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MEMORANDUM

TO: Mark Adams, Ecology
DATE: February 25, 2008

Matthew Hickey

FROM: Matthew Hickey and James Peale
PROJECT: No. 8006.08.04

RE: Groundwater Cleanup Levels for the Protection of Surface Water and Groundwater Fate and Transport Modeling for the Former Precision Engineering Site, VCP ID Number NW 1511

Maul Foster & Alongi, Inc. (MFA) has prepared this memorandum to describe groundwater fate and transport modeling for the Precision Engineering, Inc. (Precision) site located at 1231 S Director Street in Seattle, Washington. This memorandum also addresses a request by the Washington State Department of Ecology (Ecology) to develop groundwater cleanup levels (CULs) for the protection of surface water. Because the modeling shows that indicator hazardous substances (IHSs) present at the site will not reach the Duwamish River, groundwater CULs that exceed surface-water CULs can be established consistent with WAC 173-340-720(6)(c)(i)(E).

MFA used the groundwater model to derive groundwater CULs for site IHSs that, if exceeded at the eastern property boundary, are predicted to result in exceedances of surface-water criteria at the point where groundwater discharges to the Duwamish River. The following discussion includes a description of the groundwater model used, model inputs, assumptions, and results.

Model Description

MFA performed the groundwater modeling using U.S. Environmental Protection Agency's (USEPA's) BIOCHLOR model (USEPA, 2002). BIOCHLOR is based on the Domenico analytical solute transport model and has the ability to simulate 1-D advection, 3-D dispersion, linear adsorption, and biotransformation or degradation. BIOCHLOR includes three different model types:

- Type I: Solute transport without decay
- Type II: Solute transport with biotransformation or degradation modeled as a sequential first-order decay process
- Type III: Solute transport with biotransformation or degradation modeled as a sequential first-order decay process with two different reaction zones (i.e., each zone has a different set of rate coefficient values)

All compounds were modeled using the Type I or II models Type II was used for all compounds except metals. Type I was used for metals, which do not decay. Type I and Type II were used for trichloroethene (TCE) and vinyl chloride, to accommodate a request by Ecology, as explained further below.

Model Inputs, Assumptions, and Output

The model required the following data inputs:

- Source concentrations
- Source dimensions (lateral and vertical)
- Groundwater velocity (either entered directly or calculated using gradient, hydraulic conductivity, and porosity)
- Retardation factors (either entered directly or calculated using default partition coefficients and organic carbon data for soil)
- Degradation rates based on half-life data (a half-life x factor of 2 was used for TCE and VC)
- Model domain size and duration

These parameters are summarized on Table A1 and discussed further (along with the assumptions) in the following sections. The output of the model is the concentration at a designated distance downgradient of the source.

Compounds Modeled

MFA modeled the fate and transport of the following IHSs:

- Copper
- Trivalent and hexavalent chromium
- Trichloroethene (TCE)
- Vinyl chloride

Diesel- and oil-range organics are also IHSs in site groundwater, but the chemical properties necessary to run the model are not available for diesel or oil. Instead, selected polycyclic aromatic hydrocarbons (PAHs) (which are constituents of diesel- and oil-range organics) that were detected in site groundwater at a concentration above the Ecology or USEPA surface-water criteria were modeled. Benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene were modeled as surrogates.

Arsenic and selenium, which are IHSs at the site, were not modeled because based on the data collected, Precision does not appear to be a source of these IHSs. The spatial distribution of arsenic concentrations in groundwater is not consistent with what would be expected if the former Precision site was the source. The arsenic detections are representative of naturally occurring background concentrations. For example, the highest concentration of arsenic detected at the site (32.3 μg/L) was in a sample from monitoring well MW1, located upgradient of the facility. Arsenic is ubiquitous in groundwater throughout the site at concentrations that appear to be consistent with naturally occurring background levels and there is no indication that Precision is a source of the arsenic in groundwater. Selenium is detected in some of the downgradient monitoring wells at the site; however, selenium was not detected in soil and is no link between selenium and Precision.

It was not necessary to model benzo(b)fluoranthene and benzo(k)fluoranthene to demonstrate that these constituents would not reach the river reach the Duwamish River as it was already shown that they were not detected in monitoring locations at or near the property boundary nor in borings where IHSs may not be detected in downgradient locations.

Source Concentrations, Downgradient Concentrations, and Surface-Water Criteria

The maximum detected concentrations in groundwater samples collected from monitoring wells at the eastern property boundary were used as the source concentration to demonstrate that constituents at the site will not reach the river (see Table A1). Although TCE and vinyl chloride were not detected in property boundary monitoring wells, concentrations from geoprobe groundwater reconnaissance sample GP-13, located approximately 75 feet upgradient of the property boundary were used. Data from GP-13 was used as the boring was in a location where Ecology had expressed concern that IHSs may not show up in downgradient wells.

To calculate the groundwater CUL, an iterative process was used whereby assumed source concentrations were input into the model until the calculated downgradient concentration matched the most conservative applicable surface-water criteria. The groundwater CUL for a given IHS is the source concentration that predicts groundwater concentrations equal to the surface-water criteria (see Table A2). Groundwater CULs for the volatile organic compounds (VOCs) TCE and vinyl chloride were calculated in three ways: using a degradation rate based on reference values (Howard, et. El., 1991), using the same reference value multiplied by a factor of two, and with no degradation occurring (i.e., Type I model).

Table A3 summarizes applicable surface-water criteria. The most conservative (lowest) criteria from Table A3 were used for the model. Water-quality criteria were obtained from the Cleanup Levels and Risk Calculations (CLARC) Web page (Ecology, 2007). Applicable surface-water criteria included Model Toxics Control Act (MTCA) Method B and Method C CULs for surface water, and Ecology and USEPA surface-water criteria for aquatic life and for human health in both freshwater and marine environments. Criteria for both freshwater and marine environments were used based on reports that the base of the Duwamish is saline, while approximately the top 10 feet is freshwater (Duwamish Coalition, 1998). Use of water-quality criteria for the consumption of organisms and water is overly conservative, as water in the Duwamish is brackish and is not used for drinking water.

Source Area Dimensions

Source dimensions were based on the areal extent of IHS detections at the site. The extent of the contaminants was estimated to be equal to the distance between a sample location in which the constituent was detected in groundwater and the nearest sample location in which the constituent was not detected. Data from both monitoring wells and reconnaissance borings were considered in estimating the source-area widths.

The source width for trivalent chromium, and all of the PAHs was 300 feet (based on detections near the north and south property boundaries). The source width for hexavalent chromium was 50 feet (based on detections in GP6 and MW4). Copper source width was 225 feet, based on detections in MW6, MW2, and MW8. The source width for vinyl chloride was 200 feet (based on the detection of vinyl chloride in GP-13 and MW-8). The source width for TCE was 40 feet (based on the detections of TCE in GP6, GP8, and GP-13). It is important to note that hexavalent chromium, TCE, and vinyl chloride were not detected at the property boundary (i.e., applying these concentrations at the property boundary is an overly conservative case).

The source-area thickness for all IHSs was estimated as 15 feet (based on the difference in elevation between the top of the water table and the top of the aquitard).

BIOCHLOR allows the user to specify either a constant concentration source or a variety of source decay scenarios. Using a decay scenario requires an estimate of the mass contained in the original release. MFA conservatively assumed a constant, nondegrading source. This assumption significantly overestimates the amount of mass in the subsurface, considering that TCE use at the property ended in the mid-1980s, that the outside steam-cleaning area was relocated before 1986, that the boiler UST was abandoned in place and filled with a slurry in 1992, that chrome-plating operations ceased in 2005, and the evidence that the organic compounds are degrading (the presence, for example, of the TCE degradation product vinyl chloride).

Groundwater Velocity

Groundwater models are typically sensitive to variations in groundwater velocity, which is dependent on the hydraulic conductivity (K) of the water-bearing zone (as well as the porosity [n] and the gradient [i]). A gradient of 0.003 was calculated using site groundwater-elevation data collected from MW6 (located at the property boundary) on April 17, 2006, and an average daily staff-gauge elevation for the Duwamish on the same day (USGS, 2007). A porosity of 0.3 was assumed based on typical estimates for the soil types at the site.

Values of K can range over orders of magnitude. The estimate of K from the document titled Development of a Three-Dimensional Numerical Groundwater Flow Model for the Duwamish River Basin (Duwamish Coalition, 1998) is 0.001 centimeters per second for the area near the former Precision site. MFA modeled the groundwater flow using a K value five times the Duwamish Coalition estimate (i.e. 0.005 centimeters per second). Applying this value to Darcy's law results in a linear velocity of 52 feet per year. The assumed K value is conservative compared to the value used by the Duwamish Coalition (i.e., overestimates groundwater velocity and consequently potential contaminant migration).

