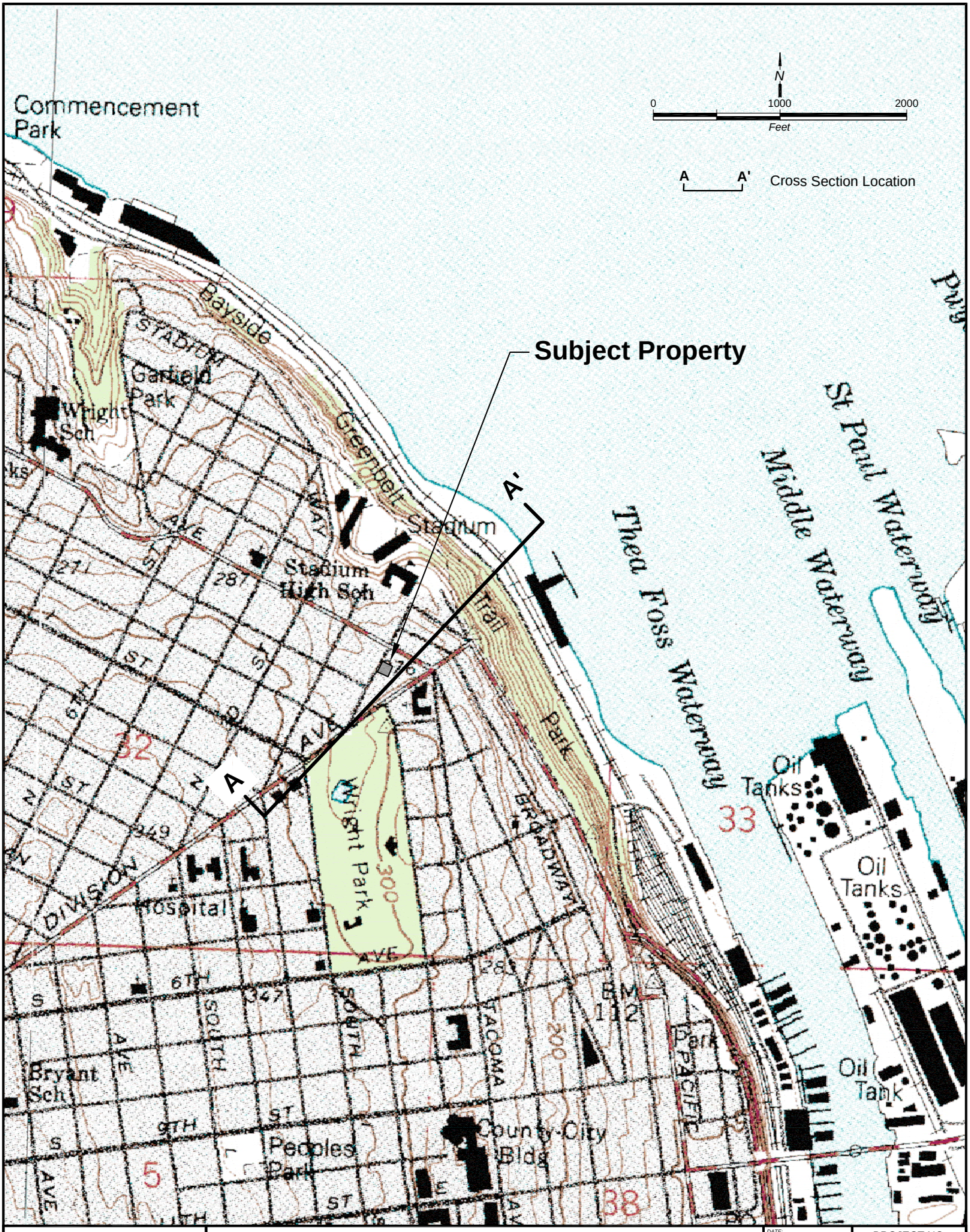


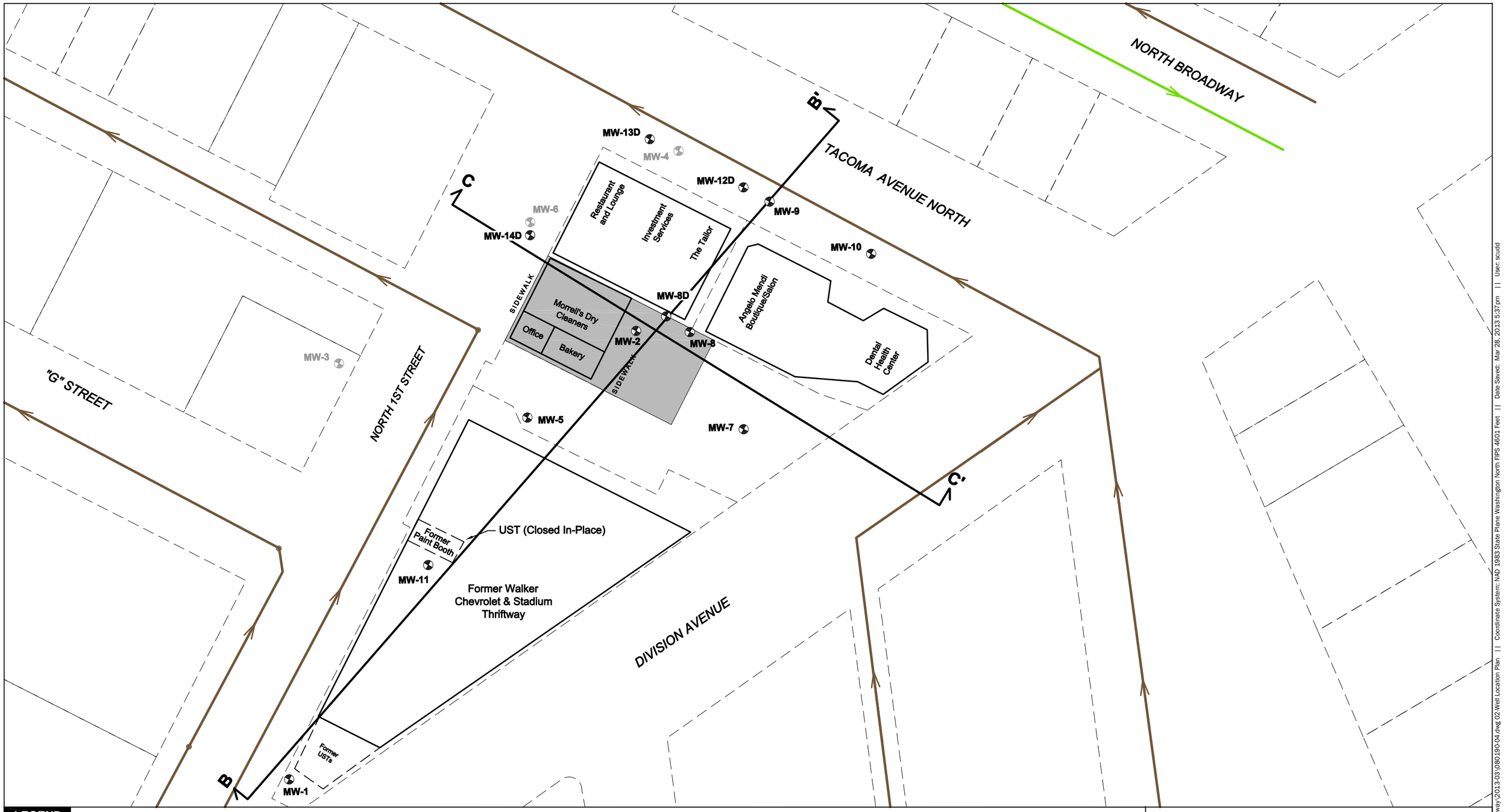
Site Vicinity Map

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

DATE: February 2011	PROJECT NO. 080190
DESIGNED BY: SCC	
DRAWN BY: SCC	FIGURE NO. 1
REVISED BY: SCC	

Aspect CONSULTING

Q:_GeoTech\080190 Stadium Thriftway\2011-02\080190-01.dwg Site Vicinity Map
Feb 11, 2011 10:58am scudd



LEGEND

- Existing Monitoring Well
- Decommissioned Monitoring Well
- C C' Cross Section Location
- Sanitary Sewer Line
- Storm Sewer Line
- Parcel Boundaries

N

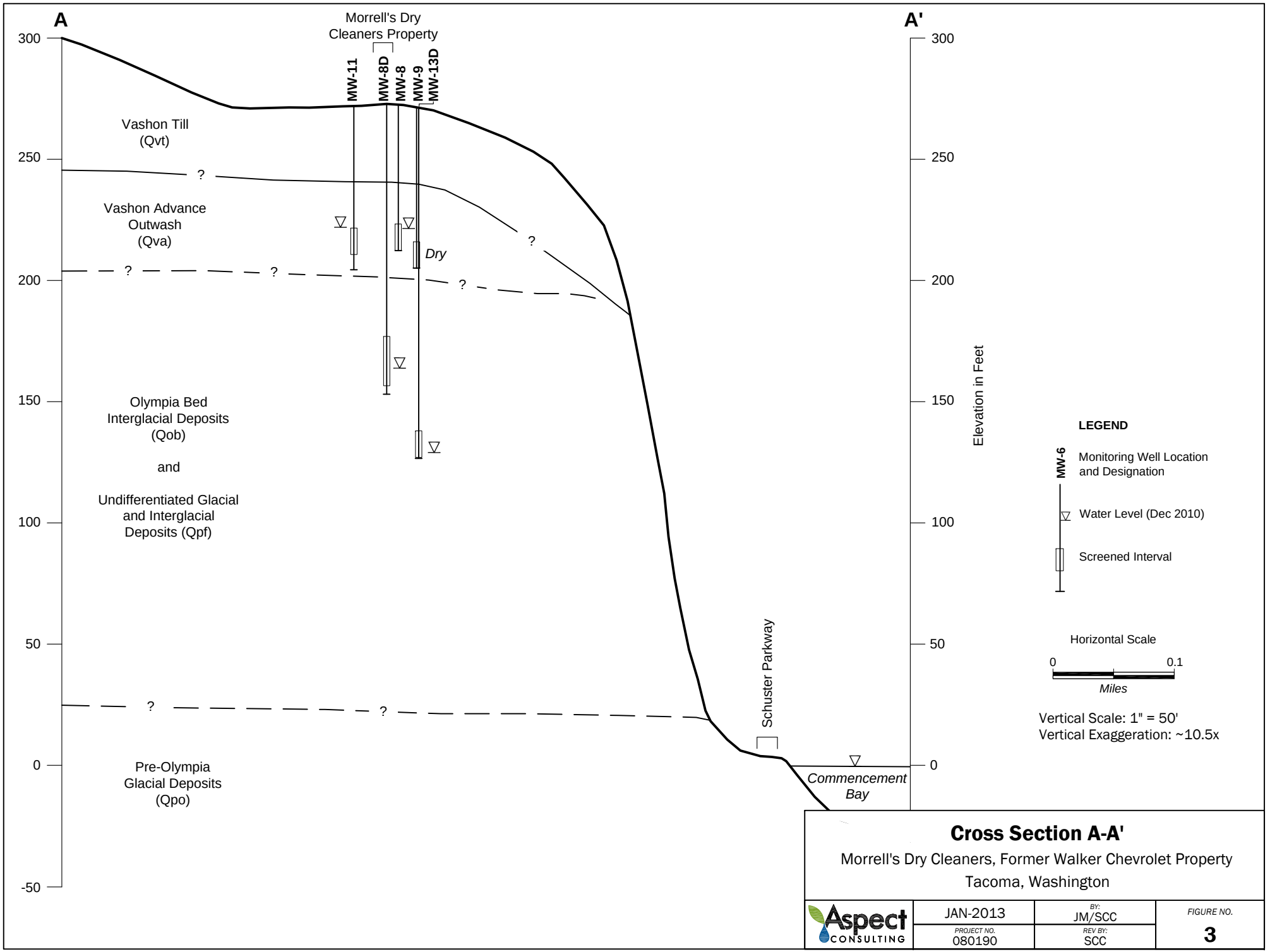
0 60 120
Feet

Well Location Plan

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect Consulting	JAN-2013	BY: JM/SCC	FIGURE NO. 2
	PROJECT NO. 080190	REV BY: SCC	

