MEMORANDUM

To:	Ching Pi Wang, Washington Dept. of Ecology	**Date:**	March 31, 2010
From:	Clay Patmont, Anchor QEA and Jeremy Porter, Aspect Consulting		
cc:	Robert Cugini, Barbee Mill Company. and Lynn Manolopoulos, Davis Wright Tremaine		
Re:	Barbee Sediment Data Gaps Evaluation		

This memorandum evaluates whether there are remaining data gaps that need to be filled to complete sediment characterization at the former Barbee Mill Site in Renton, Washington. Consistent with the requirements of Model Toxics Control Act (MTCA) Agreed Order (AO) No. DE 5396 between the Washington Department of Ecology (Ecology) and the Barbee Mill Company, this memorandum evaluates whether additional investigations are needed to delineate the extent of arsenic in sediment offshore from the northern half of the former Barbee Mill property (currently Conner Homes at Barbee Mill, LLC property) and the southwestern corner of the adjoining Quendall Terminals property). This memorandum includes the following:

- Summary of arsenic occurrences in groundwater, porewater, and sediment at the Barbee Mill Site;
- Conceptual site model of transport and attenuation pathways that may affect arsenic releases into Lake Washington sediments, building on detailed groundwater-surface water transport investigations performed at the Quendall Terminals property; and
- Identification of any remaining data gaps (if any) needed to complete the remedial investigation/feasibility study (RI/FS) of the Barbee Mill Site.

Arsenic Occurrences in Groundwater, Porewater, and Sediment

Arsenic concentrations in upland groundwater, offshore groundwater (at sediment well points typically screened 2 to 4 feet below mudline), and sediment porewater (collected at a depth of 0 to 10 centimeters [cm] below mudline) have been monitored prior to and after implementation of upland remedial actions at the Site. Groundwater and porewater data collected at the Site are summarized in Appendix A. Groundwater and porewater sampling performed during the design investigation for the passive attenuation zone (PAZ; Aspect 2006) delineated the lateral and vertical extent of arsenic in groundwater exceeding the 20 µg/L site-specific groundwater cleanup level. Exceedances of the groundwater cleanup level along the shoreline extended from boring AZ-16 on the former Barbee Mill property, north to AZ-8 on the Quendall Terminals property (sampling locations and data are provided in Appendix A). Arsenic concentrations exceeding the groundwater cleanup level were detected up to 21 feet below ground surface (bgs) along the western property boundary. To intercept the groundwater arsenic plume, the PAZ was installed along the downgradient boundary of the former Barbee Mill property to a maximum depth of 22 feet bgs.

Groundwater and porewater monitoring continues in accordance with the Ecology-approved Performance Monitoring Plan (Aspect 2010). Data collected at performance monitoring locations both before and after the installation of the PAZ are summarized in Table 1; data from the most recent sampling event (December 2009) are depicted on Figure 1. Based on these data, the effectiveness of the remedial actions in reducing groundwater and porewater arsenic concentrations is summarized in the sections below.

Upland Groundwater. Arsenic concentrations in shallow groundwater downgradient of the PAZ at wells CMW-2 through CMW-5 have declined 95 to 99 percent since the PAZ was installed (Table 1). Arsenic concentrations in deep groundwater, at wells CMW-2D and CMW-4D, have declined 50 to 65 percent following installation of the PAZ.

Concentrations of arsenic in groundwater at the south and east ends of the PAZ (39 µg/L at CMW-1 and 220 µg/L at CMW-6) are currently above the cleanup level of 20 µg/L. However, arsenic concentrations in these areas are anticipated to decrease in the future in response to remedial actions performed in upgradient areas (i.e., the 2005 soil removal and the on-going pump-and-treat system). In accordance with the AO, an updated evaluation of PAZ performance, including an updated evaluation of groundwater restoration time frames, will be performed later in 2010.

Additional data delineating the extent of arsenic in groundwater on the Quendall Terminals property have recently been collected as part of Quendall Terminals RI; these data are included in Table 1 and on Figure 1. Relevant data was collected at three well pairs: BH-21A/B, BH-26 A/B, and BH-29A/B. Each well pair includes a screen in the shallow interval (approximately 10 to 20 feet bgs) and a screen in the underlying deep aquifer interval (approximately 40 to 50 feet bgs). Arsenic was detected above the 20 µg/L groundwater cleanup level at well BH-29A, which is located within the historic Barbee arsenic plume and downgradient of the PAZ. Arsenic was not detected above the cleanup level in the deeper well screen at this location (BH-29B), corroborating the limited vertical extent of arsenic observed during the earlier design investigation (Aspect 2006). The lateral extent of arsenic exceeding the 20 µg/L cleanup level in shallow groundwater on the Quendall Terminals property is bounded by well BH-26A to the east and BH-21A to the north.

During the Quendall Terminals RI, slightly elevated concentrations of arsenic were detected at the deep interval at Quendall Terminals wells BH-21B and BH-26B. These data are consistent with arsenic concentrations observed in deep groundwater elsewhere on the Quendall Terminals property and, based on the lateral and vertical delineation of arsenic in groundwater on Barbee Mill, do not appear associated with anthropogenic releases at the Barbee Mill Site. Elevated arsenic concentrations detected in these areas are likely naturally occurring, resulting from geochemically reducing conditions at the Site. That is, when reducing conditions occur in groundwater as a result of organic enrichment (e.g., due to wood waste and/or hydrocarbon releases), the more mobile forms of arsenic (As[III]) predominate, and ferric iron, which limits the mobility of arsenic by sorption, reduces to the more soluble and mobile ferrous iron. Therefore, reducing geochemical conditions in groundwater increases the mobility of arsenic, which results in increased concentrations of arsenic in groundwater.

Offshore Groundwater. Offshore, arsenic concentrations at well point WP-1A have declined approximately 95 percent since the PAZ was installed (from 2,400 to 110 µg/L; see Table 1). Although no data were collected at well point WP-8 prior to PAZ installation, arsenic concentrations at WP-8 have declined from 680 to 450 µg/L (35 percent) since this well point was installed in January 2009. This well point is located further away from the PAZ than WP-1A, and is therefore expected to exhibit slower decreases due to treatment by the PAZ.

Arsenic Occurrences in Sediment Porewater. Porewater was sampled at a depth of 10 cm below mudline both in the sediment offshore of the Barbee Mill property as well as offshore of the Quendall Terminals property. Porewater sampling has been performed quarterly at two locations offshore of the Barbee Mill property (PW-CMW-2 and PW-CMW-3) and one location on the Quendall Terminals property (PW-CMW-4). In June 2009, porewater samples were collected at three additional locations offshore of t the Quendall Terminals property, at stations WD01, WD02, and NS-01. Arsenic concentrations in surface sediment porewater at these six stations since installation of the PAZ have ranged from non-detect to a maximum of 17 μg/L, below the groundwater cleanup level of 20 μg/L. These concentrations are also well below the surface water quality standard for dissolved arsenic based on aquatic life chronic toxicity of 190 μg/L (WAC 173-201A-240). In the area of historically highest porewater concentrations, at station PW-CMW-4, concentrations have declined from 1,400 to 2.2 μg/L since the PAZ was installed. This station is located adjacent to well point WP-1A, which has shown similar decreases (described above).