Retardation Factor

The velocity of organic constituents in the dissolved phase is usually less than (i.e., retarded relative to) the groundwater velocity due to sorption effects. Sorption of organic constituents occurs as dissolved-phase organic constituents partition to the organic carbon in soil. The rate of sorption depends on the amount of organic carbon in the soil and the distribution coefficients (K_{oc} values). The K_{oc} values for TCE, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene were obtained from Ecology's CLARC Web page (Ecology, 2007). The CLARC Web page listed distribution coefficients for volatile organic compounds (VOCs) of 94 L/kg for TCE and 19 L/kg for vinyl chloride, indicating low tendency for sorption (and thus retardation). Distribution coefficients for PAHs were significantly larger (i.e., 3.6×10^5 L/kg for benzo(a)anthracene, 1.2×10^6 L/kg for benzo(b)fluoranthene and benzo(k)fluoranthene, 4.0×10^5 L/kg for chrysene, 1.8×10^6 L/kg for dibenzo(a,h)anthracene, and 3.5×10^6 L/kg for indeno(1,2,3-cd)pyrene).

Sorption of dissolved inorganic constituents occurs primarily due to cation- or anion-exchange processes. The amount of solute that is adsorbed to the aquifer matrix is also described by a distribution coefficient (K_d). Distribution coefficients for arsenic, copper, trivalent chromium, hexavalent chromium, and selenium were also obtained from the CLARC Web page. The CLARC Web page listed distribution coefficients for metals of 29 L/kg for arsenic, 22 L/kg for copper, 1,000 L/kg for trivalent chromium, 19 L/kg for hexavalent chromium, and 5 L/kg for selenium.

No organic carbon data are available for the former Precision site. MFA used the default value (0.0018) supplied by the BIOCHLOR model and the distribution coefficients to calculate retardation factors. Resulting retardation factors for the metals and VOCs were calculated and are shown on Tables A1 and A2.

Because of the high propensity of PAHs to adhere to soil, (reflected in the high partitioning coefficients for the PAHs), calculated retardation factors for PAHs were also high. Solutions to the advection-dispersion equations using the superposition approach used by BIOCHLOR for solving the Domenico analytical model are known to diverge from solutions obtained by more robust numerical models for contaminants with large retardation factors. MFA confirmed this when attempting to model the PAH contaminants; high retardation factors caused the model to produce unrealistic results. In order to make the model function correctly, while still maintaining a high level of model conservatism, MFA set the retardation factors for all PAHs to a value of 10. This is a highly conservative approach, and resulted in migration of these contaminants being overestimated. Therefore, the CULs for the PAHs developed using these lower retardation factors are much lower than CULs that would have been calculated had the model been able to use the higher retardation factors.

Degradation Rates and Dispersion

BIOCHLOR allows the application of half-life data for calculating a first-order decay scenario. Literature values for half-lives of the VOCs and PAHs are appropriate to use. At the request of Ecology, MFA modeled a range of degradation rates for both TCE and vinyl chloride. CULs were calculated for all IHS's using the average of literature values for the degradation rates. Additionally, CULS for TCE and VC were calculated based on half lives that are two times longer than the literature values as well as with no degradation. Degradation of TCE at the site has been confirmed by the presence of vinyl chloride (a degradation product); however, to be conservative, the final groundwater CULs for TCE and vinyl chloride are assumed to be those calculated using the half lives increased by a factor of two. Degradation of total petroleum hydrocarbon constituents in the subsurface has been widely documented and can be inferred at this site.

Dispersion occurs when groundwater encounters soil grains and the contaminant molecules are deflected or dispersed away from each other. Dispersion occurs in the longitudinal direction (i.e., along the groundwater plume axis in the direction of groundwater flow) and in the transverse planes (i.e., lateral or crossgradient to groundwater flow, in two dimensions). The amount of longitudinal and lateral dispersion is typically considered to be a function of plume length. For the purposes of this model, dispersion was calculated (using the internal BIOCHLOR algorithm) to be 180 feet, based on a hypothetical plume length of 1,800 feet.

Model Domain Size and Duration

The model domain was set at 800 feet wide and 3,600 feet long, well in excess of the width of the property and the distance to the Duwamish River. The models were run assuming a 35-year period, which is the estimated approximate length of time that it would take groundwater to travel 1,800 feet (i.e., the distance from the eastern property boundary to the Duwamish River), based on estimated groundwater seepage velocity at the site. Given that the primary sources of the contamination are no longer present, it is unlikely that impacts will continue for this length of time.

It is important to note that the assumptions of constant contaminant sources at maximum detected concentrations assumed at the eastern property edge are very conservative. Mass loading to the system is in fact finite due to the UST decommissioning and soil excavation conducted in the 1980’s, and maximum concentrations in several cases were located an additional 50 to 130 feet west of the eastern property edge. The model was also set up to assume maximum concentrations throughout the source area. In reality, this would not be the case due to dispersive effects.

Results

Table A1 presents a summary of modeling results indicating that none of the IHSs at the site will reach the Duwamish River at concentrations at or above method detection limits. Figures A1 through A9 show concentration vs. distance with the assumed source area concentration at the eastern property boundary and the corresponding concentration at the river.[1]

Table A2 provides the modeling results to determine site specific CULs for the protection of surface water. Concentration vs. distance graphs showing the most stringent surface water CUL concentration at the Duwamish (i.e, at 1,800 feet, and the site specific CUL at the property boundary (0 feet), are included as Figures A10 through A20.

Table A4 compares the calculated CULs to concentrations of IHSs and PAHs detected in site groundwater samples. On-site groundwater concentrations of hexavalent chromium exceeded their respective CULs. All other IHSs and the modeled PAHs in groundwater are below their

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[1] Note that the modeled concentrations shown on the graphs are expressed in milligrams per liter. Some modeled concentrations were converted to micrograms per liter (µg/L) in the tables for the ease of comparison, as site data and criteria are presented in µg/L for the constituents modeled.

respective CULs. Hexavalent chromium concentrations that exceeded CULs were detected in groundwater samples collected from borings and MW5, located within the building footprint, and from one sample collected from MW1, located upgradient of the building. Concentrations of hexavalent chromium in wells located near the eastern property line were not detected above their method reporting limits and did not exceed CULs.

Attachments

References
Tables A1 through A4
Figures A1 through A20

References

Duwamish Coalition. 1997. Development of a three-dimensional, numerical groundwater flow model for the Duwamish River Basin. Prepared by J. Fabritz, J. Massmann, and D. Booth for City of Seattle Office of Economic Development and King County Office of Budget and Strategic Planning. August.

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USEPA. 2002. Biochlor. Natural attenuation decision support system. Ver. 2.2. U.S. Environmental Protection Agency. http://www.epa.gov/ada/csmos/models/biochlor.html. March.

USGS. 2007. Real-time water data for USGS 12113350 Green River at Tukwila, WA. Water resources. National water information system: Web interface. http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12113350&PARAmeter_cd=00060,00065.

TABLES

Appendix A Table Notes
Precision Engineering, Inc.
Seattle, Washington

Bold font indicates an exceedance of the CUL.

ARAR = applicable or relevant and appropriate requirement.
AWQC = ambient water quality criteria.
CUL = cleanup level.
J = estimated.
mg/L = milligrams per liter.
MTCA = Washington State Department of Ecology's Model Toxics Control Act.
µg/L = micrograms per liter.
NA = not analyzed.
NC = not calculated.
NR = not researched.
NV = no value.
U = not detected at or above the method reporting limit.

[a] Surface water of the Duwamish is brackish and is not used for drinking.

[b] Based on literature estimates from *Development of a Three-Dimensional Numerical Groundwater Flow Model for the Duwamish River Basin* ; University of Washington; August, 1998.

[c] Based on field data.

[d] Standard assumption.

[e] Calculated (v=(k*i)/n).

[f] Due to sorption; calculated (R=1+(rho/n)*Koc*foc).

[g] Actual calculated retardation factor or more conservative.

[h] Based on distance between sample locations with detections.

[i] Based on screen intervals/recon intervals.

[j] Groundwater Chemicals Desk Reference; Montgomery ed.; CRC Press, 1996.

[k] Concentration at a distance of 1,800 ft from eastern property boundary (distance to Duwamish River) was set equal to the surface-water criteria.