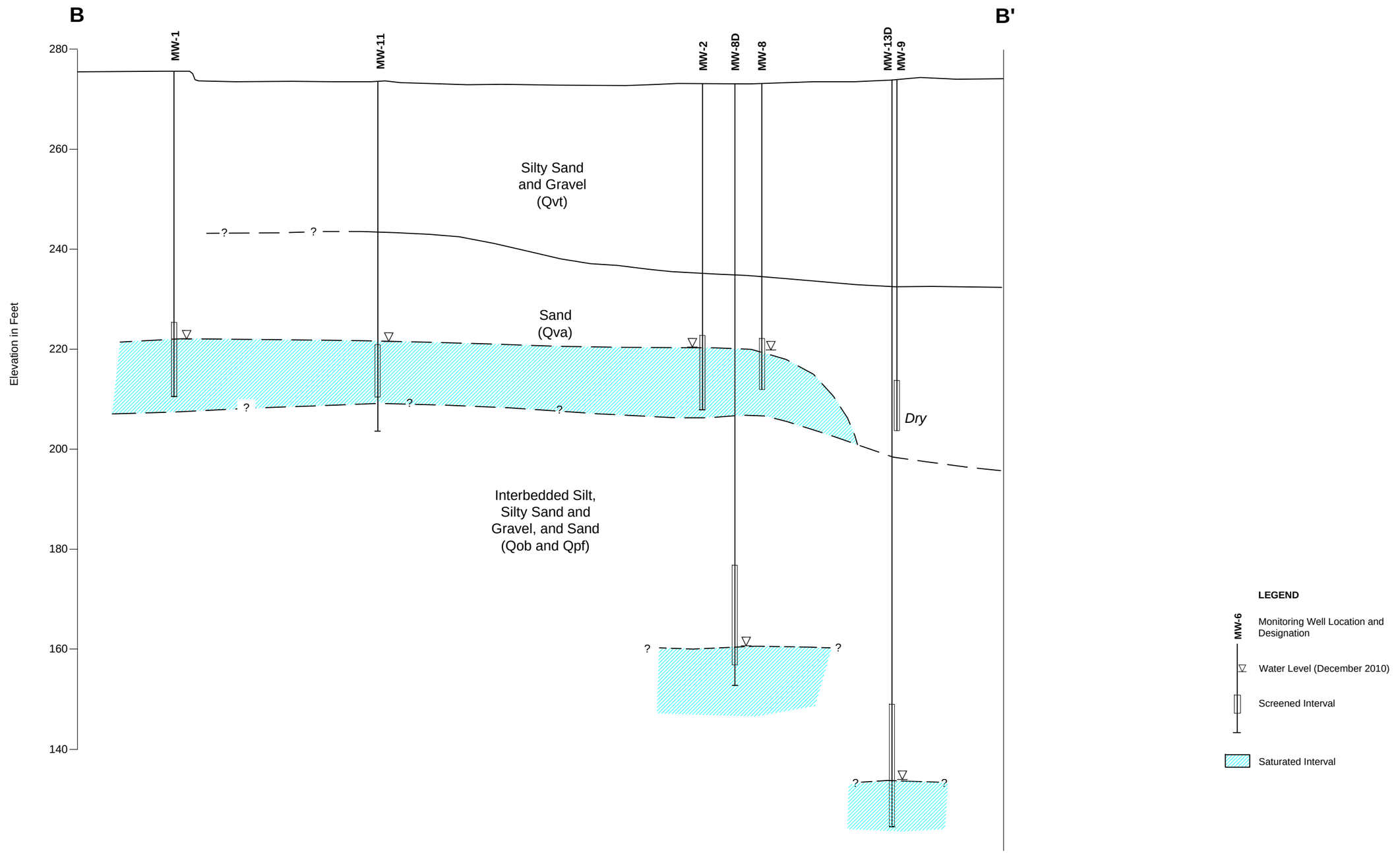
CAD Path: Q:_GeoTech\080190 Stadium Thriftway\2013-03\080190-04.dwg 02-Well Location Plan || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Mar 28, 2013 5:37pm || User: scudd



Cross Section A-A'

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect Consulting	JAN-2013	BY: JM/SCC	FIGURE NO. 3
	PROJECT NO. 080190	REV BY: SCC	



Vertical Scale: 1" = 20'
Vertical Exaggeration 2.5x

Horizontal Scale

0 50 100

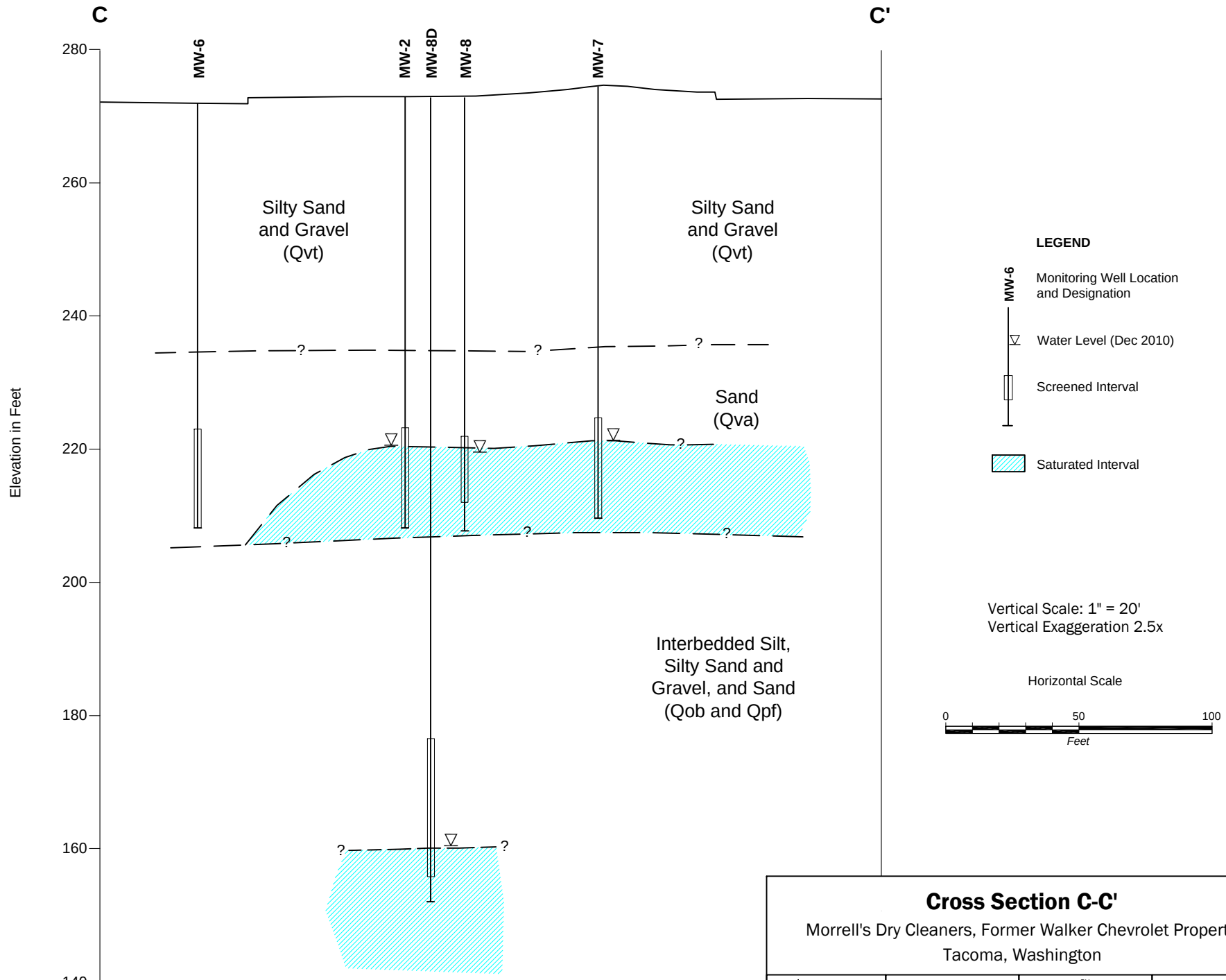
Feet

Cross Section B-B'

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect CONSULTING	JAN-2013	BY: JNM/SCC	FIGURE NO. 4
	PROJECT NO. 080190	REV BY: SCC	