Arsenic Occurrences in Sediment. Surface sediment (0 to 10 cm) samples were collected in the northern half of the Barbee Mill Site as part of the initial site investigation by Retec in 1997 (VB4 and VB8), and surface sediment samples were collected in the southwestern corner of the adjoining Quendall Terminals property during the Quendall Terminals RI in 2009 (WD-01-SS, WD01, WD02, and NS01). Data are summarized in Figure 1. Sampling locations WD-01 and WD-01-SS were located within the nearshore groundwater discharge zone of the Barbee Mill arsenic plume, close to the area of historically highest porewater concentrations. The highest surface sediment arsenic concentration detected in this area was 16 milligrams per kilogram (mg/kg; dry weight basis), below both the 31 mg/kg lowest apparent effects threshold (LAET) and the 20 mg/kg floating percentile values developed by Ecology (2003) for screening freshwater sediment quality data. Bioassays were also performed on surface sediment collected from nearshore stations NS-01, NS-02 and WD-01 in December 2009 (see Figure 1). These samples did not exhibit any statistically significant differences in *Hyalella* or *Chironomus* survival or growth relative to appropriately matched reference samples, further confirming that there are no impacts to benthic macroinvertebrates in this area.

Summary. The groundwater data indicate that arsenic concentrations in groundwater leaving the former Barbee Mill property are declining due to completed remedial actions at the Site. Groundwater concentrations at the edges of the PAZ are currently elevated but are expected to decline; monitoring of the performance of the PAZ and the pump-and-treat system is ongoing.

The available site characterization data support the following conceptual site model:

- There is significant attenuation of arsenic concentrations along the groundwater-to-surface water discharge pathway. Concentrations of arsenic at closely located well point and porewater stations indicate substantial reductions in concentrations along the flowpath (e.g., from 110 μg/L at WP-1A [screened 2 to 4 feet below mudline] to 2.3 μg/L at PW-CMW-4 [located 10 cm below mudline]). Similar attenuation of arsenic concentrations was observed in well point/porewater data pairs collected during the design investigation and pilot test of the PAZ (Aspect 2006). Arsenic concentrations in nearshore porewater are below both the site-specific groundwater cleanup level and the surface water quality standard.

- There has also not been a significant accumulation of arsenic in sediments at the point of discharge within the plume. The maximum detected concentration in sediment was 16 mg/kg, which is below applicable sediment criteria. Confirmatory bioassay testing further verified the absence of impacts to benthic macroinvertebrates in this area.

To further confirm these empirical observations, sediment fate-and-transport modeling was performed. This modeling is described in the section below.

Conceptual Site Model of Transport and Attenuation Pathways

For the PAZ design, a three-dimensional groundwater flow model was constructed to further evaluate groundwater hydraulics and arsenic fate-and-transport, complementing the site characterization data summarized above. Model results were summarized in the Engineering Design Report (Aspect 2006). This model was subsequently applied to the adjacent Quendall Terminals Site for the Quendall RI (Anchor QEA and Aspect 2010), which also included a 1-dimensional analytical model to evaluate chemical fate-and-transport through sediment. Given the close similarities in groundwater flow and sediment characteristics between the Barbee and Quendall Sites, many of the fate-and-transport processes characterized at the Quendall Terminals Site also apply to the Barbee Mill arsenic plume. A description of the groundwater and sediment models and results is provided below.

The shallow groundwater flowpath through the northern portion of the former Barbee Mill property and the southern portion of the Quendall Terminals property is predominantly horizontal. Groundwater containing arsenic concentrations above the 20 μg/L cleanup level flow though this shallow zone and discharge to Lake Washington along upward flowpaths (i.e., vertical seepage through the lake bed). Groundwater modeling performed for the PAZ design (Aspect 2006) predicted that the arsenic plume enters Lake Washington within 100 feet of the shoreline, with the highest concentrations located adjacent to the shore. Groundwater flowpaths and velocities are also very similar between the former Barbee Mill property and the adjacent Quendall Terminals property, and the groundwater model developed for the Quendall Terminals RI (Anchor and Aspect 2010) corroborates the earlier predictions. Based on available groundwater modeling and empirical measurements, the estimated seepage rate at both properties is approximately 0.44 cm/day with a standard error of ± 0.27 cm/day (160 ± 97 cm/year; see Appendix B summary of seepage data collected in the Site vicinity).

As discussed above, the Site-specific groundwater cleanup level for arsenic at Barbee Mill is 20 μg/L. The surface water quality standard for dissolved arsenic based on aquatic life chronic toxicity is considerably higher at 190 μg/L (WAC 173-201A-240). While shallow groundwater arsenic concentrations at the Barbee Mill Site (including shoreline well point data) are declining rapidly (Table 1), maximum near-term (i.e., transient) groundwater concentrations of up to 1,200 μg/L may continue to flow toward Lake Washington in localized areas until the PAZ successfully attenuates the arsenic plume. In order to evaluate whether additional data may be needed to characterize these transient releases, further evaluation of the groundwater-to-surface water transport pathway was performed and is presented below.

For the Quendall Terminals RI, a combination of detailed sampling and analysis and application of a peer-reviewed 1-dimensional contaminant transport model was used to characterize physical mixing processes occurring within 4 feet of the lake bed and refine the conceptual site model of nearshore groundwater discharge into Lake Washington. Detailed concentration profiles of cations (sodium, potassium, calcium, and magnesium) were measured in the nearshore zone at the Quendall Terminals property to quantify the combined effects of diffusion/ dispersion, bioturbation/bioirrigation, and exchange with the overlying surface water (see Appendix B summary of cation profiles). The framework used to evaluate these cation data and to refine the conceptual site model of arsenic transport and attenuation at the Barbee Mill Site was the 1-dimensional steady state model developed by the University of Texas (UT) and widely used at other sediment cleanup sites (Lampert and Reible 2009). The UT model simulates chemical (dissolved and sorbed phase) fate and transport under the processes of advection, diffusion/dispersion, bioturbation/bioirrigation, and exchange with the overlying surface water.

The UT model works under the assumption that the overlying surface water contaminant concentrations are negligible. While this assumption is reasonable for arsenic (lake water concentrations average roughly 0.75 μg/L based on King County data collected at Lake Washington station #831 from 2006 to 2008; n=11), the cation data exhibit non-zero concentrations in surface water. In order to appropriately evaluate the cation data profiles given their non-zero concentrations in the surface water, concentrations measured within the porewater were normalized by first subtracting the surface water concentration from the porewater cation data, and then by dividing them by the maximum cation concentration collected from the 4-foot depth within each profile.