Table A1
Fate and Transport Model Inputs and Results Showing no Discharge of IHSs to the Duwamish
Precision Engineering, Inc.
Seattle, Washington

Model Parameters	Chromium, Trivalent	Chromium, Hexavalent	Copper	Trichloro-ethene	Vinyl Chloride
Hydraulic Conductivity (k, cm/sec)[b]	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03
Gradient (i)[c]	0.003	0.003	0.003	0.003	0.003
Porosity (n)[d]	0.3	0.3	0.3	0.3	0.3
Groundwater Velocity (v, ft/yr)[e]	52	52	52	52	52
Retardation Factor[f]	5334	102	118	1.90	1.18
Modeled Retardation[g]	10	10	10	1.90	1.18
Simulation Time (yrs)	35	35	35	35	35
Source Concentration (µg/L)	47	7.38	4.02	0.220	16.5
Source Width (ft)[h]	300	50	225	40	200
Source Thickness (ft)[i]	15	15	15	15	15
Modeled Half-life (days)[j]	NV	NV	NV	1751	832
Results					
Detection Limits (µg/L)	10	10	1	0.2	0.2
Concentration at Duwamish (ug/L)	<10	<10	<1	<0.01	<0.1

Table A1
Fate and Transport Model Inputs and Results Showing no Discharge of IHSs to the Duwamish
Precision Engineering, Inc.
Seattle, Washington

Model Parameters	Benzo(a) anthracene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Chrysene	Dibenzo(a,h) anthracene	Indeno(1,2,3-cd)pyrene
Hydraulic Conductivity (k, cm/sec)[b]	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03
Gradient (i)[c]	0.003	0.003	0.003	0.003	0.003	0.003
Porosity (n)[d]	0.3	0.3	0.3	0.3	0.3	0.3
Groundwater Velocity (v, ft/yr)[e]	52	52	52	52	52	52
Retardation Factor[f]	3,433	11,809	11,809	3,822	17,176	33,313
Modeled Retardation[g]	10	10	10	10	10	10
Simulation Time (yrs)	35	35	35	35	35	35
Source Concentration (µg/L)	0.035	ND	ND	0.013	0.038	0.039
Source Width (ft)[h]	300	300	300	300	300	300
Source Thickness (ft)[i]	15	15	15	15	15	15
Modeled Half-life (days)[j]	782	970	3,029	1,371	1,301	1,330
Results						
Detection Limits (µg/L)	0.01	0.01	0.01	0.01	0.01	0.01
Concentration at Duwamish (ug/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table A2
Development of Site Specific Groundwater Clean-up Levels
Precision Engineering, Inc.
Seattle, Washington

Model Parameters	Chromium, Trivalent	Chromium, Hexavalent	Copper	Trichloro-ethene	Vinyl Chloride
Hydraulic Conductivity (k, cm/sec)[b]	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03
Gradient (i)[c]	0.003	0.003	0.003	0.003	0.003
Porosity (n)[d]	0.3	0.3	0.3	0.3	0.3
Groundwater Velocity (v, ft/yr)[e]	52	52	52	52	52
Retardation Factor[f]	5334	102	118	1.9	1.18
Modeled Retardation[g]	10	10	10	1.9	1.18
Simulation Time (yrs)	35	35	35	35	35
Source Width (ft)[h]	300	50	225	40	200
Source Thickness (ft)[i]	15	15	15	15	15
Half-life (days)[j]	NV	NV	NV	876	416
Concentration of groundwater discharge to surface water = Surface Water Criteria value (µg/L)[k]	74	11	3.1	1.5	0.025
Results (Source Area Concentration)					
Type I	3,600,000,000,000	160	22	188	18.70
Type II	NC	NC	NC	128,800	2,640
Type II with Half-life x factor of 2 for TCE and VC (µg/L)	NC	NC	NC	1,630	52

Table A2
Development of Site Specific Groundwater Clean-up Levels
Precision Engineering, Inc.
Seattle, Washington

Model Parameters	Benzo(a) anthracene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Chrysene	Dibenzo(a,h) anthracene	Indeno(1,2,3-cd)pyrene
Hydraulic Conductivity (k, cm/sec)[b]	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03
Gradient (i)[c]	0.003	0.003	0.003	0.003	0.003	0.003
Porosity (n)[d]	0.3	0.3	0.3	0.3	0.3	0.3
Groundwater Velocity (v, ft/yr)[e]	52	52	52	52	52	52
Retardation Factor[f]	3,433	11,809	11,809	3,822	17,176	33,313
Modeled Retardation[g]	10	10	10	10	10	10
Simulation Time (yrs)	35	35	35	35	35	35
Source Width (ft)[h]	300	300	300	300	300	300
Source Thickness (ft)[i]	15	15	15	15	15	15
Half-life (days)[j]	782	970	3,029	1,371	1,301	1,330
Concentration of groundwater discharge to surface water = Surface Water Criteria value (µg/L)[k]	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Results (Source Area Concentration)						
Type I	NC	NC	NC	NC	NC	NC
Type II	200,000,000	165,000,000	55,000,000	130,000,000	135,000,000	132,000,000
Type II with Half-life x factor of 2 for TCE and VC (µg/L)	NC	NC	NC	NC	NC	NC

Table A3
Applicable Surface-Water Criteria
Precision Engineering, Inc.
Seattle, Washington

Surface-Water Criteria	Hexavalent Chromium (mg/L)	Dissolved Trivalent Chromium[a] (mg/L)	Copper (µg/L)	Trichloro-ethene (µg/L)	Vinyl chloride (µg/L)	Benzo(a) anthracene (µg/L)	Benzo(b) fluoranthene (µg/L)
MTCA Method B Surface Water CULs, carcinogen or non-carcinogen	0.490	240	2700	**1.5**	3.7	0.0300	0.0300
MTCA Method C Surface Water CULs, carcinogen or non-carcinogen	1.20	610	6,700	37	92	0.74	0.74
AWQC—Human Health	NR	NR	1,300	2.5	**0.025**	**0.0038**	**0.0038**
Surface Water ARAR—Aquatic Life—Freshwater/Acute	0.15	1.8	4.6	NR	NR	NR	NR
AWQC—Aquatic Life—Chronic	**0.011**	**0.074**	**3.1**	NR	NR	NR	NR

*Lowest CUL bolded

Table A3
Applicable Surface-Water Criteria
Precision Engineering, Inc.
Seattle, Washington

Surface-Water Criteria	Benzo(k) fluoranthene (µg/L)	Benzo(b+k) fluoranthene (µg/L)	Chrysene (µg/L)	Dibenzo(a,h) anthracene (µg/L)	Indeno(1,2,3-cd) pyrene (µg/L)	Diesel-Range Organics (mg/L)	Oil-Range Organics (mg/L)
MTCA Method B Surface Water CULs, carcinogen or non-carcinogen	0.0300	0.0300	0.0300	0.0300	0.0300	NV	NV
MTCA Method C Surface Water CULs, carcinogen or non-carcinogen	0.74	0.74	0.74	0.74	0.74	NV	NV
AWQC—Human Health	**0.0038**	NR	**0.0038**	**0.0038**	**0.0038**	NV	NV
Surface Water ARAR—Aquatic Life—Freshwater/Acute	NR	NR	NR	NR	NR	NV	NV
AWQC—Aquatic Life—Chronic	NR	NR	NR	NR	NR	NV	NV

*Lowest CUL bolded

Table A4
Risk Screening
Groundwater Protection of Surface Water
Precision Engineering, Inc.
Seattle, Washington