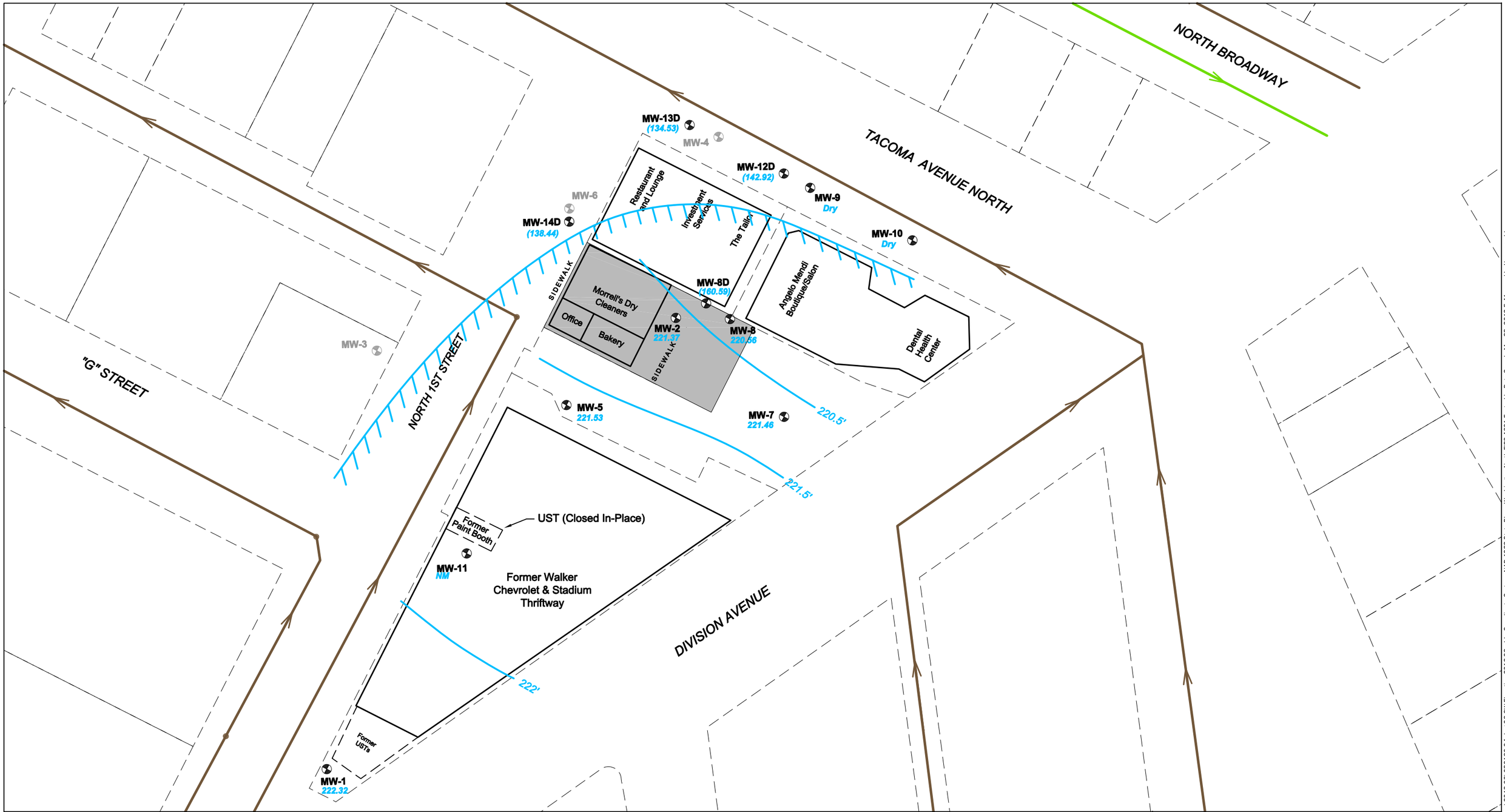
CAD Path: Q:_GeoTech\080190 Stadium Thriftway\2013-01\080190BB.dwg 11x17 Landscape || Date Saved: Jan 15, 2013 4:17pm || User: scudd



Cross Section C-C'

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect CONSULTING	JAN-2013	BY: JNM/SCC	FIGURE NO. 5
	PROJECT NO. 080190	REV BY: SCC	



LEGEND

- Existing Monitoring Well
- Decommissioned Monitoring Well
- Sanitary Sewer Line
- Storm Sewer Line
- Shallow Aquifer Groundwater Elevation Contour in Feet
- Estimated Limit of Shallow Aquifer
- 220.85 — Groundwater Elevation in Shallow Aquifer
- (160.55) — Groundwater Elevation in Deep Aquifer
- NM — Not Measured

N

0 60 120
Feet

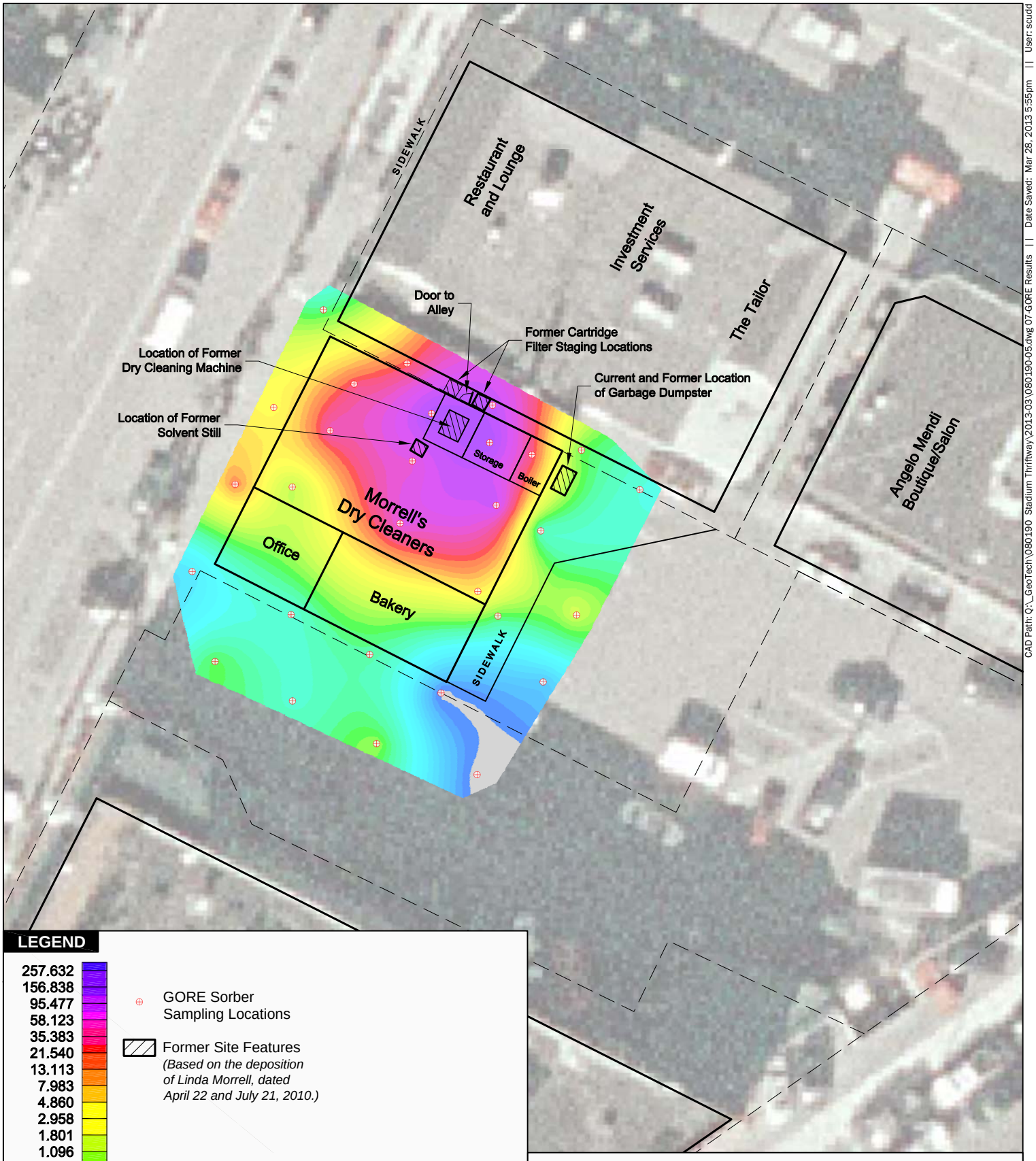
Groundwater Elevation Contour Map
February 2012

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect CONSULTING

JAN-2013	BY: JM/SCC	FIGURE NO. 6
PROJECT NO. 080190	REV BY: SCC	

CAD Path: Q:_GeoTech\080190 Stadium Thriftway\2013-03\080190-04.dwg 06-GW Elevation 2012-02 || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Mar 28, 2013 5:41pm || User: scudd



LEGEND

257.632
156.838
95.477
58.123
35.383
21.540
13.113
7.983
4.860
2.958
1.801
1.096
0.667
0.406
0.247
0.151
0.092
0.056
0.034
0.021
0.013

GORE Sorber Sampling Locations

Former Site Features
(Based on the deposition of Linda Morrell, dated April 22 and July 21, 2010.)

N

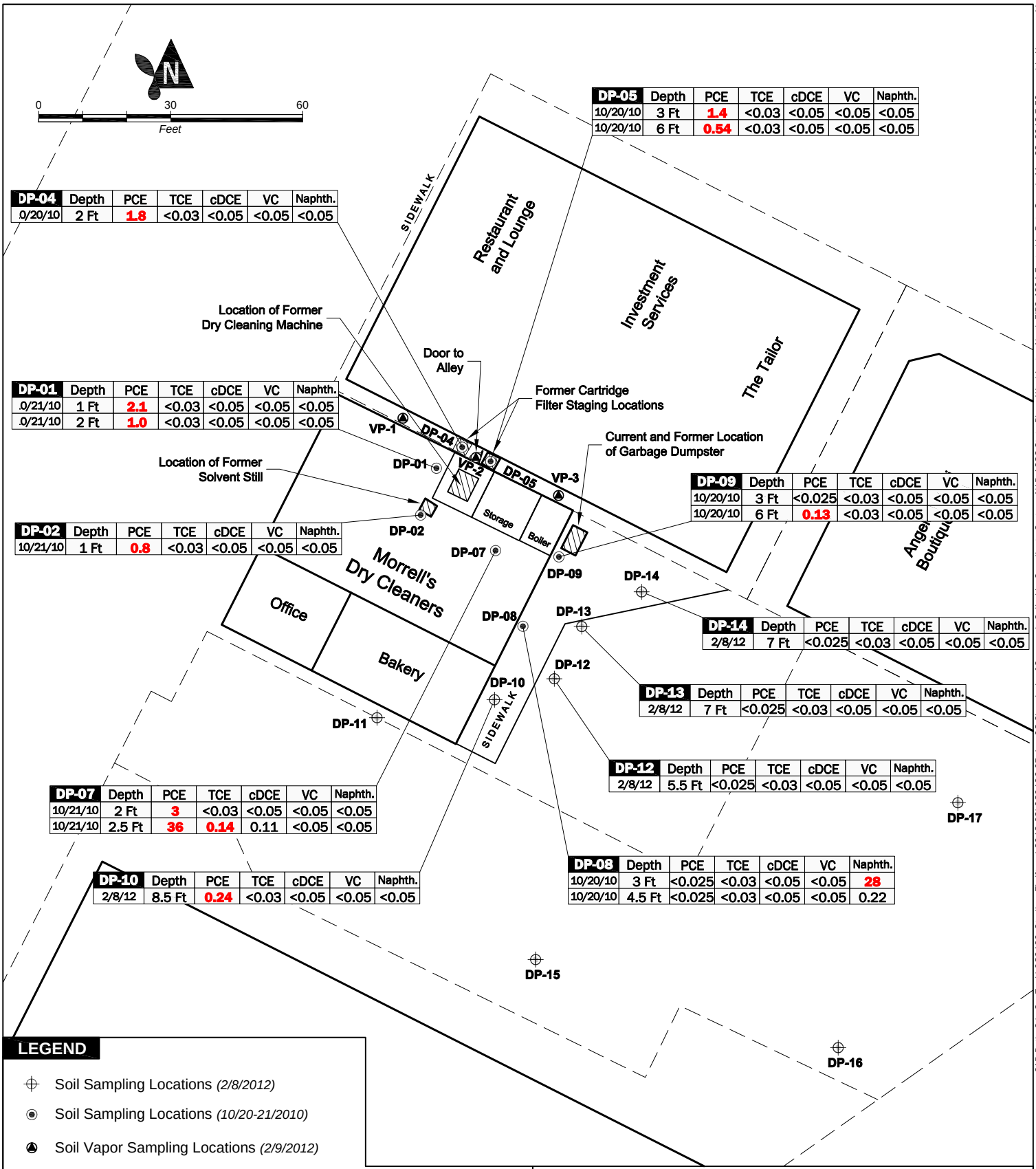
0 30 60
Feet

GORE Sorber Survey Results - Tetrachloroethene (PCE) in µg

GORE® Module Results for PCE
February 2010

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect Consulting	JAN-2013	BY: JM/SCC	FIGURE NO. 7
	PROJECT NO. 080190	REV BY: SCC	