The UT model coefficients were developed based on site-specific data or literature values. For example, the range of net sedimentation rates measured at the Quendall Terminals property of 0.2 to 0.7 cm/yr was input into the model. Coefficients that were expected to exhibit little variability or those to which the model is relatively insensitive were treated as fixed values. The model was then calibrated to the cation porewater data by adjusting the two key site-specific coefficients—the boundary layer mass transfer coefficient and dispersivity—so that the predictions closely matched the measured vertical profiles of cation concentrations. This calibration was performed separately for the seepage and sedimentation rate ranges (± 1 standard error) noted above (see Appendix B). The calibration to the cation dataset resulted in estimates of the boundary layer mass transfer coefficient in the range of 1 to 5 cm/day, within the literature range. The calibration also resulted in a range of dispersivity coefficients from 12 to 30 cm; this range is towards the upper end of the modeled domain length that is often used as a rule-of-thumb in groundwater models. However, this calibrated dispersivity value range represents the combined effects of several mixing-like processes in the sediment bed, including dispersion associated with groundwater flow, bioturbation, and hyporheic exchange. Based on the correspondence of these data, the calibrated UT model provides a reliable basis to assess transport and attenuation processes along the groundwater-to-surface water pathway at the Barbee Mill Site.

Based on this calibration range developed from the cation data, the model was then used to simulate arsenic transport at the Barbee Mill Site. The only model inputs that changed when it was used to calculate arsenic concentrations were the chemical-specific coefficients for arsenic (diffusivity in water and partition coefficient (K_d). Based on co-located analyses of surface sediment arsenic and porewater arsenic concentration at the Barbee Mill Site, the average Log-K_d of 3.6 was applied to the model (this value is also within the middle of the range of literature values of sediment arsenic K_d).

Even under worst-case maximum transient groundwater arsenic concentrations of up to 1,200 μg/L and under the range of site-specific seepage rates, sedimentation rates, boundary layer mass transfer coefficients and dispersivity values summarized above, the maximum surface sediment (0 to 10 cm average) porewater concentrations predicted by the UT model are less than 5 μg/L, well below the surface water quality standard for dissolved arsenic based on aquatic life chronic toxicity of 190 μg/L (WAC 173-201A-240). The available surface sediment porewater data collected at the Barbee Mill Site are consistent with this prediction, and corroborate the model results (Figure 1). The conceptual site model summarized above reveals that groundwater arsenic concentrations attenuate to levels well below the surface water quality standard prior to discharge into Lake Washington.

As described above, the highest surface sediment arsenic concentration detected in the nearshore groundwater discharge zone of the Barbee Mill arsenic plume is 16 mg/kg, below both the 31 mg/kg lowest LAET and the 20 mg/kg floating percentile values developed by Ecology (2003) for screening freshwater sediment quality data. Similarly, the UT model predicts maximum surface sediment arsenic concentrations of less than 20 mg/kg, even under worst-case maximum transient groundwater arsenic concentrations of up to 1,200 μg/L and under the range of site-specific seepage rates, sedimentation rates, boundary layer mass transfer coefficients and dispersivity values summarized above. Similar to the conceptual site model for groundwater-to-surface water transport summarized above, surface sediment arsenic concentrations are currently attenuated to levels below freshwater sediment screening values.

Remaining Data Gaps

Based on the information summarized above, no additional sediment investigations are needed to delineate the extent of arsenic in sediment offshore from the northern half of the Barbee Mill property and the southwestern corner of the adjoining Quendall Terminals property. The existing data, when supplemented with available fate and transport models, are sufficient to complete the RI/FS of the Barbee Mill Site.

However, it would be beneficial to obtain more data on the rate of groundwater restoration before performing an RI/FS for the Barbee Mill Site. As discussed above, the Ecology-approved performance monitoring plan (Aspect 2010) specifies periodic monitoring of arsenic concentrations at 16 monitoring wells located on the former Barbee Mill property, and two well points located on the Quendall Terminals property. The rate of groundwater restoration on the former Barbee Mill and Quendall Terminals properties will be re-estimated annually based on data collected under the plan. Because of the significant declines in groundwater concentrations observed to date due to completed remedial actions at the Site and their influence on sediment conditions, the Barbee Mill sediment RI/FS should be sequenced to occur after the rate of groundwater restoration has been accurately estimated, which likely will require at least two more years of performance monitoring.

References

Anchor and Aspect, 2010. Draft Remedial Investigation, Quendall Terminals Site. Prepared by Anchor QEA LLC and Aspect Consulting LLC. In preparation.

Aspect, 2006. Draft Engineering Design Report, Barbee Mill Groundwater Remediation. Prepared by Aspect Consulting LLC, August 2, 2006.

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Ecology, 2003. Development of Freshwater Sediment Quality Values for Use in Washington State. Publication Number 03-09-088. September.

Lampert, D. J. and D. Reible, 2009. An Analytical Modeling Approach for Evaluation of Capping of Contaminated Sediments. Soil and Sediment Contamination: An International Journal, 18:4, 470-488.

Attachments

Table 1 – Summary of Water Level and Chemical Data
Figure 1 – Summary of Arsenic Occurrences in Groundwater, Porewater, and Sediment
Appendix A – Historical Arsenic Concentrations in Groundwater
Appendix B – Cation Concentrations in Sediment Porewater and Lakebed Seepage Rates – Quendall Terminals