Location	Date	Dissolved Chromium (Trivalent)	Chromium (Hexavalent)	Copper	Selenium	Trichloro-ethene	Vinyl chloride	Diesel-Range Organics	Oil-Range Organics
		mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
Site-Specific Groundwater CUL for the Protection of Surface Water		2,800,000,000	0.15	22	25	1,630	52	NV	NV
Monitoring Well Groundwater Data									
MW1	6/16/2005	NC	**0.269**	NA	NA	1 U	1 U	NA	NA
	12/27/2005	NC	0.00625 U	1.01	1.00 U	0.200 U	0.200 U	0.248 U	0.495 U
	04/18/2006	NC	0.02 U	2.0 U	2.0 U	1 U	1 U	0.26 U	0.52 U
MW2	6/17/2005	NC	0.01 U	NA	NA	1 U	1 U	0.438	0.512
	12/28/2005	0.00879	0.00625 U	1.17	6.28	0.200 U	0.200 U	1.19	1.04
	04/19/2006	0.021	0.02 U	2.5	10	1 U	1 U	0.41	0.58 U
MW3	6/7/2005	NC	0.01 U	NA	NA	1 U	1 U	NA	NA
	12/29/2005	0.00215	0.00625 U	1.00 U	1.00 U	0.200 U	0.200 U	0.312	0.505 U
	04/17/2006	0.0078	0.02 U	2.0 U	2.0 U	1 U	1 U	0.28 U	0.57 U
MW4	6/9/2005	NC	0.01 U	NA	NA	1 U	1 U	NA	NA
	6/9/2005	NC	0.01 U	NA	NA	1 U	1 U	NA	NA
	12/27/2005	NC	0.00625 U	1.00 U	1.00 U	0.200 U	0.200 U	0.248 U	0.495 U
	04/18/2006	NC	0.023	2.0 U	2.0 U	1 U	1 U	0.27 U	0.54 U
MW5	12/28/2005	47	**450**	3.67	1000 U	22.1	0.200 U	0.831	0.495 U
	04/19/2006	NC	**350**	2.0 U	2.0 U	7.9	0.14 U	0.26 U	0.51 U
MW6	12/29/2005	0.0187	0.00625 U	4.02	12.3	1 U	1 U	2.64	1.32
	04/19/2006	0.047	0.02 U	5.1	19	1 U	1 U	0.76	1.2
MW7	12/28/2005	0.0106	0.00738	2.12	2.77	0.200 U	0.200 U	0.248 U	0.495 U
	04/18/2006	0.013	0.02U	2.4	5	1 U	1 U	0.26 U	0.51 U
	04/18/2006	NC	0.02 U	NA	NA	1 U	1 U	0.26 U	0.51 U
MW8	12/28/2005	0.00755	0.00625 U	1.00 U	4.11	0.200 U	0.560	1.71	1.00
	12/28/2005	0.00849	0.02 U	1.03	4.27	0.200 U	0.400	1.79	1.21
	04/18/2006	0.021	0.02 UJ	2.0 U	3.6	1 U	0.80 J	0.45	0.58 U

Table A4
Risk Screening
Groundwater Protection of Surface Water
Precision Engineering, Inc.
Seattle, Washington

Location	Date	Dissolved Chromium (Trivalent)	Chromium (Hexavalent)	Copper	Selenium	Trichloro-ethene	Vinyl chloride	Diesel-Range Organics	Oil-Range Organics
		mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
Site-Specific Groundwater CUL for the Protection of Surface Water		2,800,000,000	0.15	22	25	1,630	52	NV	NV
Reconnaissance Groundwater Data									
GP2	6/9/2005	32.38	**4.72**	NA	NA	5 U	5 U	NA	NA
GP4	6/16/2005	31	**236**	NA	NA	1 U	1 U	0.325	0.478 U
GP5	6/16/2005	NC	0.0897	NA	NA	1 U	1 U	NA	NA
GP6	6/16/2005	43	**300**	NA	NA	1,130	20 U	NA	NA
GP7	6/16/2005	NC	0.101	NA	NA	1 U	1 U	NA	NA
GP8	6/16/2005	61	**294**	NA	NA	16.8	1 U	0.814	0.479 U
GP-13	12/14/2005	NC	NA	NA	NA	0.220	16.5	NA	NA
GP-15	12/14/2005	NC	NA	NA	NA	0.2 U	0.2 U	NA	NA

Table A4
Risk Screening
Groundwater Protection of Surface Water
Precision Engineering, Inc.
Seattle, Washington

Location	Date	Benzo(a) anthracene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(b+k) fluoranthene	Chrysene	Dibenzo(a,h) anthracene	Indeno(1,2,3-cd) pyrene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Site-Specific Groundwater CUL for the Protection of Surface Water		145,000,000	108,000,000	38,000,000	NV	95,000,000	100,000,000	97,000,000
Monitoring Well Groundwater Data								
MW1	6/16/2005	NA	NA	NA	NA	NA	NA	NA
	12/27/2005	0.107	0.104	0.108	NA	0.132	0.0114 U	0.0114 U
	04/18/2006	0.029 J	NA	NA	0.030 U	0.014 J	0.095 U	0.034 J
MW2	6/17/2005	0.192 U	NA	NA	0.962 U	0.192 U	0.192 U	0.192 U
	12/28/2005	0.00990 U	0.00990 U	0.00990 U	NA	0.00990 U	0.00990 U	0.00990 U
	04/19/2006	0.031 J	NA	NA	0.034 U	0.11 U	0.11 U	0.11 U
MW3	6/7/2005	NA	NA	NA	NA	NA	NA	NA
	12/29/2005	0.0100 U	0.0100 U	0.0100 U	NA	0.0100 U	0.0100 U	0.0100 U
	04/17/2006	0.11 U	NA	NA	0.033 U	0.11 U	0.11 U	0.11 U
MW4	6/9/2005	NA	NA	NA	NA	NA	NA	NA
	6/9/2005	NA	NA	NA	NA	NA	NA	NA
	12/27/2005	0.0100 U	0.0100 U	0.0100 U	NA	0.0100 U	0.0100 U	0.0100 U
	04/18/2006	0.10 U	NA	NA	0.032 U	0.10 U	0.10 U	0.10 U
MW5	12/28/2005	0.00990 U	0.00990 U	0.00990 U	NA	0.00990 U	0.00990 U	0.00990 U
	04/19/2006	0.095 U	NA	NA	0.030 U	0.095 U	0.095 U	0.095 U
MW6	12/29/2005	0.00990 U	0.00990 U	0.00990 U	NA	0.00990 U	0.00990 U	0.00990 U
	04/19/2006	0.10 U	NA	NA	0.032 U	0.10 U	0.10 U	0.10 U
MW7	12/28/2005	0.00990 U	0.00990 U	0.00990 U	NA	0.00990 U	0.00990 U	0.00990 U
	04/18/2006	0.035 J	NA	NA	0.031 U	0.013 J	0.038 J	0.039 J
	04/18/2006	0.10 U	NA	NA	0.031 U	0.10 U	0.10 U	0.10 U
MW8	12/28/2005	0.0100 U	0.0100 U	0.0100 U	NA	0.0100 U	0.0100 U	0.0100 U
	12/28/2005	0.0990 U	0.00990 U	0.00990 U	NA	0.00990 U	0.00990 U	0.00990 U
	04/18/2006	0.13 U	NA	NA	0.039 U	0.13 U	0.13U	0.13 U

Table A4
Risk Screening
Groundwater Protection of Surface Water
Precision Engineering, Inc.
Seattle, Washington

Location	Date	Benzo(a) anthracene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(b+k) fluoranthene	Chrysene	Dibenzo(a,h) anthracene	Indeno(1,2,3-cd) pyrene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Site-Specific Groundwater CUL for the Protection of Surface Water		145,000,000	108,000,000	38,000,000	NV	95,000,000	100,000,000	97,000,000
Reconnaissance Groundwater Data								
GP2	6/9/2005	NA	NA	NA	NA	NA	NA	NA
GP4	6/16/2005	0.191 U	0.954 U	NA	NA	0.191 U	0.191 U	0.191 U
GP5	6/16/2005	NA	NA	NA	NA	NA	NA	NA
GP6	6/16/2005	NA	NA	NA	NA	NA	NA	NA
GP7	6/16/2005	NA	NA	NA	NA	NA	NA	NA
GP8	6/16/2005	0.194 U	0.97 U	NA	NA	0.194 U	0.194 U	0.194 U
GP-13	12/14/2005	NA	NA	NA	NA	NA	NA	NA
GP-15	12/14/2005	NA	NA	NA	NA	NA	NA	NA

FIGURES

Figure A1
Fate and Transport Modeling
Trivalent Chromium
Precision Engineering, Inc.
Seattle, Washington