DP-05	Depth	PCE	TCE	cDCE	VC	Naphth.
10/20/10	3 Ft	1.4	<0.03	<0.05	<0.05	<0.05
10/20/10	6 Ft	0.54	<0.03	<0.05	<0.05	<0.05

DP-04	Depth	PCE	TCE	cDCE	VC	Naphth.
0/20/10	2 Ft	1.8	<0.03	<0.05	<0.05	<0.05

DP-01	Depth	PCE	TCE	cDCE	VC	Naphth.
0/21/10	1 Ft	2.1	<0.03	<0.05	<0.05	<0.05
0/21/10	2 Ft	1.0	<0.03	<0.05	<0.05	<0.05

DP-09	Depth	PCE	TCE	cDCE	VC	Naphth.
10/20/10	3 Ft	<0.025	<0.03	<0.05	<0.05	<0.05
10/20/10	6 Ft	0.13	<0.03	<0.05	<0.05	<0.05

DP-02	Depth	PCE	TCE	cDCE	VC	Naphth.
10/21/10	1 Ft	0.8	<0.03	<0.05	<0.05	<0.05

DP-14	Depth	PCE	TCE	cDCE	VC	Naphth.
2/8/12	7 Ft	<0.025	<0.03	<0.05	<0.05	<0.05

DP-13	Depth	PCE	TCE	cDCE	VC	Naphth.
2/8/12	7 Ft	<0.025	<0.03	<0.05	<0.05	<0.05

DP-12	Depth	PCE	TCE	cDCE	VC	Naphth.
2/8/12	5.5 Ft	<0.025	<0.03	<0.05	<0.05	<0.05

DP-07	Depth	PCE	TCE	cDCE	VC	Naphth.
10/21/10	2 Ft	3	<0.03	<0.05	<0.05	<0.05
10/21/10	2.5 Ft	36	0.14	0.11	<0.05	<0.05

DP-08	Depth	PCE	TCE	cDCE	VC	Naphth.
10/20/10	3 Ft	<0.025	<0.03	<0.05	<0.05	28
10/20/10	4.5 Ft	<0.025	<0.03	<0.05	<0.05	0.22

DP-10	Depth	PCE	TCE	cDCE	VC	Naphth.
2/8/12	8.5 Ft	0.24	<0.03	<0.05	<0.05	<0.05

LEGEND

- Soil Sampling Locations *(2/8/2012)*
- Soil Sampling Locations *(10/20-21/2010)*
- Soil Vapor Sampling Locations *(2/9/2012)*
- Former Site Features *(Based on the deposition of Linda Morrell, dated April 22 and July 21, 2010.)*

Clean Up Levels

PCE:	0.05
TCE:	0.03
cDCE:	NA
VC:	NA
Naphthalene:	5.0

1. All concentrations are in mg/kg.
2. Depths are in feet.
3. Red value indicates a detection exceeding the clean up level.
4. NA = Not Applicable.

Concentrations of Chemicals of Concern in Soil

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect CONSULTING	JAN-2013	BY: JM/SCC	FIGURE NO. 8
	PROJECT NO. 080190	REV BY: SCC	

MW-13D	PCE	TCE	cDCE	VC
12/22/10	14	3.2	30	<0.2
2/6/12	4.2	2.4	28	<0.2

MW-12D	PCE	TCE	cDCE	VC
12/22/10	6.1	<1	22	<0.2
2/6/12	<1	<1	17	<0.2

MW-9D	PCE	TCE	cDCE	VC
5/11/09	<1	<1	11	<0.2
12/22/10	<1	<1	21	<0.2
2/6/12	<1	<1	26	<0.2

MW-14D	PCE	TCE	cDCE	VC
2/6/12	4.2	3.3	28	<0.2

MW-8	PCE	TCE	cDCE	VC
4/22/08	1300	780	2400	0.2
10/02/08	680	390	3600	6.9
5/12/09	780	370	2600	2.0
12/22/10	470	150	1800	1.4
2/6/12	960	610	1600	<20

MW-5	PCE	TCE	cDCE	VC
1/22/08	67	3	13	<0.2
1/30/08	31	1.1	4.5	<0.2
10/2/08	75	3.2	17	<0.2
5/11/09	17	1.1	44	<0.2
12/22/10	190	14	41	<0.2
2/6/12	140	8.7	25	<0.2

MW-2	PCE	TCE	cDCE	VC
8/28/07	2900	Note 3	7100	19
1/30/08	1400	520	2000	<0.2
10/2/08	1900	880	2300	3.1
5/12/09	1600	930	2400	2.7
12/22/10	2100	1100	2100	2.7
2/6/12	1,600	810	1400	<20

MW-7	PCE	TCE	cDCE	VC
1/22/08	6.6	<1	<1	<0.2
1/30/08	1.5	<1	<1	<0.2
10/2/08	<1	<1	<1	<0.2
5/11/09	1.1	<1	<1	<0.2
12/22/10	1.4	<1	<1	<0.2
2/6/12	<1	<1	<1	<0.2

MW-11	PCE	TCE	cDCE	VC
5/12/09	<1	2.3	<1	<0.2
12/22/10	<1	4.6	<1	<0.2
2/6/12	NS	NS	NS	NS

MW-1	PCE	TCE	cDCE	VC
8/28/07	1.3	<1	<1	<0.2
1/30/08	<1	<1	<1	<0.2
10/2/08	<1	<1	<1	<0.2
5/11/09	<1	<1	<1	<0.2
12/22/10	<1	<1	<1	<0.2
2/6/12	<1	<1	<1	<0.2

NORTH BROADWAY
TACOMA AVENUE NORTH
"G" STREET
NORTH 1ST STREET
DIVISION AVENUE
SIDEWALK
SIDEWALK
Restaurant and Lounge
Investment Services
The Tailor
Morrell's Dry Cleaners
Office
Bakery
Angelo Mendi Boutique/Salon
Dental Health Center
Former Paint Booth
UST (Closed In-Place)
Former Walker Chevrolet & Stadium Thriftway
Former USTs
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
MW-8D
MW-9
Dry
MW-10
Dry
MW-11
MW-12D
MW-13D
MW-14D

LEGEND

- Existing Monitoring Well
- Decommissioned Monitoring Well
- Sanitary Sewer Line
- Storm Sewer Line

Clean Up Levels

PCE (Tetrachloroethylene):	5.0
TCE (Trichloroethylene):	5.0
cDCE (cis-1,2-Dichloroethylene):	70.0
VC (Vinyl Chloride):	0.2

Notes

1) All concentrations are in µg/L.
2) **Red value** indicates a detection exceeding the clean up level.
3) For the sample collected from MW-2 on 8/28/07, the lab reported 1,800 µg/L benzene and <1 µg/L TCE. This is likely an error; apparently the gas chromatograph peak identified by the lab as benzene was actually a TCE peak.

NS: Not Sampled

N

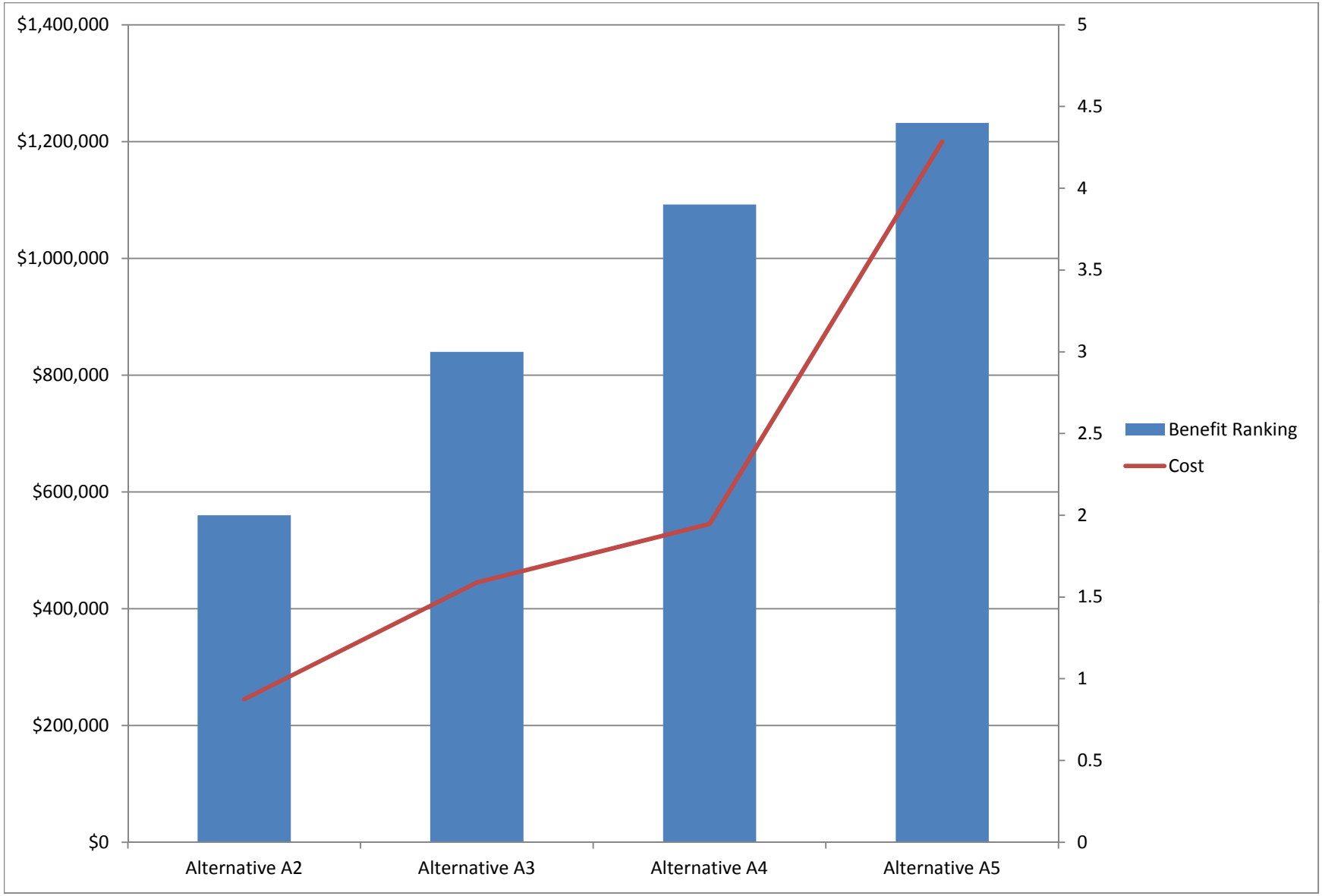
0 60 120
Feet

Concentrations of Chemicals of Concern in Groundwater

Morrell's Dry Cleaners, Former Walker Chevrolet Property
Tacoma, Washington

Aspect CONSULTING | JAN-2013 | BY: JM/SCC | FIGURE NO. 9
PROJECT NO. 080190 | REV BY: SCC

CAD Path: Q:_GeoTech\080190 Stadium Thriftway\2013-03\080190-04.dwg 09-Chemicals in GW || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Mar 28, 2013 5:43pm || User: scudd