Table 1 - Summary of Water Level and Chemical Data
Barbee Mill Site

					Concentration in ug/L						Concentration in mg/L
Well	TOC Elevation	Date	Depth to Water in Feet	Groundwater Elevation in Feet	Arsenic	Zinc	Lead	Copper	TPH-D	TPH-O	Iron
		Cleanup Level/Performance Standard (See Note 2)			*20*	*32*	*2.5*	*3.5*	*0.5*	*0.5*	*70*
Performance Monitoring Wells											
CMW-1	22.75	*7/19/2006*			*31*						26
		8/30/2007	4.63	18.12	33						27
		5/5/2009	3.58	19.17	37				0.27 U	0.43 U	42
		9/8/2009	4.61	18.14	53				0.25 U	0.41 U	41
		12/23/2009	**5.36**	**17.39**	**39**				**0.26 U**	**0.41 U**	**39**
CMW-2S	22.27	*5/23/2006*			*120*						
		8/30/2007	4.32	17.95	4.1		1 U	1 U			1.4
		5/5/2009	3.28	18.99	1.7	5 U	1 U	1 U			0.63
		9/8/2009	4.52	17.75	2.1	6.3	1 U	1 U			1.9
		12/23/2009	**5.11**	**17.16**	**2.1**	**5 U**	**1 U**	**1 U**			**3.1**
CMW-2D	22.20	*7/19/2006*			*250*						
		8/30/2007	3.99	18.21	33		1 U	1 U			9.2
		4/30/2009	3.29	18.91	92	14	1 U	1 U			4.5
		9/8/2009	4.20	18.00	92	8.8	1 U	1 U			4.2
		12/23/2009	**4.81**	**17.39**	**92**	**12**	**1 U**	**1 U**			**3.4**
CMW-3	22.41	*7/19/2006*			*110*						90 (3)
		8/30/2007	3.78	18.63	1.3		1 U	1 U			2.9
		4/30/2009	2.32	20.09	1 U	5 U	1 U	1 U			0.11
		9/8/2009	4.02	18.39	1.1	5 U	1 U	1 U			0.086
		12/22/2009	**4.02**	**18.39**	**1 U**	**5 U**	**1 U**	**1 U**			**0.23**
CMW-4S	27.44	*7/19/2006*			*4300*						50
		8/30/2007	9.40	18.04	510		1 U	1 U			28
		4/30/2009	8.11	19.33	180	5 U	1 U	1 U			12
		9/8/2009	9.57	17.87	230	5 U	1 U	1 U			8
		12/22/2009	**9.82**	**17.62**	**210**	**5 U**	**1 U**	**1 U**			**17**
CMW-4D	27.92	*2/15/2007*			*3400*						13
		8/30/2007	9.51	18.41	1700		1 U	1 U			10
		4/30/2009	8.20	19.72	1400	5 U	1 U	1 U			6
		9/8/2009	9.71	18.21	420	5 U	1 U	1 U			2
		12/22/2009	**10.16**	**17.76**	**1700**	**5 U**	**1 U**	**1 U**			**9**
CMW-5	31.07	*6/23/2006*			*2900*						
		8/30/2007	12.32	18.75	22		1 U	1 U			1.8
		5/5/2009	10.87	20.20	6	5 U	1 U	1 U			1.8
		9/8/2009	12.72	18.35	7.8	5 U	1 U	1 U			0.069
		12/22/2009	**12.56**	**18.51**	**18**	**5 U**	**1.4**	**1 U**			**5.8**
CMW-6	31.03	*6/5/2006*			*23*						
		8/30/2007	11.61	19.42	110						25
		5/1/2009	9.70	21.33	210						21
		9/8/2009	12.17	18.86	210						17
		12/23/2009	**11.63**	**19.40**	**220**						**16**
WP-1A		*8/10/2005*			*2,490*						
		5/1/2009			430						20
		9/9/2009			52						7.2
		12/22/2009			**110**						**17**
WP-8		5/1/2009			680						11
		9/9/2009			490						9.5
		12/22/2009			**450**						**18**
Extraction Wells											
EW-1	26.81	6/3/2009			41				0.26 U	0.42 U	14
		9/9/2009	6.86	19.95	63				0.25 U	0.4 U	12
		12/23/2009	**10.12**	**16.69**	**110**				**0.26 U**	**0.41 U**	**22**
EW-2	26.67	6/3/2009			12				0.27 U	0.42 U	4.2
		9/9/2009	6.88	19.79	100				0.25 U	0.4 U	12
		12/23/2009	**10.71**	**15.96**	**140**				**0.26 U**	**0.41 U**	**19**
EW-3	26.77	6/3/2009			51						24
		9/9/2009	7.67	19.10	150						26
		12/23/2009	**7.11**	**19.66**	**130**						**21**
EW-4	27.65	9/9/2009	8.38	19.27	14						0.056 U
		12/23/2009	**8.37**	**19.28**	**10**						**0.056 U**
EW-5	28.34	6/3/2009			61						1.3
		9/9/2009	8.05	20.29	39						1.9
		12/23/2009	**8.98**	**19.36**	**44**						**1.6**
EW-6	28.61	6/3/2009			140						2.7
		9/9/2009	11.15	17.46	360						7.8
		12/23/2009	**9.25**	**19.36**	**230**						**2.7**
EW-7	28.66	6/3/2009			110						2.5
		9/9/2009	9.61	19.05	300						6
		12/23/2009	**9.32**	**19.34**	**350**						**7.6**
EW-8	28.88	6/3/2009			560						21
		9/9/2009	10.11	18.77	750						16
		12/23/2009	**10.36**	**18.52**	**610**						**16**
PZ-1	27.78	5/5/2009	6.59	21.19							
		9/9/2009	7.39	20.39							
		12/23/090	**7.17**	**20.61**							
PZ-2	27.87	5/5/2009	5.76	22.11							
		9/9/2009	8.17	19.70							
		12/23/2009	**7.74**	**20.13**							
Porewater Stations											
PW-CMW-2		*7/1/2006*			*1.5*						
		2/16/2007			3.1						4.9
		9/21/2007									4.8
		5/22/2009			1 U						0.056 U
		10/9/2009			17						9.8
		1/5/2010			**1.1**						**0.1**
PW-CMW-3		*7/1/2006*			*1.7*						
		3/12/2007									1.5
		5/22/2009			1 U						0.056 U
		10/9/2009			1.8						0.082
		1/5/2010			**1 U**						**0.063**
PW-CMW-4		*9/9/2005*			*1,400*						
		9/21/2007									26
		5/22/2009			2.2						0.056 U

Table 1 - Summary of Water Level and Chemical Data

Barbee Mill Site

					Concentration in ug/L						Concentration in mg/L
Well	TOC Elevation	Date	Depth to Water in Feet	Groundwater Elevation in Feet	Arsenic	Zinc	Lead	Copper	TPH-D	TPH-O	Iron
		Cleanup Level/Performance Standard (See Note 2)			*20*	*32*	*2.5*	*3.5*	*0.5*	*0.5*	*70*
		10/9/2009			2.6						0.12
		1/5/2010			**2.3**						**0.23**
NS01-C1		6/22/2009			7.4						6.67
WD01-PW		6/18/2009			5.7						3.83
WD02-PW		6/18/2009			3.2						3.11
Quendall Terminals Monitoring Wells											
BH-21A	26.16	9/9/2009	8.11	18.05	5.9						
		12/23/2009	**8.69**	**17.47**							
BH-21B	25.88	9/9/2009	6.43	19.45	109						
		12/23/2009	6.63	19.25	77/65.5 [1]						
BH-26A	28.98	9/9/2009	9.29	19.69	3.8						
		12/23/2009	**8.27**	**20.71**							
BH-26B	26.62	9/9/2009	6.88	19.74	31.8						
		12/23/2009	**6.98**	**19.64**							
BH-29A	27.64	9/9/2009	9.65	17.99	389						
		12/23/2009	**9.91**	**17.73**	400/372 [1]						
BH-29B	27.8	9/9/2009	8.59	19.21	3						
		12/23/2009	**8.80**	**19**							

Notes:

[1] Results from ICP/MS analysis and Arsenic Hydride analysis

[2] Cleanup levels and performance standards identified in Performance Monitoring Plan (Aspect, in progress) and are based as follows:

Arsenic: Cleanup level based on natural background concentration of arsenic in groundwater.