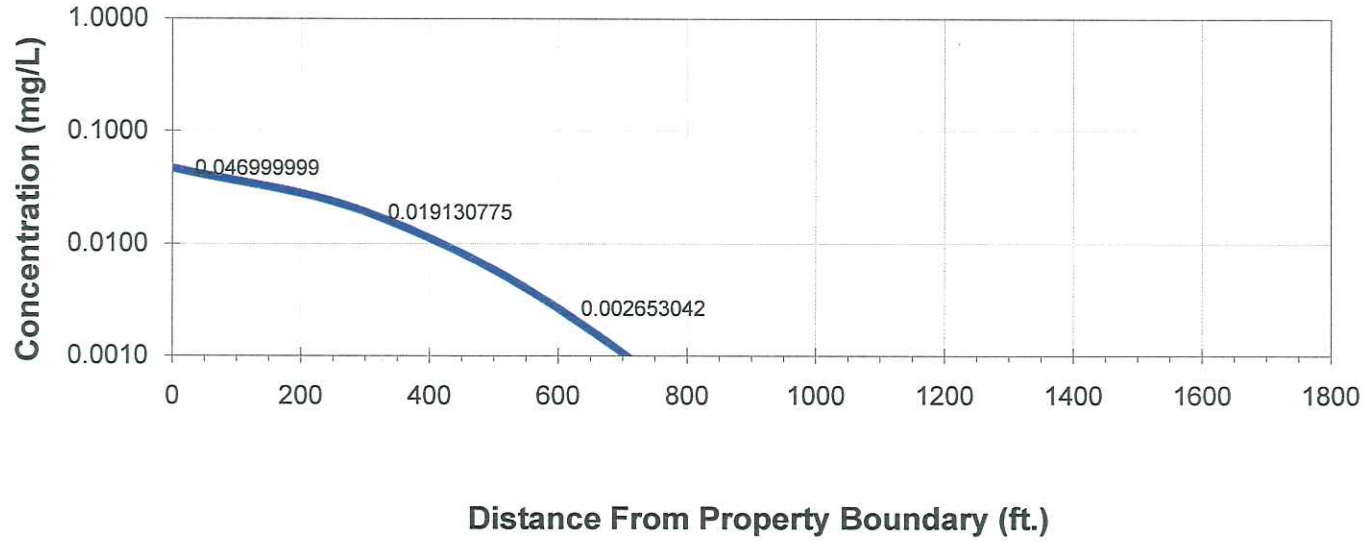

Figure A2
Fate and Transport Modeling
Hexavalent Chromium
Precision Engineering, Inc.
Seattle, Washington

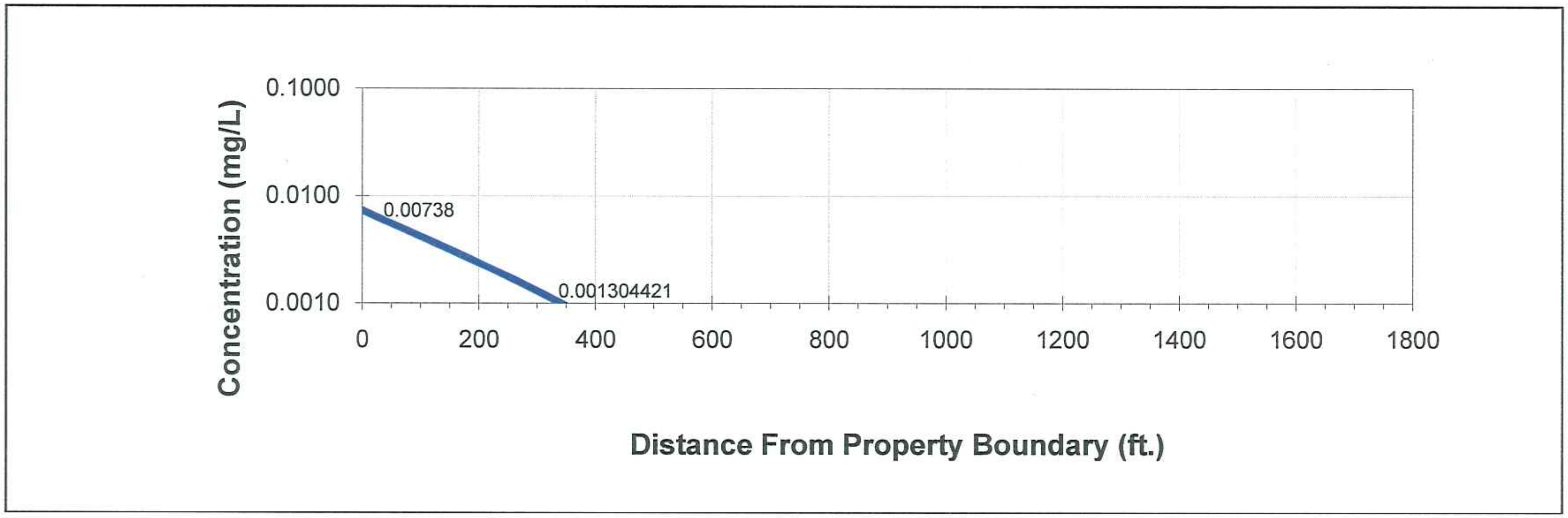

Figure A3
Fate and Transport Modeling
Copper
Precision Engineering, Inc.
Seattle, Washington

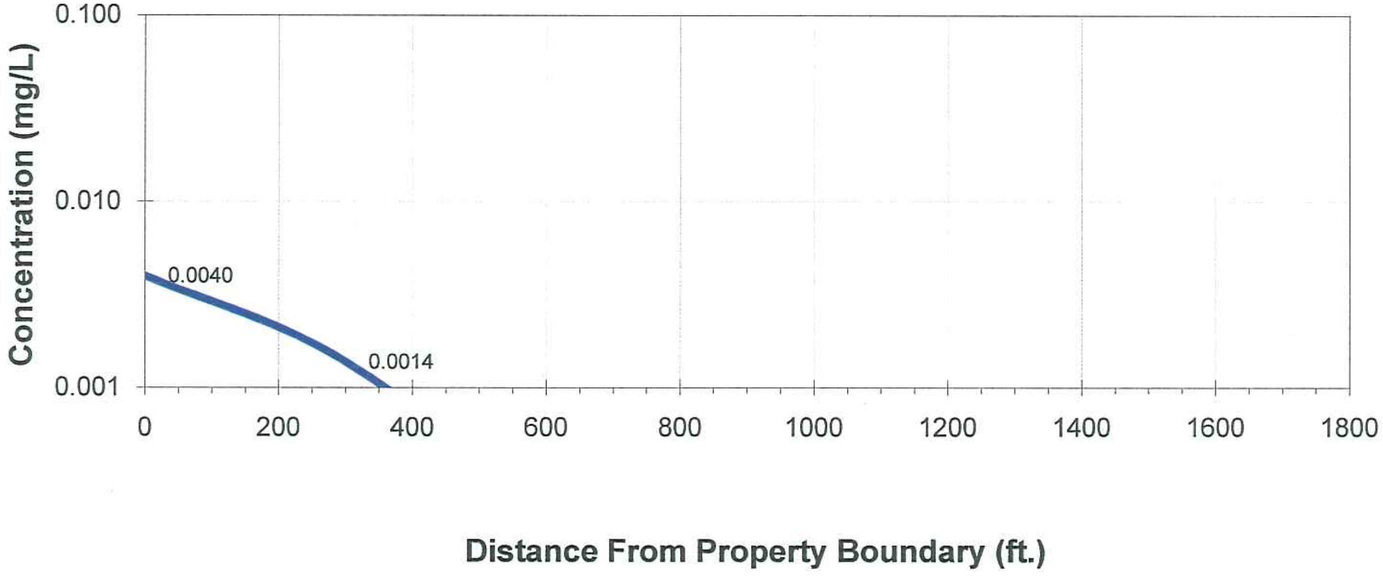

Figure A4
Fate and Transport Modeling
Trichloroethene
Precision Engineering, Inc.
Seattle, Washington