Aspect Consulting
3/26/2013
V:\080190 Stadium Thriftway LLC\Deliverables\FFS\Final\Figure 10

Figure 10
Disproportionate Cost Evaluation
Morell's Dry Cleaners, Tacoma, WA

APPENDIX A

Data Tables

Table A.1 - Soil Sample Results

Morrell's Dry Cleaner, Former Walker Chevrolet Property, Tacoma, Washington

Boring ID	Sample Depth (ft)	Date	Metals	VOCs										
			Lead	PCE	TCE	cis-1,2-DCE	Vinyl Chloride	Naphthalene	Total Xylenes	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	tert-Butylbenzene	sec-Butylbenzene	p-Isopropyltoluene
Cleanup Level (mg/kg)			**250**	**0.05**	**0.03**	**NE**	**NE**	**5**	**9**	**NE**	**NE**	**NE**	**NE**	**NE**
DP-01	1	10/21/10	NA	**2.1**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
	2	10/21/10	NA	**1.0**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-02	1	10/21/10	NA	**0.8**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-04	2	10/20/10	NA	**1.8**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-05	3	10/20/10	NA	**1.4**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
	6	10/20/10	NA	**0.54**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-07	2	10/21/10	NA	**3**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
	2.5	10/21/10	NA	**36**	**0.14**	0.11	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-08	3	10/20/10	NA	<0.025	<0.03	<0.05	<0.05	**28**	1.16	76	26	0.43	1.8	12
	4.5	10/20/10	NA	<0.025	<0.03	<0.05	<0.05	0.22	<0.15	0.49	0.35	<0.05	0.14	0.10
DP-09	3	10/20/10	NA	<0.025	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
	6	10/20/10	NA	**0.13**	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-10	8.5	02/08/12	1.70	**0.24**	<0.03	<0.05	<0.05	<0.05	<0.15	0.054	<0.05	0.083	0.94	0.21
DP-11	4	02/08/12	1.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DP-12	5.5	02/08/12	1.75	<0.025	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	0.13	<0.05
DP-13	7	02/08/12	1.66	<0.025	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-14	7	02/08/12	2.08	<0.025	<0.03	<0.05	<0.05	<0.05	<0.15	<0.05	<0.05	<0.05	<0.05	<0.05
DP-15	4	02/08/12	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DP-16	4	02/08/12	2.81	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DP-17	4	02/08/12	1.96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
All values are in units of mg/kg
VOCs - volatile organic compounds
PCE - tetrachloroethylene
TCE - trichloroethylene
cis-1,2-DCE - cis-1,2-dichloroethylene
trans-1,2-DCE - trans-1,2-dichloroethylene
BOLD signifies exceedence of soil cleanup level (See Table 2.1)
NE - not established

Table A.2 - Groundwater Elevation Data

Morrell's Dry Cleaner, Former Walker Chevrolet Property, Tacoma, Washington

Well ID	Date	Screened Interval in Feet bgs	Top of Casing Elevation	Depth to Water	Groundwater Elevation
MW-1	2/27/2008	50 to 65	275.25	52.32	222.93
	10/2/2008			53.09	222.16
	5/11/2009			53.68	221.57
	12/22/2010			53.61	221.64
	2/6/2012			52.93	222.32
MW-2	2/27/2008	50 to 65	273.14	51.50	221.64
	10/2/2008			51.84	221.30
	5/12/2009			52.42	220.72
	12/22/2010			52.44	220.70
	2/6/2012			51.77	221.37
MW-3	2/27/2008	52 to 67	272.77	dry	dry
	10/2/2008			dry	dry
	5/11/2009			dry	dry
MW-4	2/27/2008	49 to 64	273.01	dry	dry
	10/2/2008			dry	dry
	5/11/2009			dry	dry
MW-5	2/27/2008	50 to 65	273.13	50.87	222.26
	10/2/2008			51.65	221.48
	5/11/2009			52.28	220.85
	12/22/2010			52.21	220.92
	2/6/2012			51.60	221.53
MW-6	2/27/2008	49 to 64	272.55	dry	dry
	10/2/2008			dry	dry
	5/11/2009			dry	dry
MW-7	2/27/2008	50 to 65	274.44	52.90	221.54
	10/2/2008			53.08	221.36
	5/11/2009			53.69	220.75
	12/22/2010			53.73	220.71
	2/6/2012			52.98	221.46
MW-8	10/2/2008	51 to 61	273.14	52.68	220.46
	5/12/2009			53.28	219.86
	12/22/2010			53.32	219.82
	2/6/2012			52.58	220.56
MW-8D	5/11/2009	96 to 116	273.11	112.56	160.55
	12/22/2010			112.58	160.53
	2/6/2012			112.52	160.59
MW-9	5/11/2009	60 to 70	273.78	dry	dry
	12/22/2010			dry	dry
	2/6/2012			dry	dry
MW-10	5/11/2009	60 to 70	274.45	dry	dry
	12/22/2010			dry	dry
	2/6/2012			dry	dry
MW-11	5/12/2009	53 to 63	273.52	52.20	221.32
	12/22/2010			52.24	221.28
MW-12D	12/22/2010	113 to 123	272.72	129.96	142.76
	2/6/2012			129.80	142.92
MW-13D	12/22/2010	125 to 145	271.96	137.88	134.08
	2/6/2012			137.43	134.53
MW-14D	2/6/2012	123 to 143	272.46	134.02	138.44

All measurements are in feet
bgs - below ground surface

Table A.3 - Groundwater Sample Results

Morrell's Dry Cleaner, Former Walker Chevrolet Property, Tacoma, Washington

Well ID	Date	Metals	VOCs									
		Lead	PCE	TCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	Chloroethane	Chloroform	Carbon Tetrachloride	Acetone	Benzene
Cleanup Level (µg/L)		**15**	**5**	**5**	**70**	**100**	**0.2**	**NE**	**7.2**	**5**	**NE**	**5**
MW-1	8/28/07	NA	1.3	<1	<1	<1	<0.2	<1	<1	<1	<10	2.2
	1/30/08	NA	<1	<1	<1	<1	<0.2	<1	<1	<1	<10	<1
	10/2/08	NA	<1	<1	<1	<1	<0.2	<1	<1	<1	<10	<1
	5/11/09	NA	<1	<1	<1	<1	<0.2	<1	<1	<1	<10	<1
	12/22/10	NA	<1	<1	<1	<1	<0.2	<1	<1	<1	14	<0.35
	2/6/12	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<10	<0.35
MW-2	8/28/07	NA	**2,900**	(Note 1)	**7,100**	7.4	**19**	8.1	1	1.0	<10	(Note 1)
	1/30/08	NA	**1,400**	**520**	**2,000**	3	<0.2	<1	2.5	<1	<10	<1
	10/2/08	NA	**1,900**	**880**	**2,300**	5.3	**3.1**	1.0	3.5	1.0	<10	<1
	5/12/09	NA	**1,600**	**930**	**2,400**	5.7	**2.7**	<1	4.0	<1	<10	<1
	12/22/10	NA	**2,100**	**1,100**	**2,100**	4.8	**2.7**	<1	5.0	<1	16	<0.35
	2/6/12	<1	**1,600**	**810**	**1400**	<100	<20	<100	<100	<100	<1,000	<35
MW-5	1/22/08	NA	**67**	3	13	<1	<0.2	<1	2.1	3.3	<10	<1
	1/30/08	NA	**31**	1.1	4.5	<1	<0.2	<1	1.8	2.0	<10	<1
	10/2/08	NA	**75**	3.2	17	<1	<0.2	<1	1.9	1.2	<10	<1
	5/11/09	NA	**17**	1.1	44	<1	<0.2	<1	<1	<1	<10	<1
	12/22/10	NA	**190**	**14**	41	<1	<0.2	<1	2.9	3.2	15	1.1
	2/6/12	<1	**140**	**8.7**	25	<1	<0.2	<1	<1	<1	<10	<0.35
MW-7	1/22/08	NA	**6.6**	<1	<1	<1	<0.2	<1	<1	<1	<10	<1
	1/30/08	NA	1.5	<1	<1	<1	<0.2	<1	<1	1.5	<10	<1
	10/2/08	NA	<1	<1	<1	<1	<0.2	<1	<1	1.5	<10	<1
	5/11/09	NA	1.1	<1	<1	<1	<0.2	<1	<1	2.0	<10	<1
	12/22/10	NA	1.4	<1	<1	<1	<0.2	<1	<1	3.3	11	<0.35
	2/6/12	<1	<1	<1	<1	<1	<0.2	<1	<1	2.2	<10	<0.35
MW-8	4/22/08	NA	**1,300**	**780**	**2,400**	6.3	0.2	<1	2.5	<1	<10	<1
	10/2/08	NA	**680**	**390**	**3,600**	7.6	**6.9**	<1	2.5	<1	<10	<1
	5/12/09	NA	**780**	**370**	**2,600**	3.7	**2.0**	<1	2.5	<1	<10	<1
	12/22/10	NA	**470**	**150**	**1,800**	3.3	**1.4**	<1	2.2	<1	10	<0.35
	2/6/12	<1	**960**	**610**	**1,600**	<100	<20	<100	<100	<100	<1,000	<35
MW-8D	5/11/09	NA	<1	<1	11	<1	<0.2	<1	<1	1.9	<10	<1
	12/22/10	NA	<1	<1	21	<1	<0.2	<1	<1	2.0	13	<0.35
	2/6/12	<1	<1	<1	26	<1	<0.2	<1	<1	1.8	<10	<0.35
MW-11	5/12/09	NA	<1	2.3	<1	<1	<0.2	<1	1.9	1.4	<10	<1
	12/22/10	NA	<1	4.6	<1	<1	<0.2	<1	2.0	2.8	12	<0.35
	2/6/12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-12D	12/22/10	NA	**6.1**	<1	22	<1	<0.2	<1	<1	<1	12	<0.35
	2/6/12	<1	<1	<1	17	<1	<0.2	<1	<1	<1	<10	<0.35
MW-13D	12/22/10	NA	**14**	3.2	30	<1	<0.2	<1	<1	<1	18	<0.35
	2/6/12	<1	4.2	2.4	28	<1	<0.2	<1	<1	<1	<10	<0.35
MW-14D	2/6/12	<1	4.2	3.3	28	<1	<0.2	<1	<1	<1	<10	<0.35

Notes:

1) For the sample collected from MW-2 on 8/28/07, the lab reported 1,800 µg/L benzene and <1 µg/L TCE. This is likely an error; apparently the gas chromatograph peak identified by the lab as benzene was actually a TCE peak.