Zinc: Cleanup level based on current ARARs for fresh water, superceeding the previous cleanup level of 105 ug/L identified in Independent Remedial Action Plan (Hart Crowser 2000).

TPH: Cleanup level based on MTCA Method A cleanup level for unrestricted use.

Iron: Performance standard is for the PAZ to not significantly elevate natural concentrations, which are naturally elevated due to reducing conditions created by peat deposits in Site soils.

Copper and Lead: Performance standard for passive attenuation zone is to not result in exceedance of surface water standard listed in table.

[3] Iron concentrations in samples collected prior to the wall being installed are not compared to the performance criteria

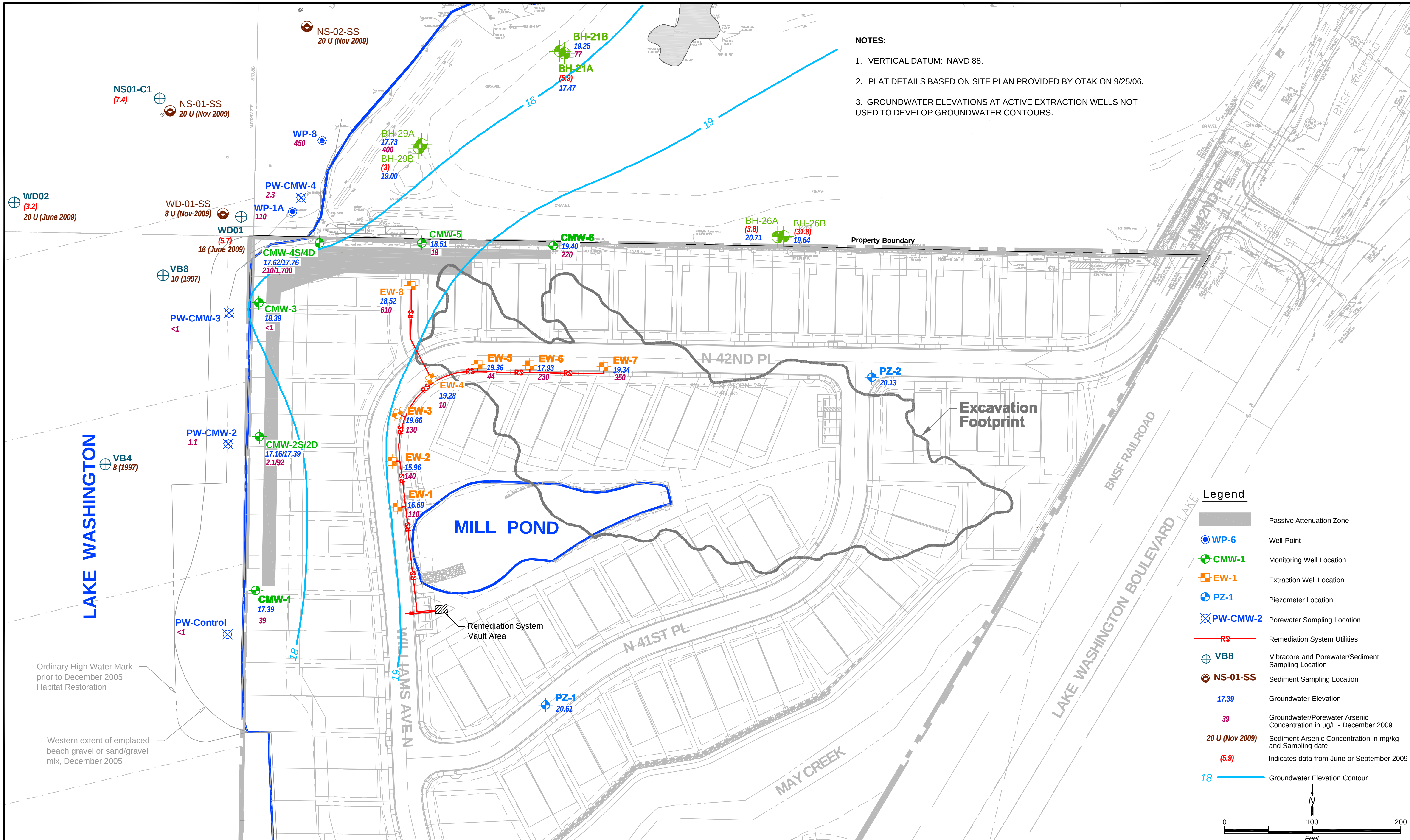
U =not detected at indicated reporting limit

bold = data collected during this reporting period

Blue italics indicates baseline sample from location closest to current sample location, as follows:

existing location	baseline location
CMW-1	AZ-16
CMW-2S	AZ-3
CMW-2D	AZ-18
CMW-3	RMW-01
CMW-4S	AZ-5
CMW-4D	HCMW-01D
CMW-5	AZ-11
CMW-6	AZ-9
WP-1A	WP-1B
PW-CMW-2	PW-M
PW-CMW-3	PW-N
PW-CMW-4	PW-WP1B

highlighted cells indicate exceedance of cleanup levels



Aspect consulting earth+water
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Summary of Arsenic Occurences in Groundwater, Porewater, and Sediment
Barbee Mill
4101 Lake Washington Blvd. North, Renton, Washington

DATE: Feb 2010	PROJECT NO. 050004
DESIGNED BY: JJP/DFR	
DRAWN BY: PMB	FIGURE NO. 1
REVISED BY: JJP (March 2010)	