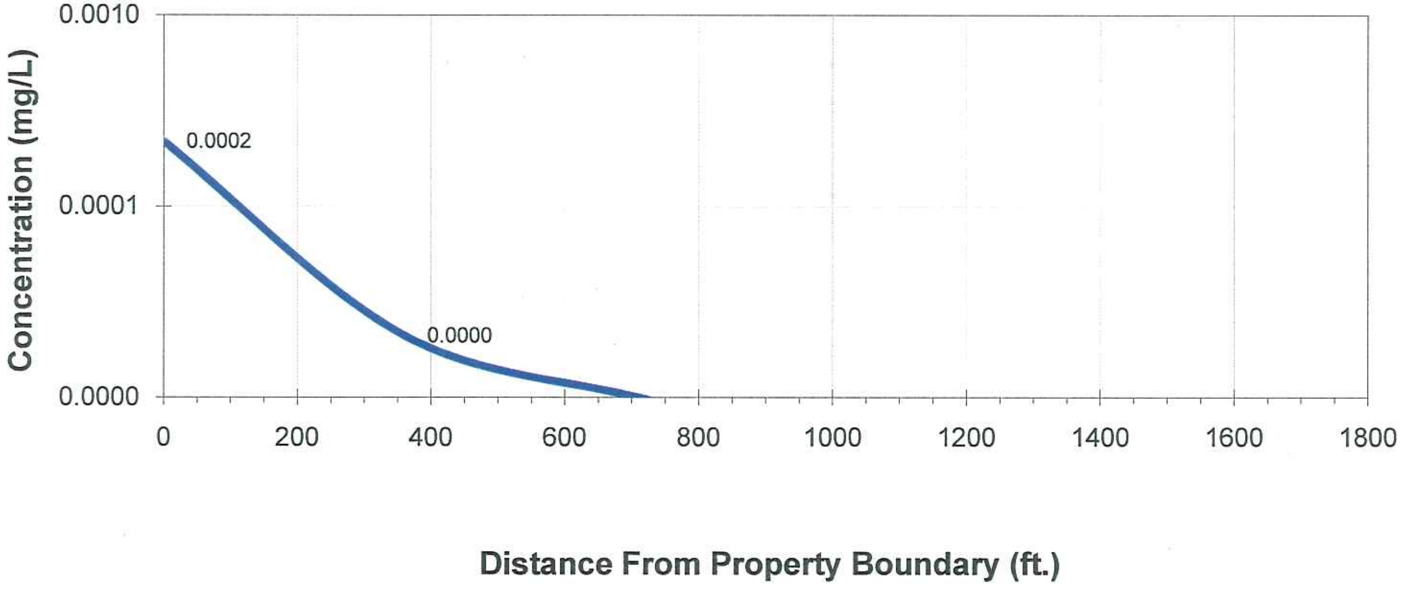

Figure A5
Fate and Transport Modeling
Vinyl Chloride
Precision Engineering, Inc.
Seattle, Washington

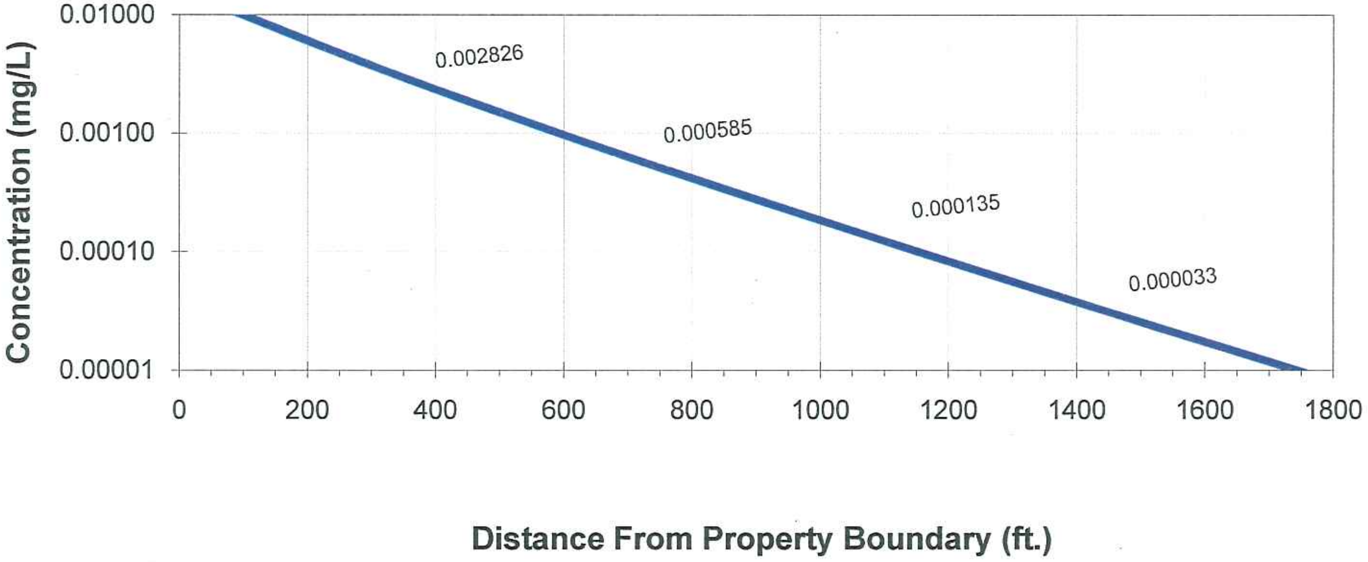

Figure A6
Fate and Transport Modeling
Benzo(a)anthracene
Precision Engineering, Inc.
Seattle, Washington

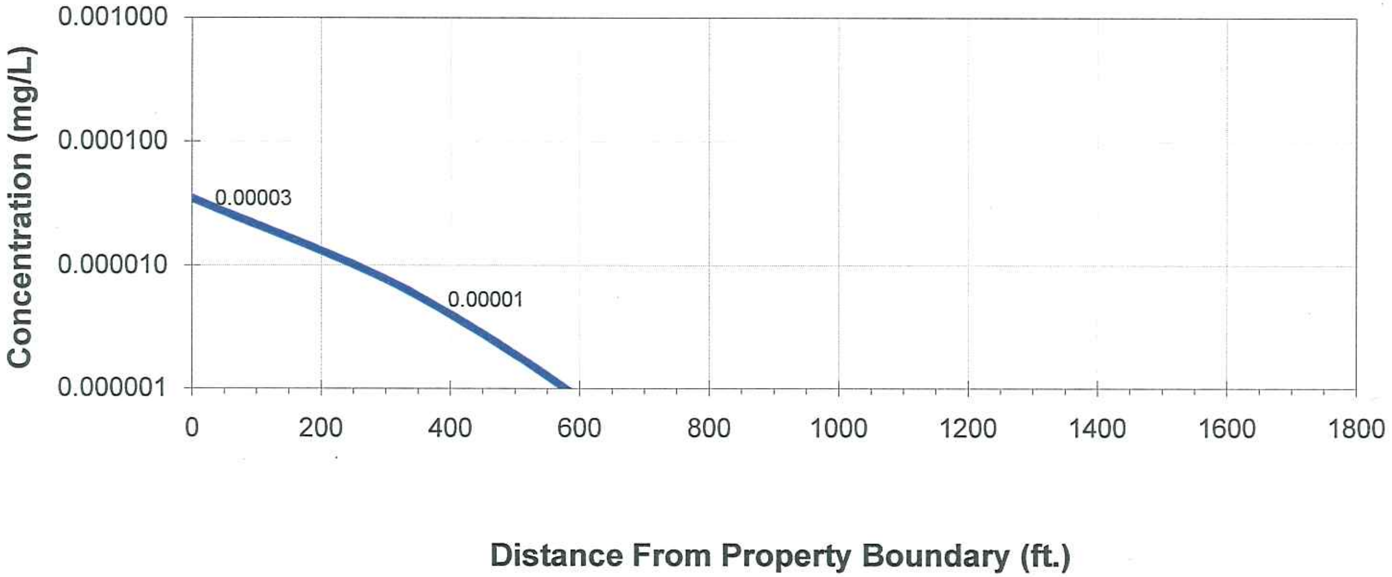

Figure A7
Fate and Transport Modeling
Chrysene
Precision Engineering, Inc.
Seattle, Washington

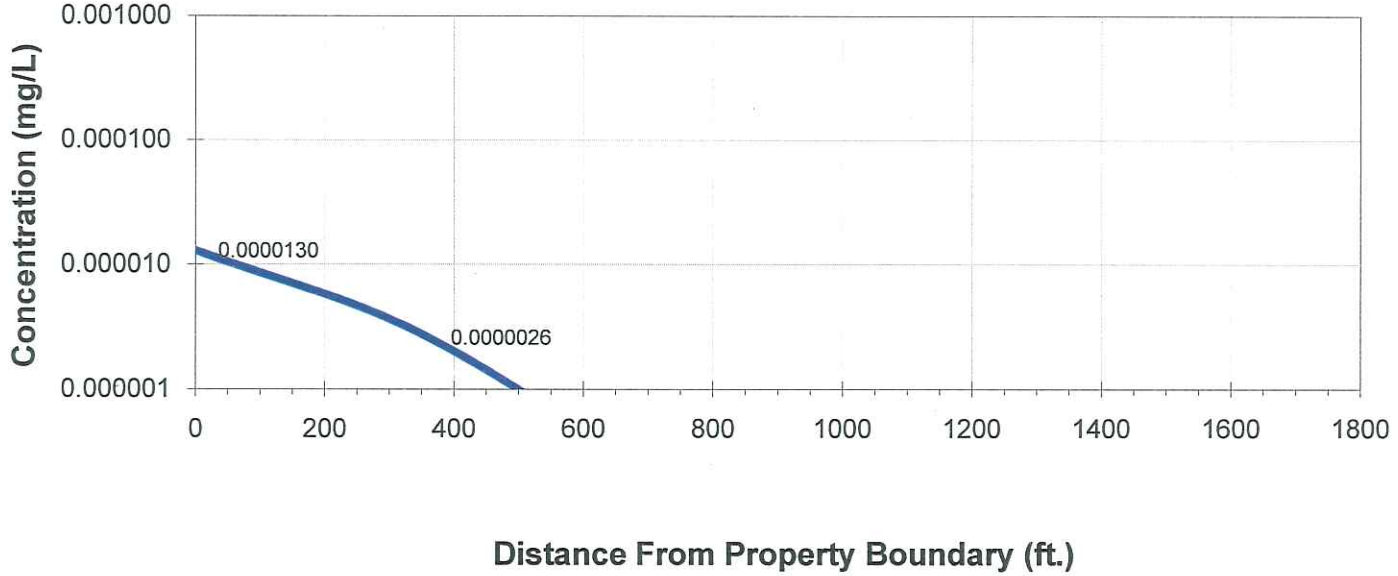

Figure A8
Fate and Transport Modeling
Dibenzo(a,h)anthracene
Precision Engineering, Inc.
Seattle, Washington