All values are in units of µg/L

VOCs - volatile organic compounds

BOLD signifies exceedence of groundwater cleanup levels (see Table 2.2) (Federal MCLs apply when MTCA Method A value not identified)

PCE - tetrachloroethylene
TCE - trichloroethylene
cis-1,2-DCE - cis-1,2-dichloroethylene
trans-1,2-DCE - trans-1,2-dichloroethylene
NS - not sampled
NE - not established

Table A.4 - Sub-Slab Vapor Sample Results

Morrell's Dry Cleaners, Former Walker Chevrolet Property, Tacoma, Washington

Constituent	Screening Level [(2)]	VP-1 Results	VP-2 Results	VP-3 Results
Tetrachloroethylene	96	**270**	**150,000**	**380**
Trichloroethylene	3.7	1.1	**<230**	1.9
cis-1,2-Dichloroethylene	160	<0.72	**<170**	<1.2
trans-1,2-Dichloroethylene	320	<0.72	<170	<1.2
Vinyl chloride	2.8	<0.47	**<110**	<0.78
Benzene	3.2	<0.58	**<140**	<0.97
Ethylbenzene	4,600	<0.79	<180	1.8
Toluene	22,000	0.69	<160	6.0
Xylenes (total)	460	4.1	<180	9.3
Naphthalene	14	<4.8	**<900**	<8.0
Helium (%)		0.56	<0.086	<0.086

Notes:

1) All concentrations are in units of micrograms per cubic meter ($\mu g/m^3$).

2) Values in this column were obtained by multiplying the most stringent MTCA Method B air cleanup level by 10, to conservatively account for soil vapor attenuation across the floor slab in accordance with Ecology's draft *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology, 2009).*

Table A.5 - Indoor Air Sample Results

Morrell's Dry Cleaners, Former Walker Chevrolet Property, Tacoma, Washington

Constituent	Cleanup Level [2]	Outdoor (Background)	Morrell's [3]	Thriftway Office [3]
Tetrachloroethylene	9.6	0.42	**22**	**15**
Trichloroethylene	0.37	<0.17	**9.0**	**5.7**
cis-1,2-Dichloroethylene	16	<0.12	<0.14	<0.14
trans-1,2-Dichloroethylene	32	<0.63	<0.72	<0.69
Vinyl chloride	0.28	<0.040	<0.047	<0.045
Benzene	0.32	**2.0**	0.2	0.2
Ethylbenzene	460	1.7	0.3	0.5
Toluene	2,200	6.3	1.0	2.7
Xylenes (total)	46	7.9	2.1	3.3
Naphthalene	1.4	<4.1	<4.8	<4.6

Notes:

1) All concentrations are in units of micrograms per cubic meter ($\mu g/m^3$).

2) Indoor Air Cleanup Levels are the most stringent MTCA Method B air cleanup levels for carcinogens and non-carcinogens. PCE and TCE cleanup values were calculated using equations 750-1 and 750-2, WAC 173-340-750(3) and updated versions of the RfDi and CPFi (September 2012). The indoor air cleanup levels for the remaining compounds were selected from Table B-1 (Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Review Draft, Publication No. 09-09-047, October 2009).

3) Analytical results corrected by subtracting background results from indoor air results when detected.

APPENDIX B

Cleanup Alternative Components and Cost Estimates

Table B.1 - Summary of Components and Cost Estimates for Cleanup Alternatives

Morrell's Dry Cleaners (VCP Site SW1039)
Focused Feasibility Study

	Current Use Scenarios				
Cleanup Alternative Components	**Alternative A1** No Action	**Alternative A2** Engineering & Institutional Controls	**Alternative A3** SVE and Engineering & Institutional Controls	**Alternative A4** SVE, Biostimulation, and Engineering & Institutional Controls	**Alternative A5** Building Demolition, Excavation and Shoring, Capping, Institutional Controls, and ISCO
Engineering controls to inhibit soil vapor intrusion for existing construction		X	X	X	NA
Soil vapor extraction through horizontal well(s)			X	X	
Biostimulation through horizontal leach well(s) and/or existing wells on edge of source area				X	
In-situ chemical oxidation in soil and groundwater in source area					X
Demolition of Dry Cleaner Building and Removal of Foundation					X
Installation of shoring and excavation of soil beneath dry cleaner building and adjacent alleyway					X
Environmental covenant requiring cap or cover to inhibit direct exposure, prohibiting groundwater use, and stipulating monitoring for attenuation.		X	X	X	
Environmental covenant requiring hydraulic cap to inhibit direct exposure and leaching to groundwater, prohibiting groundwater use, and stipulating monitoring for attenuation.					X
Present Value of Future Costs[1,2]	$25,000	$245,000	$445,000	$545,000	$1,200,000

Notes:
1) These FS-level cost estimates have an accuracy of -30/+50 percent.
2) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent, and estimates are rounded to the nearest $1,000.

Table B.2 - Cost Estimate for Alternative A2

Engineering & Institutional Controls

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	No. of Units	Units	Unit Cost	Year of Expenditure	Present Value Cost[(2)]
Project Management					
Consulting, negotiation with Ecology, and reporting	1	LS	$25,000.00	2013	$25,000
Institutional Controls					
Environmental covenant	1	LS	$15,000.00	2013	$15,000
Groundwater Sampling per Environmental Covenant					
Annual sampling of 7 wells for VOCs and MNA parameters, validation, and reporting	30	YR	$7,500.00	2013 - 2042	$147,003
Engineering Controls for Existing Construction					
Sewer line repair	1	LS	$15,000.00	2013	$10,000
Seal cracks and other openings in foundation	1,300	FT	$3.88	2013	$5,044
Vapor barrier by epoxy paint	3,600	SF	$9.06	2013	$32,616
Engineering & design for soil vapor barrier	1	LS	$10,000.00	2013	$10,000
PRESENT VALUE OF FUTURE COSTS					**$244,663**

Notes:

1) These FS-level cost estimates have an accuracy of -30/+50 percent.

2) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent.

3) Soil vapor mitigation costs are derived from Indoor Air Vapor Intrusion Mitigation Approaches (EPA/600/R-08/115)

Table B.3 - Cost Estimate for Alternative A3

Soil Vapor Extraction and Engineering & Institutional Controls

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	No. of Units	Units	Unit Cost	Year of Expenditure	Present Value Cost[(2)]
Project Management					
Consulting, negotiation with Ecology, and reporting	1	LS	$25,000.00	2013	$25,000
Institutional Controls					
Environmental covenant	1	LS	$15,000.00	2013	$15,000
Groundwater Sampling per Environmental Covenant					
Annual sampling of 7 wells for VOCs and MNA parameters, validation, and reporting	15	YR	$7,500.00	2013 - 2027	$89,535
Engineering Controls for Existing Construction					
Sewer line repair	1	LS	$15,000.00	2013	$10,000
Seal cracks and other openings in foundation	1,300	FT	$3.88	2013	$5,044
Vapor barrier by epoxy paint	3,600	SF	$9.06	2013	$32,616
Modification of SVE wells to subslab ventilation system	1	LS	$10,000.00	2014	$9,709
Engineering & design for soil vapor barrier	1	LS	$10,000.00	2013	$10,000
Soil Vapor Extraction					
Construction of pilot test wells	3	EA	$4,500.00	2013	$13,500
Pilot test, evaluation, and reporting	1	LS	$15,000.00	2013	$15,000
Engineering & design for soil vapor extraction	1	LS	$20,000.00	2013	$20,000
Mobilization of specialized drill rig	1	LS	$15,000.00	2013	$15,000
Construction of horizontal well	3	EA	$15,000.00	2013	$45,000
Mobilization and construction of SVE system	1	LS	$20,000.00	2013	$20,000
Equipment lease, operation & maintenance, and reporting	6	MO	$20,000.00	2013	$120,000
				PRESENT VALUE OF FUTURE COSTS	**$445,403**

Notes:

1) These FS-level cost estimates have an accuracy of -30/+50 percent.

2) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent.

3) Soil vapor mitigation costs are derived from Indoor Air Vapor Intrusion Mitigation Approaches (EPA/600/R-08/115)

Table B.4 - Cost Estimate for Alternative A4

Soil Vapor Extraction, Biostimulation, and Engineering & Institutional Controls

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	No. of Units	Units	Unit Cost	Year of Expenditure	Present Value Cost[(2)]
Project Management					
Consulting, negotiation with Ecology, and reporting	1	LS	$25,000.00	2013	$25,000
Institutional Controls					
Environmental covenant	1	LS	$15,000.00	2013	$15,000
Groundwater Sampling per Environmental Covenant					
Annual sampling of 7 wells for VOCs and MNA parameters, validation, and reporting	10	YR	$7,500.00	2013 - 2022	$63,977
Engineering Controls for Existing Construction					
Sewer line repair	1	LS	$15,000.00	2013	$15,000
Seal cracks and other openings in foundation	1,300	FT	$3.88	2013	$5,044
Vapor barrier by epoxy paint	3,600	SF	$9.06	2013	$32,616
Modification of SVE wells to subslab ventilation system	1	LS	$10,000.00	2014	$9,709
Engineering & design for soil vapor barrier	1	LS	$10,000.00	2013	$10,000
Soil Vapor Extraction					
Construction of pilot test wells	3	EA	$4,500.00	2013	$13,500
Pilot test, evaluation, and reporting	1	LS	$15,000.00	2013	$15,000
Engineering & design for soil vapor extraction	1	LS	$20,000.00	2013	$20,000
Mobilization of specialized drill rig	1	LS	$15,000.00	2013	$15,000
Construction of horizontal well	3	EA	$15,000.00	2013	$45,000
Mobilization and construction of SVE system	1	LS	$20,000.00	2013	$20,000
Equipment lease, operation & maintenance, and reporting	6	MO	$20,000.00	2013	$120,000
Biostimulation through Leachate Wells (converted SVE wells) and Monitoring Wells					
Installation of					
Engineering & design for biostimulation	1	LS	$15,000.00	2013	$10,000
Chemical reagent, 1st batch	1	LS	$25,000.00	2013	$25,000
Injection of reagent, 1st batch	1	EA	$5,000.00	2013	$5,000
Chemical reagent, 2nd batch	1	LS	$25,000.00	2015	$23,565
Injection of reagent, 2nd batch	1	EA	$5,000.00	2015	$4,713
Semi-annual evaluation sampling and reporting	8	EA	$7,000.00	2013 - 2016	$51,638
			PRESENT VALUE OF FUTURE COSTS		**$544,761**

Notes:

1) These FS-level cost estimates have an accuracy of -30/+50 percent.

2) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent.

3) Soil vapor mitigation costs are derived from Indoor Air Vapor Intrusion Mitigation Approaches (EPA/600/R-08/115)

Table B.5 - Cost Estimate for Alternative A5

Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and *In Situ* Chemical Oxidation

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	No. of Units	Units	Unit Cost	Year of Expenditure	Present Value Cost[(2)]
Project Management					
Consulting, negotiation with Ecology, and reporting	1	LS	$25,000.00	2013	$25,000
Institutional Controls					
Environmental covenant	1	LS	$15,000.00	2013	$15,000
Groundwater Sampling per Environmental Covenant					
Annual sampling of 7 wells for VOCs and MNA parameters, validation, and reporting	10	YR	$7,500.00	2013 - 2022	$63,977
Demolition					
Building demolition, excluding foundation	1	LS	$18,000.00	2013	$18,000
Concrete removal, 6-inch reinforced	67	CY	$124.00	2013	$8,308
Demolition disposal charges	270	TON	$90.00	2013	$24,300
Property Devaluation					
Building market value (per Pierce County Assessor)	1	LS	$377,200.00	2013	$377,200
Excavation and Shoring, Disposal, Backfill, and Capping					
Engineering & design	1	LS	$30,000.00	2013	$30,000
Mobilization of equipment	1	LS	$5,000.00	2013	$5,000
Rental stell sheet piling and wales, first month	24	Ton	$322.00	2013	$7,728
Sheet pile shoring, 20-ft deep, 27 psf, drive, extract & salvage	3,000	SF	$26.72	2013	$80,160
Excavation, staging, and loading of soil	2,000	BCY	$7.00	2013	$14,000
Hauling, 18 tons/load, 2 tons/BCY	223	LOAD	$600.00	2013	$133,800
Disposal, non-hazardous, soil	4,000	TON	$40.00	2013	$160,000
Placement and compaction of imported fill	2,000	BCY	$10.00	2013	$20,000
Trench and install horizontal slotted pipe	120	FT	$7.00	2013	$840
Passive ventilation surface completions	1	LS	$1,000.00	2013	$1,000
60-mil HDPE liner	4,320	SF	$1.46	2013	$6,307
Trench and key 60-mil HDPE liner	240	FT	$7.50	2013	$1,800
In-Situ Chemical Oxidation in Excavation and Treatment Wells					
Engineering & design for ISCO	1	LS	$25,000.00	2013	$25,000
Chemical reagent, in-situ mixing	1	LS	$15,000.00	2013	$15,000
In situ mixing of permanganate	1	DAY	$7,500.00	2013	$7,500
Installation of treatment wells	6	EA	$3,500.00	2013	$21,000
Chemical reagent, 1st batch	1	LS	$30,000.00	2013	$30,000
Injection of reagent, 1st batch	1	EA	$15,000.00	2013	$15,000
Chemical reagent, 2nd batch	1	LS	$30,000.00	2015	$28,278
Injection of reagent, 2nd batch	1	EA	$15,000.00	2015	$14,139
Semi-annual evaluation sampling and reporting	8	EA	$7,000.00	2013 - 2016	$51,638
			PRESENT VALUE OF FUTURE COSTS		**$1,199,975**

Notes:

1) These FS-level cost estimates have an accuracy of -30/+50 percent.

2) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent.

APPENDIX C

Comparative Evaluation Tables for Cleanup Alternatives

Table C.1 - Evaluation of Cleanup Alternatives for Threshold Criteria

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

Cleanup Alternatives	Protection of Human Health and the Environment	Compliance with Cleanup Standards and Applicable Laws	Provision for Compliance Monitoring	Conclusions
Alternative A1 No Action	Provides no additional protection. Current development prevents direct exposure, ingestion, and inhalation exposure pathways in soil, and limits infiltration for soil-to-groundwater leaching pathway. Building is not specifically design to inhibit indoor air exposure pathway. No projected groundwater use, and sufficient attenuation mechanisms protect surface water and ecological receptors.	Contaminants would remain in soil and groundwater at concentrations above cleanup levels, and potential indoor air pathway would not be addressed.	No provision is made for compliance monitoring.	Eliminated
Alternative A2 Engineering and Institutional Controls	Provides engineering controls to mitigate indoor air exposure pathway and provides environmental covenant to restrict access and use of impacted media.	Leaves soil and groundwater contamination above cleanup levels.	Environmental covenant would require compliance monitoring. Compliance monitoring points could be defined in downgradient wells in lower water bearing unit.	Retained
Alternative A3 Soil Vapor Extraction and Engineering and Institutional Controls	Provides engineering controls to mitigate indoor air exposure pathway and provides environmental covenant to restrict access and use of impacted media. Reduces soil contamination and leaching to groundwater. Although SVE permanently removes accessible source contamination from beneath the building and pedestrian alley, the SVE wells would not intersect the migration pathway of the vertically distributed contamination beneath the building, which limits SVE effectiveness.	Although response action reduces soil contamination, residual soil contamination would remain beneath structure, and the soil cleanup criteria would be based on diminishing returns for SVE treatment. Does not address groundwater, where COCs exceed cleanup levels.	Environmental covenant would require compliance monitoring. Compliance monitoring points could be defined in downgradient wells in lower water bearing unit.	Retained

Table C.1 - Evaluation of Cleanup Alternatives for Threshold Criteria

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

Cleanup Alternatives	Protection of Human Health and the Environment	Compliance with Cleanup Standards and Applicable Laws	Provision for Compliance Monitoring	Conclusions
Alternative A4 Soil Vapor Extraction, Biostimulation, and Engineering and Institutional Controls	Provides engineering controls to mitigate indoor air exposure pathway and provides environmental covenant to restrict access and use of impacted media. Reduces soil contamination and leaching to groundwater. Although SVE permanently removes accessible source contamination from beneath the building and pedestrian alley, the SVE wells would not intersect the migration pathway of the vertically distributed contamination beneath the building, which limits SVE effectiveness. Biostimulation reduces source contamination in upper water bearing zone, and enhances natural attenuation prior to potential compliance wells in lower water bearing unit. However, biostimulation is limited to edges of source area in upper water bearing unit.	Although response action reduces soil contamination, residual soil contamination would remain beneath structure, and the soil cleanup criteria would be based on diminishing returns for SVE treatment. Although biostimulation does not address the center of the groundwater plume, biostimulants would be placed in the accessible cross-gradient edge of the plume. Chlorinated VOC bioattenuation daughter products would remain above cleanup levels in upper water bearing unit.	Environmental covenant would require compliance monitoring. Compliance monitoring points could be defined in downgradient wells in lower water bearing unit.	Retained

Table C.1 - Evaluation of Cleanup Alternatives for Threshold Criteria

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

Cleanup Alternatives	Protection of Human Health and the Environment	Compliance with Cleanup Standards and Applicable Laws	Provision for Compliance Monitoring	Conclusions
Alternative A5 Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and In-Situ Chemical Oxidation	Removes the indoor air exposure pathway to the existing building. Removes source contamination to 15 feet bgs beneath building and alley using sheet pile shoring, reducing soil vapor emissions and leaching potential to groundwater. Hydraulic cap allows passive ventilation of soil vapor and prevents infiltration of surface water to decrease the leaching of soil contamination to groundwater. ISCO would destroy contamination in soil beneath the practical extent of excavation and in groundwater in the upper water bearing unit. Sequential ISCO treatments would be performed to address contaminant rebound.	Removes soil contamination to 15 feet bgs by excavation using sheet pile shoring. Hydraulic cap prevents infiltration of surface water, allowing the calculation of higher cleanup levels for soil. ISCO destroys accessible contamination beneath excavation area by in-situ mixing and leaching and in unsaturated and saturated intervals of advance outwash by direct injection. Second ISCO application performed to oxidize rebounded contamination after dissolution, desorption, and leaching. Concentrations of metal increase before attenuating to background levels. Oxidation interferes with natural attenuation process in the upper water bearing unit and potentially in interglacial deposits, but groundwater will eventually recover to background conditions.	Environmental covenant would require compliance monitoring. Compliance monitoring points could be defined in downgradient wells in lower water bearing unit. Performance monitoring would be done to evaluate effectiveness and permanence of response actions. Performance monitoring would be done to evaluate effectiveness and permanence of response actions.	Retained

Table C.2 - Evaluation of Cleanup Alternatives for Permance Criteria and Disproportionate Cost Analysis