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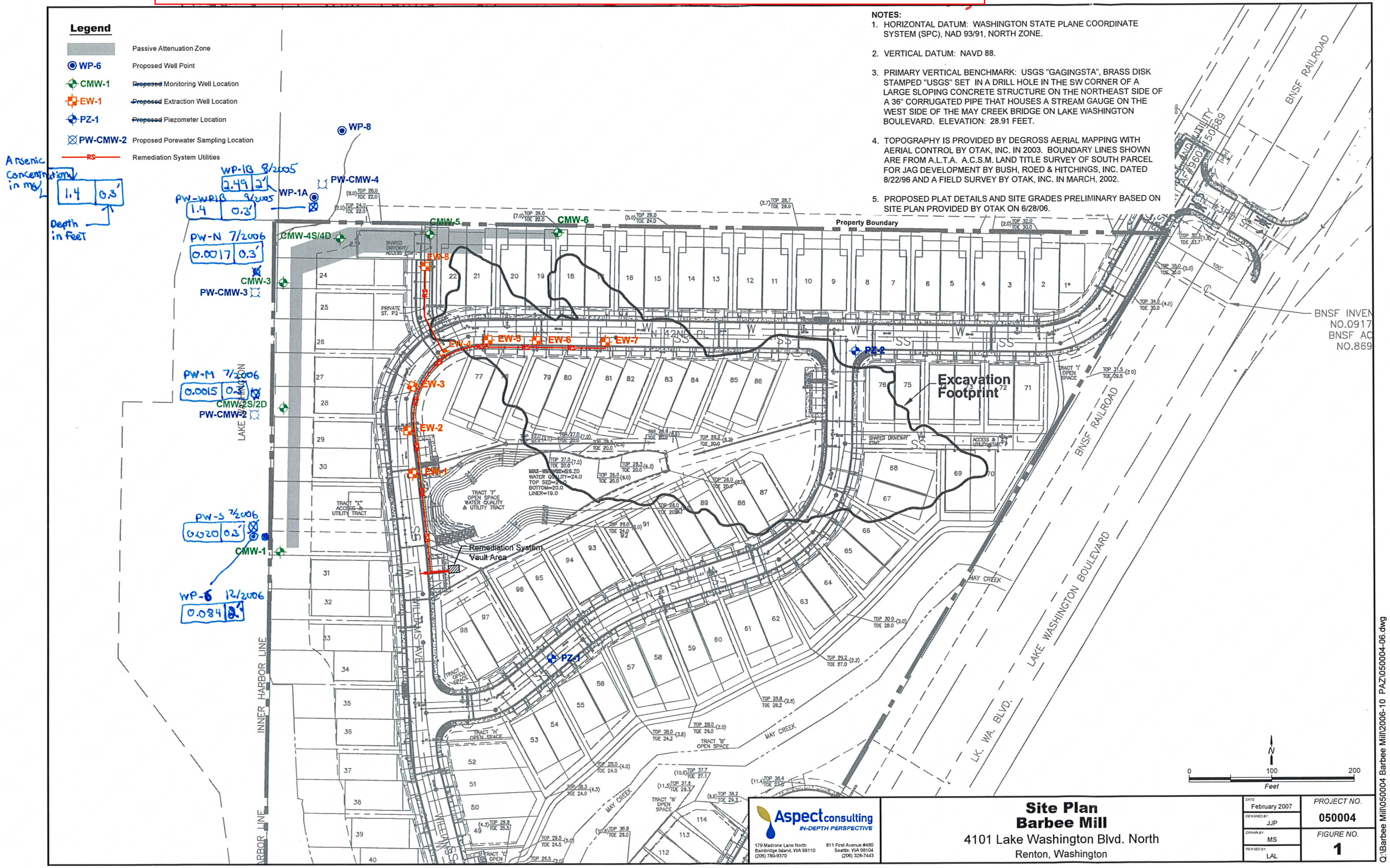
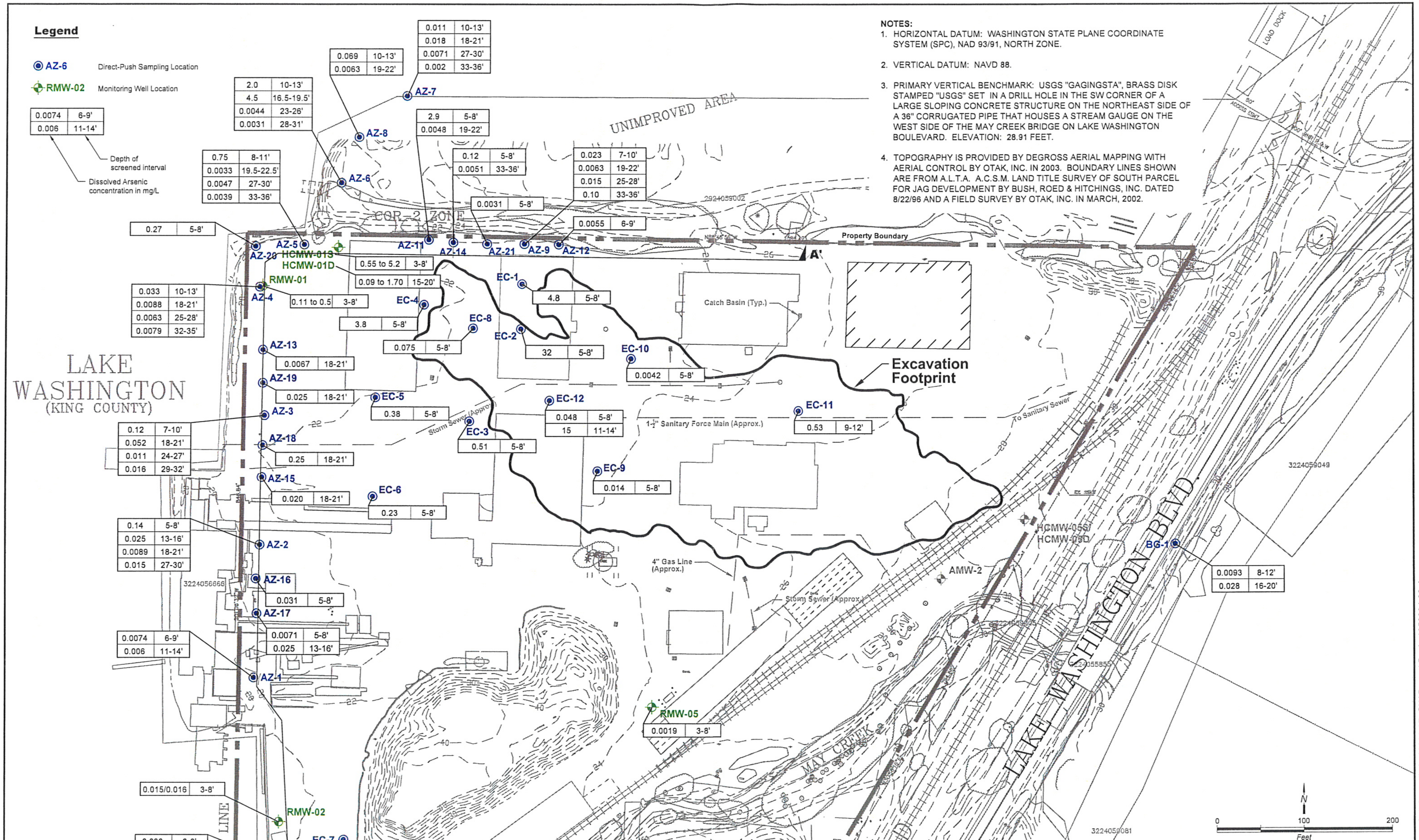
APPENDIX A