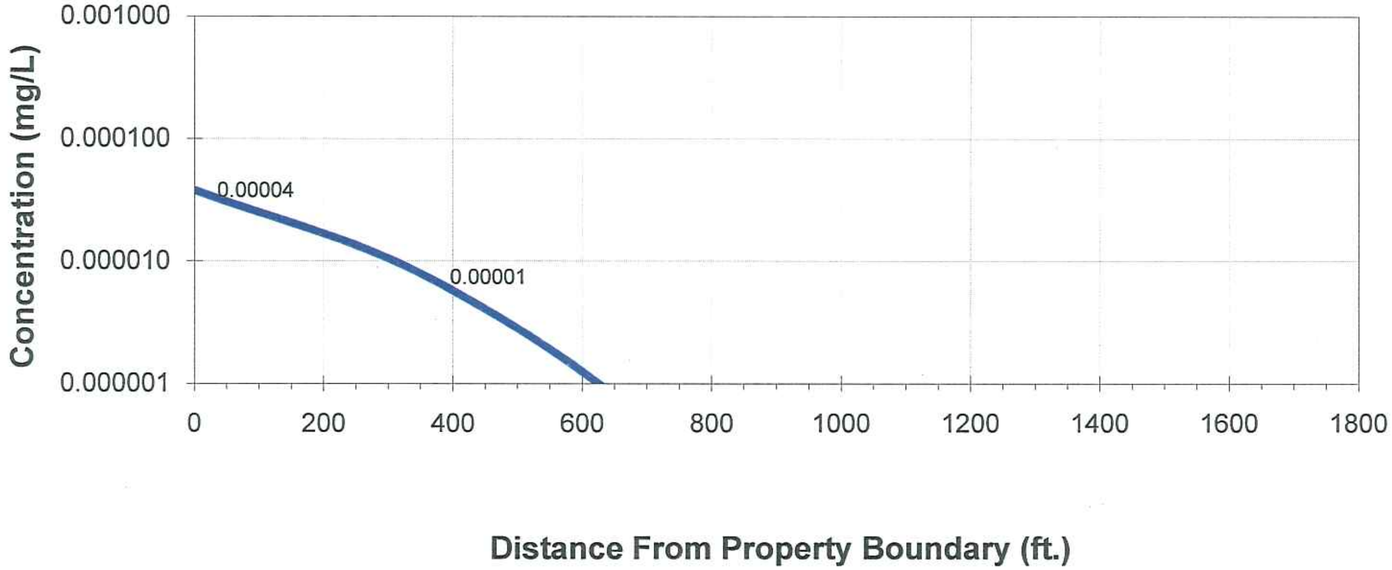

Figure A9
Fate and Transport Modeling
Indeno(1,2,3,-cd)pyrene
Precision Engineering, Inc.
Seattle, Washington

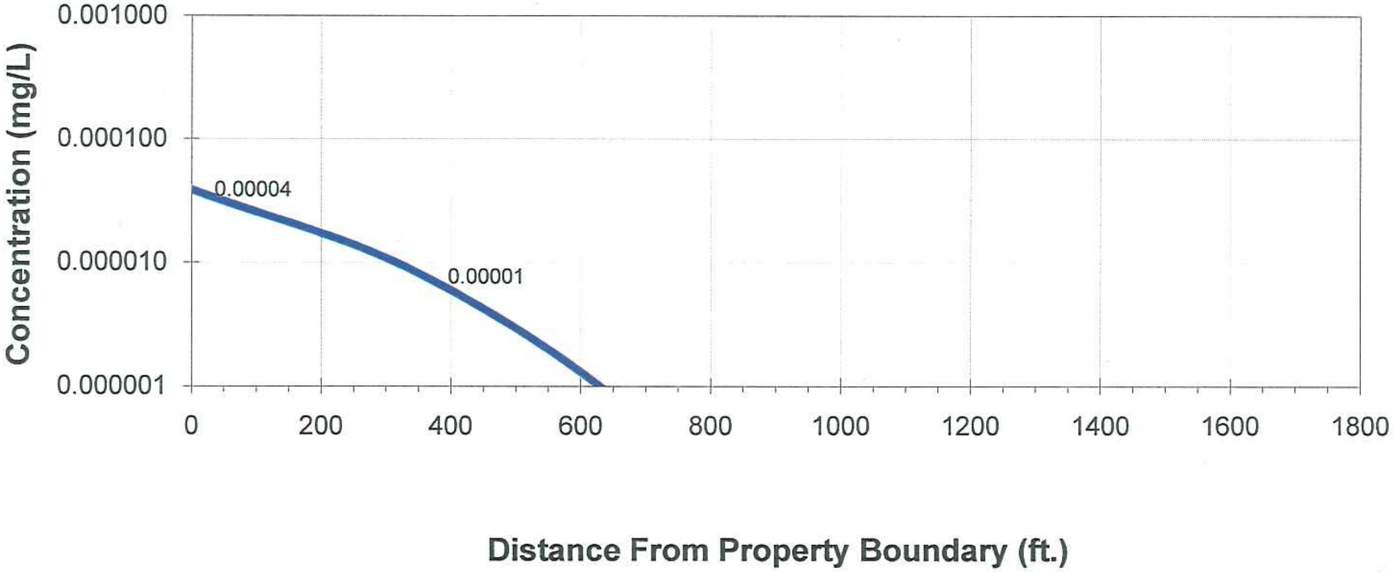

Figure A10
Fate and Transport Modeling for Site Specific CULs
Trivalent Chromium
Precision Engineering, Inc.
Seattle, Washington

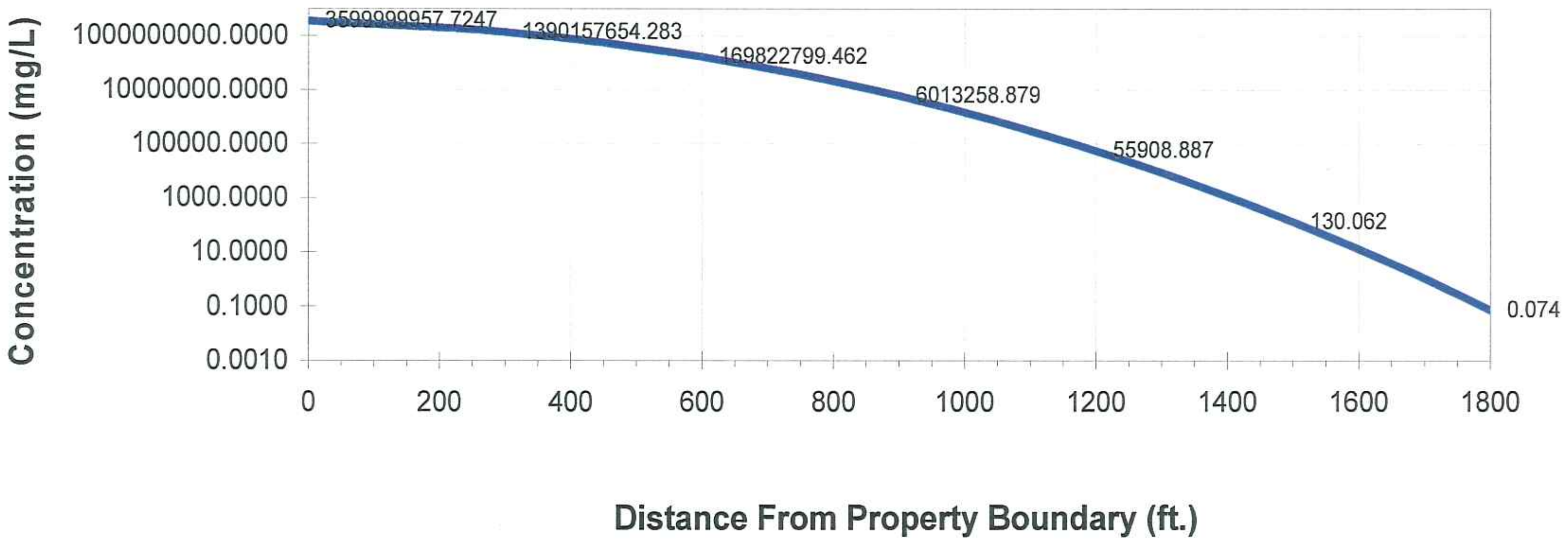

Figure A11
Fate and Transport Modeling for Site Specific CULs
Hexavalent Chromium
Precision Engineering, Inc.
Seattle, Washington