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

Perrmance Criteria (Weighting Factor)	**Alternative A2** Engineering and Institutional Controls	**Alternative A3** Soil Vapor Extraction and Engineering and Institutional Controls	**Alternative A4** Soil Vapor Extraction, Biostimulation, and Engineering and Institutional Controls	**Alternative A5** Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and In-Situ Chemical Oxidation
Protectiveness (30%)	(1) Restricts exposure to impacted media and mitigates exposure through indoor air.	(3) Restricts exposure to impacted media and mitigates exposure through indoor air. Reduces accessible soil contamination, protecting indoor air and groundwater leaching exposure pathways.	(4) Restricts exposure to impacted media and mitigates exposure through indoor air. Reduces accessible soil contamination, protecting indoor air and groundwater leaching exposure pathways. Decreases contamination in upper water bearing unit on the edge of source area.	(5) Eliminates onsite indoor air exposure pathway and reduces soil vapors to offsite property. Removes soil contamination to 15 feet bgs directly beneath sources by excavation using sheet pile shoring. Oxidizes chlorinated VOCs from glacial till through in-situ mixing and leaching. Significantly reduces surface water infiltration through residual soil contamination. Treats entire groundwater source area in upper water bearing unit. Oxidizes all chlorinated VOC compounds in advance outwash. Second ISCO application performed to treat additional dissolving, desorbing, and leaching sources. Does not complement natural attenuation processes observed in interglacial till.
Permanence (20%)	(1) Permanent institutional controls only. Effectiveness of engineering controls for indoor air would deteriorate.	(2) Removes accessible soil contamination, but limited by radius of influence and diminishing returns of treatment. Does not address groundwater contamination.	(4) Removes accessible soil contamination, but limited by radius of influence and diminishing returns of treatment. Provides significant contaminant reduction in upper water bearing unit along edge of plume, and does not inhibit natural bioattenuation processes.	(5) Removes soil contamination to 15 feet bgs by using shoring to protect adjacent structures. ISCO destroys additional soil contamination beneath excavation by in-situ mixing and leaching. ISCO permanently destroys chlorinated VOC contamination in upper water bearing unit, but sequential application needed to treat rebounded contamination.
Long-Term Effectiveness (20%)	(1) Permanent institutional controls only. Effectiveness of engineering controls for indoor air would deteriorate.	(2) Soil vapor concentrations will partially rebound, but the mass of contamination in soil is permanently removed by SVE. Does not address groundwater contamination.	(3) Soil vapor concentrations will partially rebound, but the mass of contamination in soil is permanently removed by SVE. Biostimulation permanently reduces PCE and TCE, but may lead to build-up of cDCE and vinyl chloride daughter products. Biostimulation does no harm to natural bioattenuation processes.	(4) Permanently removes soil to 15 feet bgs directly beneath source area using sheet pile shoring. Destroys additional soil contamination by ISCO treatment through in-situ mixing and leaching. Treatment of groundwater source area much more effective with the removal of building. ISCO destroys all chlorinated VOC compounds, but additional treatment needed to treat remaining contamination. ISCO would inhibit subsequent natural attenuation of non-accessible contamination in the interglacial deposits.
Short-Term Risk Management (10%)	(5) Minimal short-term risk associated with installation of engineering controls.	(5) Minimal short-term risk associated with installation and operation of of engineering controls and SVE system.	(5) Minimal short-term risk associated with installation and operation of of engineering controls and SVE system and injection of non-toxic biostimulation reagents.	(4) Higher short-term risk to workers and public of exposure to contaminants during building demolition and soil excavation and off-Site transport. Handling and injection of highly reactive permangenate presents additoianl short-term risks.
Implementability (10%)	(5) Engineering controls for vapor intrusion are limited on adjacent property.	(4) Engineering controls for vapor intrusion are limited on adjacent property. Horizontal wells needed to access contamination, and radius of influence may be limited.	(4) Engineering controls for vapor intrusion are limited on adjacent property. Horizontal wells needed to access contamination, and radius of influence may be limited. Injection permit needed for biostimulation.	(4) Excavation limited by adjacent building, street, and utilities. Excavation performed using sheet pile shoring installed as close to adjacent building and street as possible given property lines and utilities, and performed to extent practicable using backhoe. In-situ mixing of ISCO may be limited in glacial till. In-situ mixing is also limited by maximum moisture content for compaction. Flexible membrane liner and vertical groundwater treatment wells are readily implemented. Injection permit needed for ISCO.
Public Concerns (10%)	(3) Limited response and need to maintain soil vapor barriers have negative perception.	(4) SVE will create noise nuissance for approximately 6 months, creating business interference for neighboring businesses. Need to maintain soil vapor barriers has negative perception.	(4) SVE will create noise nuissance for approximately 6 months, creating business interference for neighboring businesses. Need to maintain soil vapor barriers has negative perception. Limited concern for biostimulation.	(3) More intrusive demolition and excavation activities expected to be of concern to commercial and retail neighbors. Building demolition would displace long-term commercial tenants.
Environmental Benefit[(2)]	2.0	3.0	3.9	4.4
Present Value Cost[(3)]	$245,000	$445,000	$545,000	$1,200,000

Notes:

1) A numeric scale of 1 to 5 is used to rate the alternatives with respect to the criteria to evaluate use of permanent solutions to the maximum extent practicable, as follows:

1 - meets criterion to a very low degree

2 - meets criterion to a low degree

3 - meets criterion to a moderate degree

4 - meets criterion to a high degree

5 - meets criterion to a very high degree

2) The environmental benefit is calculated as the sum of the products of the weighting factor and numerical ranking for each criterion.

3) Present value costs are based on 2013 dollars and are calculated using a discount factor of 3 percent, and estimates are rounded to the nearest $1,000.

Itemized estimates are provided in Appendix B.

Table C.3 - Evaluation of Cleanup Alternatives for Reasonable Restoration Time Frame

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	Current Use Scenarios			
Reasonable Restoration Time Frame Criteria	**Alternative A2** Engineering and Institutional Controls	**Alternative A3** Soil Vapor Extraction and Engineering and Institutional Controls	**Alternative A4** Soil Vapor Extraction, Biostimulation, and Engineering and Institutional Controls	**Alternative A5** Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and In-Situ Chemical Oxidation
Potential Risk	Mitigates indoor air exposure risk and restricts access to contaminated media. Does not address leaching or migration of groundwater contamination.	Mitigates indoor air and leaching exposure risks and restricts access to contaminated media. Does not address migration of groundwater contamination.	Mitigates indoor air, leaching, and groundwater migration exposure risks and restricts access to contaminated media.	Eliminates onsite indoor air exposure and controls offsite vapor migration. Excavation removes direct contact exposure risk and engineering controls restrict leaching to groundwater exposure risks. Institutional controls restrict groundwater use, and sequential ISCO treatment reduces contamination in groundwater.
Practicality of Achieving Shorter Time Frame	No restoration performed.	SVE implemented within six months and performed until diminished treatment effectiveness. Source area contamination not addressed.	SVE implemented within six months and performed until diminished treatment effectiveness. Groundwater treatment does not address main source of contamination. Biostimulation follows SVE response and uses SVE wells. Biostimulation remains effective for several years and complements natural attenuation processes. Bioattenuation daughter products, including cDCE and vinyl chloride, will likely exceed cleanup levels after treatment.	Excavation and capping performed within construction schedule. ISCO performed in source area initially within redevelopment construction schedule. Second ISCO application in source area performed 2 to 3 years later to address rebound after attenuation of permanganate. ISCO temporarily increases concentrations of metals due to low pH and high ORP, but metal concentrations will attenuate as the groundwater recovers.
Impact to Current Use	Business disturbance to implement indoor air controls.	Business disturbance to implement indoor air controls. SVE causes business disturbance during drilling, construction, and operation.	Business disturbance to implement indoor air controls. SVE causes business disturbance during drilling, construction, and operation.	Eliminates current commercial use of existing building.
Impact to Future Use	Environmental covenant restricts future use. Engineering controls for indoor air must be maintained.	Environmental covenant restricts future use. The need of indoor air engineering controls could be re-evaluated.	Environmental covenant restricts future use. The need of indoor air engineering controls could be re-evaluated.	Environmental covenant restricts future use. Hydraulic cap would be maintained. Sequential ISCO treatment performed to reduce all chlorinated VOC compounds to below cleanup levels in upper water bearing unit.
Availability of Alternate Water Supplies	No impact. Properties connected to public water supply.	No impact. Properties connected to public water supply.	No impact. Properties connected to public water supply.	No impact. Properties connected to public water supply.
Likely Effectiveness and Reliability of Institutional Controls	Restricts access, but does not mitigate contaminant migration.	Restricts access, but does not mitigate contaminant migration.	Restricts access and reduces need for restrictions.	Restricts access and reduces need for restrictions. Institutional controls not needed to eliminate the soil direct contact exposure pathway.
Ability to Control and Monitor Contaminant Migration	Soil vapor intrusion is mitigated by engineered controls and groundwater contamination is monitored pursuant to institutional controls.	Soil vapor intrusion is mitigated by engineered controls and groundwater contamination is monitored pursuant to institutional controls.	Soil vapor intrusion is mitigated by engineered controls and groundwater contamination is monitored pursuant to institutional controls. Performance sampling conducted for biostimulation to evaluate effectiveness and permanence.	Onsite soil vapor intrusion exposure pathway eliminated, and source reduction and passive ventilation to reduce potential offsite soil vapor migration. Groundwater contamination is monitored pursuant to institutional controls. Performance sampling conducted for ISCO response action to evaluate effectiveness and permanence.
Toxicity of Contamination	Controls exposure. Does not reduce the concentration or toxicity of contamination.	Controls exposure and reduces total contamination. Does not change toxicity of contamination.	Controls exposure and reduces total contamination. Biostimulation would increase concentrations of vinyl chloride, which has higher toxicity than PCE.	Controls exposure and reduces total contamination. ISCO temporarily increases concentrations of metals. The oxidation of chromium increases its toxicity and mobility, but the concentrations will attenuate as the oxidation-reduction potential in groundwater recovers.
Potential for Contaminant Degradation Over Time	Bioattenuation is observed in groundwater, and Olympia Bed interglacial deposits provide an attenuation barrier above the lower water bearing units.	Reduces source contamination that leaches to groundwater. Bioattenuation is observed in groundwater, and Olympia Bed interglacial deposits provide an attenuation barrier above the lower water bearing units.	Reduces source contamination that leaches to groundwater. Biostimulation is limited to edge of source area in upper water bearing unit. Biostimulation would significantly increase the natural bioattenuation observed in groundwater, and complement natural attenuation processes. Olympia Bed interglacial deposits provide an attenuation barrier above the lower water bearing units.	Reduces and controls source contamination that leaches to groundwater. ISCO performed over entire groundwater source area in upper water bearing unit. ISCO oxidizes all chlorinated VOC compounds, but inhibits the observed natural bioattenuation processes. Olympia Bed interglacial deposits provide an attenuation barrier above the lower water bearing units, however, the attenuation potential may be temporarily reduced by ISCO treatment in the overlying advance outwash.

Table C.3 - Evaluation of Cleanup Alternatives for Reasonable Restoration Time Frame

Morrell's Dry Cleaners (VCP Site SW1039) Focused Feasibility Study

	Current Use Scenarios			
Reasonable Restoration Time Frame Criteria	**Alternative A2** Engineering and Institutional Controls	**Alternative A3** Soil Vapor Extraction and Engineering and Institutional Controls	**Alternative A4** Soil Vapor Extraction, Biostimulation, and Engineering and Institutional Controls	**Alternative A5** Building Demolition, Excavation with Shoring, Capping, Institutional Controls, and In-Situ Chemical Oxidation
Conclusions	Controls established, including engineering controls that diminish with time. Natural attenuation processes are slow and limited. Institutional controls restrict soil direct contact and groundwater ingestion exposure risks.	Controls indoor air exposure and performs short-term response to mitigate indoor air and leaching exposure risks. Bioattenuation is limited, but Olympia Bed interglacial deposits may effectively limit offsite migration. Institutional controls restrict soil direct contact and groundwater ingestion exposure risks.	Controls indoor air exposure and performs short-term response to mitigate indoor air and leaching exposure risks. Biostimulation would be perform on edge of source area and significantly enhance natural bioattenuation, which increases likelihood that Olympia Bed interglacial deposits effectively limit offsite migration. Institutional controls restrict soil direct contact and groundwater ingestion exposure risks.	Removal of the building eliminates the onsite soil vapor exposure risk. Excavation and passive ventilation reduce potential offsite soil vapor migration. Excavation with shoring eliminates soil direct contact exposure pathway. Hydraulic cap significantly reduces leaching-to-groundwater exposure risk. ISCO would treat residual soil contamination through in-situ mixing and leaching. ISCO would treat all chlorinated VOC compounds in the unsaturated and saturated intervals of the advance outwash. Sequential ISCO would be performed to treat residual dissolving, desorbing, and leaching contamination. ISCO adversely impacts natural bioattenuation in the upper water bearing unit for many years, and may reduce the natural bioattenuation potential of the underlying interglacial deposits. ISCO responses unlikely to impact natural bioattenuation in the lower water bearing units. Institutional controls restrict groundwater ingestion exposure risks.