Historical Arsenic Concentrations in Groundwater

Arsenic Concentrations in Sediment Porewater and at Well Points Prior to PAZ Installation - 2005 and 2006





Distribution of Arsenic in Groundwater

2006: Prior to PAZ Installation (from Engineering Design Report, Aspect 2006)

Renton, Washington

DATE:	July 2006
DESIGNED BY:	JJP
DRAWN BY:	JRS/PMB
REVISED BY:	
PROJECT NO.	050004
FIGURE NO.	1

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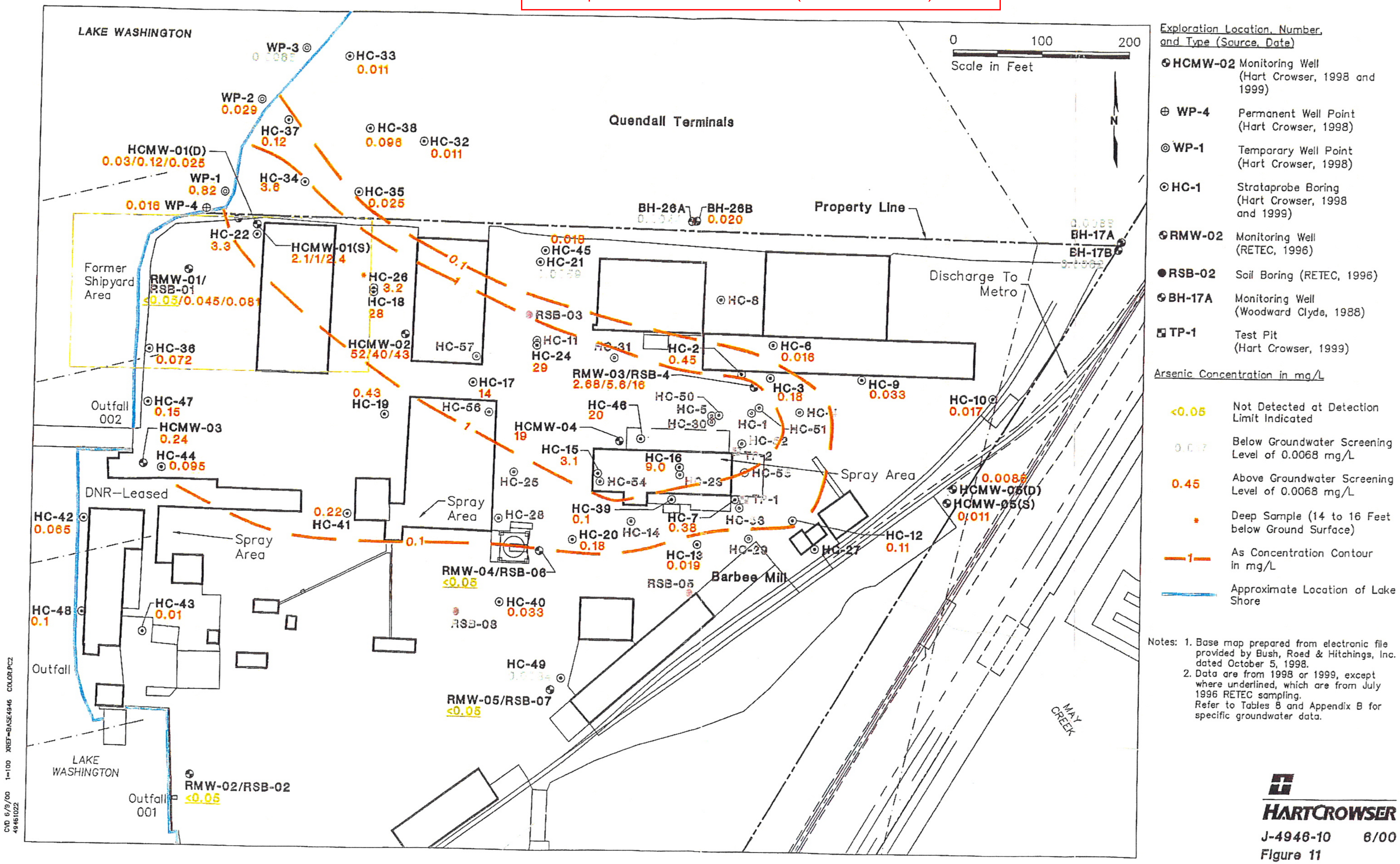
Arsenic Concentrations in Groundwater

1998 and 1999 Site Investigations, Prior to Remedial Activities. Figure from Independent Remedial Action Plan (Hart Crowser 2000).



APPENDIX B

Cation Concentrations in Sediment Porewater and Lakebed Seepage Rates – Quendall Terminals

Table 3.1-3a
Summary of Lakebed Seepage Estimates

		Sediment Type - Surface to Depth of Seepage Meter Imbedment		
Study and Method	**Location**	**Based on Closest Exploration**	**Observed in Field**	**Darcy Velocity in cm/day**
Aspect 2003				
Field-measured permeability and gradient across upper 10 to 12 inches of surface sediment at each location				
	WP-19A	No Adjacent Exploration	Silty Sand	4.88
		No Adjacent Exploration	Silty Sand	1.65
		No Adjacent Exploration	Sand	7.25
	WP-20A	Sandy Silt (VC-20A)	Silty Sand	2.44
		Sandy Silt (VC-20A)	Silty Sand	11.58
Aspect 2003				
Field-measured gradient across upper 4 to 6 feet of surface sediment at each location.				
Permeability of sand measured at other locations with similar sediment type (Aspect 2003). Permeability of silt based on calibrated groundwater model (Retec 1998)				
	WP-21A	Sand (VS-36)	Not Reported	5.49
	WP-21B	Sand (VS-36)	Not Reported	9.75
	WP-19C	Peaty Silt	Not Reported	0.21
	WP-19B	Sandy Silt	Not Reported	0.13
EPA 2009				
Bucket-and-bag seepage meters. Imbedment depth not reported. Assumed to be 1 foot or less for identifying sediment type.				
Data from May dive report (EPA, June 2009) assuming a bucket cross-sectional area of 559 cm2 (EPA, May 2009)				
	A (near VS-28)	Sandy Silt	Not Reported	0.70
				2.22
				0.10
				0.05
	B (near VS-23)	Silty Sand	Not Reported	2.99
				0.08
				0.31
	C (near VS-30)	Sand	Not Reported	0.82
				0.80
				0.21
				1.06
	D (near VS-3)	Silty Peat	Not Reported	1.73
				0.05
Minimum				0.05
Maximum				11.58
Geometric Mean				0.83

Table 3.1-3a
Summary of Lakebed Seepage Estimates (continued)

		Sediment Type - Surface to Depth of Seepage Meter Imbedment		
Study and Method	**Location**	**Based on Closest Exploration**	**Observed in Field**	**Darcy Velocity in cm/day**
Aspect 2009	Calibrated Groundwater Model - Accounts for local variation in gradients and the thickness of the shallow alluvium. Does not account for local variation in material type.			
		Darcy Velocity along Transect		
	Distance from Shore in Feet	WP-21 (south of T-Dock)	WP-20 (T-Dock)	WP-19 (North of T-Dock)
	37.5	0.76	0.66	0.46
	62.5	0.61	0.53	0.40
	87.5	0.52	0.46	0.36
	112.5	0.47	0.41	0.32
	137.5	0.49	0.37	0.30
	162.5	0.52	0.35	0.29
	187.5	0.52	0.34	0.28
	212.5	0.53	0.34	0.28
	237.5	0.66	0.35	0.28
Minimum		0.47	0.34	0.28
Maximum		0.76	0.66	0.46
Average		0.56	0.42	0.33
Average - All three transects			0.44	
Standard deviation - All three transects			0.13	

Table 3.1-3b
Summary of Lakebed Seepage Estimates

Variability of Shallow Alluvium Composition (Anchor 2009)		Percent of Core Thickness Comprised Primarily of Silt	
		Short cores less than 6 feet deep excluded	
	Location	C1	C2 (Duplicate Location)
South of T-Dock			
	NS01	3	27
	NS02	42	
	NS03	45	18
	NS04	78	60
	NS06	40	
	NS07	54	24
	NS08	55	67
	NS12	29	39
		Average (C1 and C2)	42

Table 3.1-3b
Summary of Lakebed Seepage Estimates (continued)

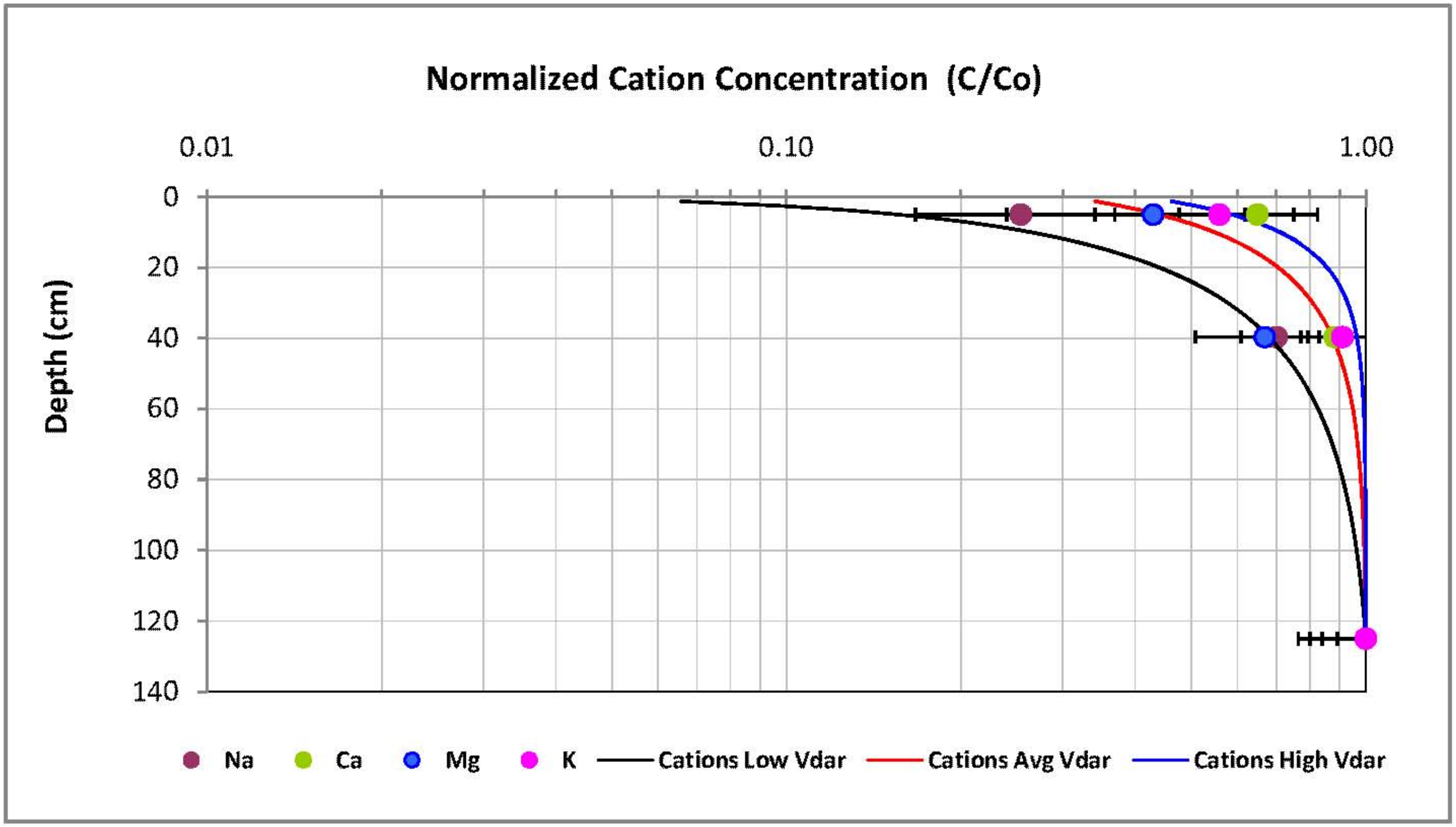
Variability of Shallow Alluvium Composition (Anchor 2009)		Percent of Core Thickness Comprised Primarily of Silt	
		Short cores less than 6 feet deep excluded	
	Location	C1	C2 (Duplicate Location)
North of T-Dock			
	NS05	91	93
	NS09	57	58
	NS10	8	
	NS11	69	
	NS13	60	
	NS14	10	
	NS15	56	
		Average (C1 and C2)	56
		Average for Nearshore Area	47
		Standard deviation in nearshore area	25

Notes:

1. No sediment core collected close to well point.

Data Sources:

Aspect 2003: Draft RA/FS (Anchor and Aspect 2004); Appendix F - Groundwater Vertical Permeability and Vertical Head Study
Anchor 2009: Sediment Core Logs - NS01 through NS15
EPA, May 2009: Interim Dive Report, May 1, 2009
EPA, April 2009: Dive Report, June 11, 2009



Notes:
Data points are normalized average porewater concentrations +/- standard error. Calibrations were performed for three Darcy velocities:
Low Vdar = 63 cm/yr, vg Vdar = 160 cm/yr, High Vdar = 257 cm/yr.

Figure 6.4-5
Cation Calibration Results
Draft Remedial Investigation
Quendall Terminals RI/FS

ANCHOR QEA