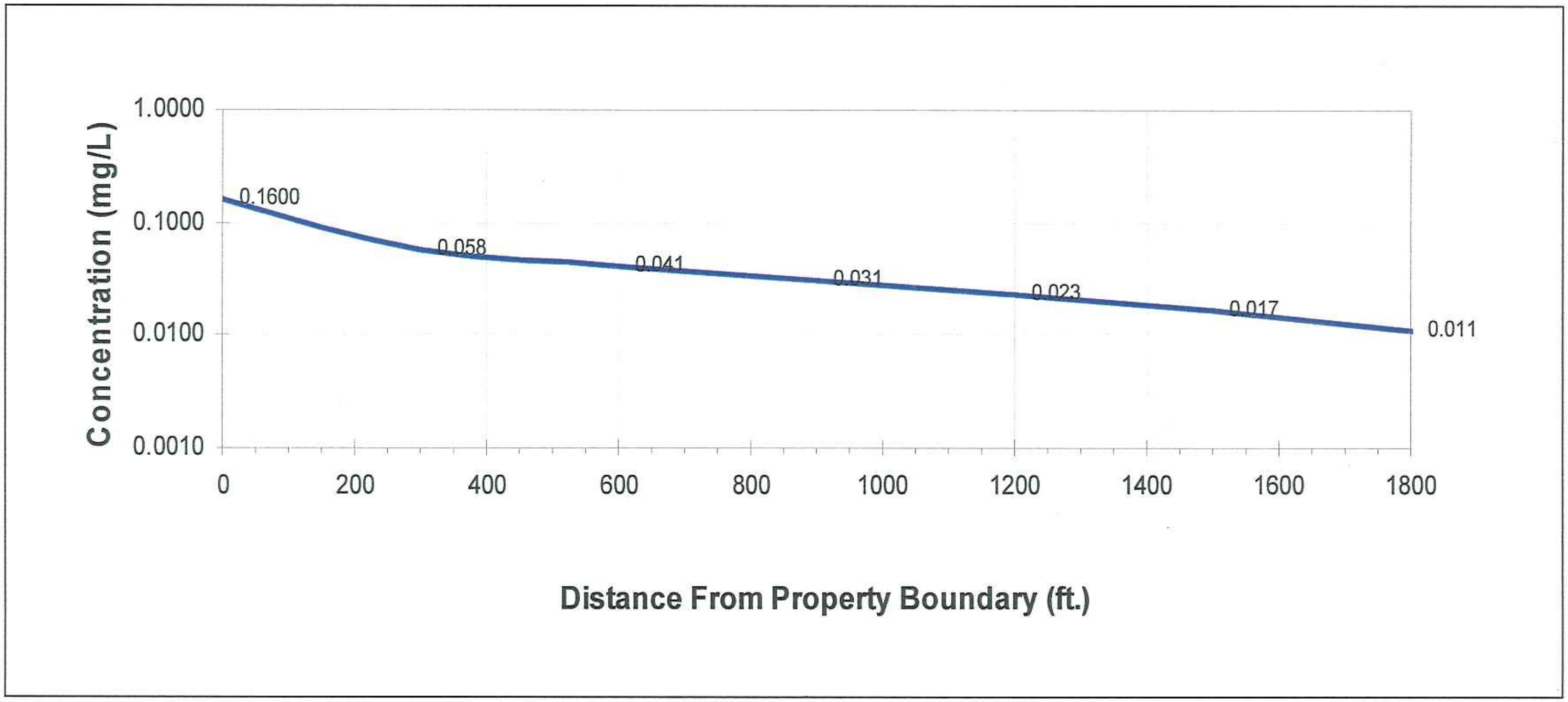

Figure A12
Fate and Transport Modeling for Site Specific CULs
Copper
Precision Engineering, Inc.
Seattle, Washington

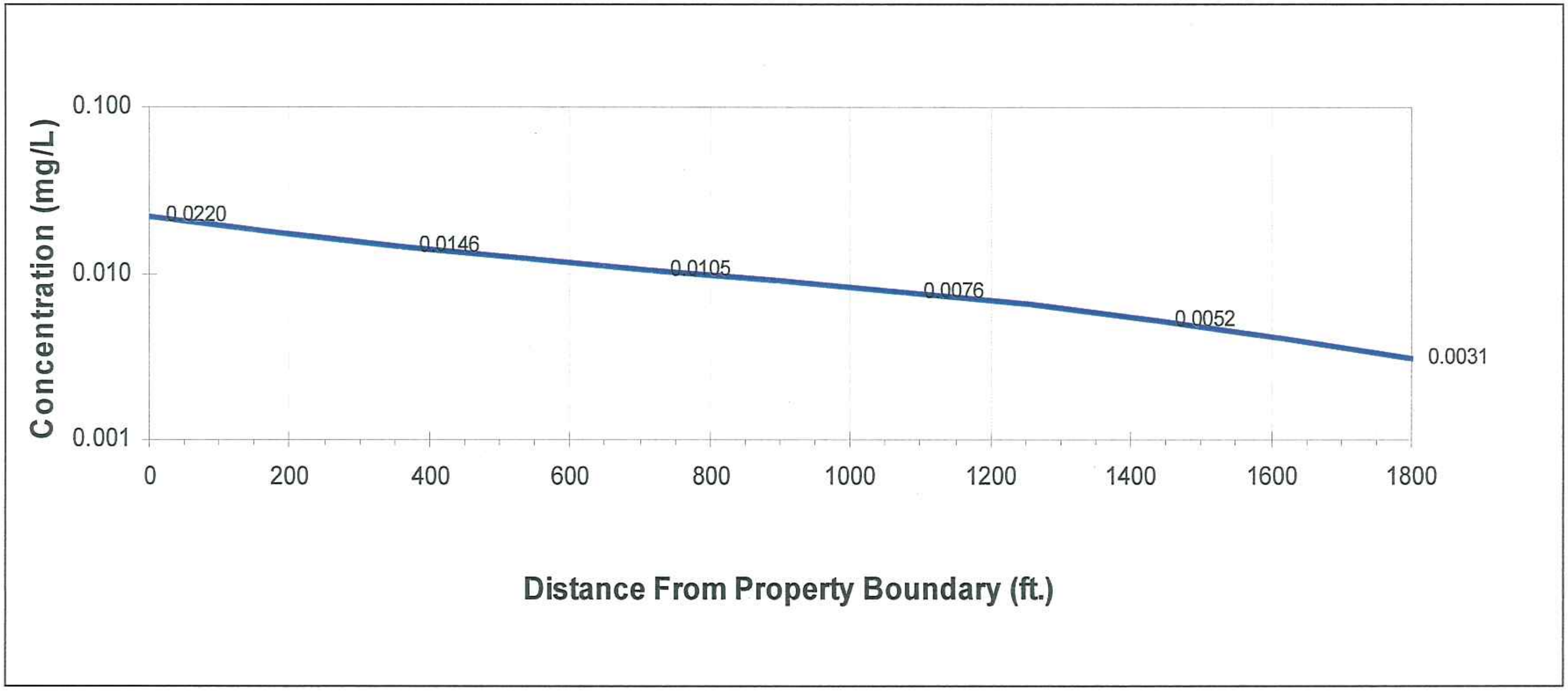

Figure A13
Fate and Transport Modeling for Site Specific CULs
TCE
Precision Engineering, Inc.
Seattle, Washington

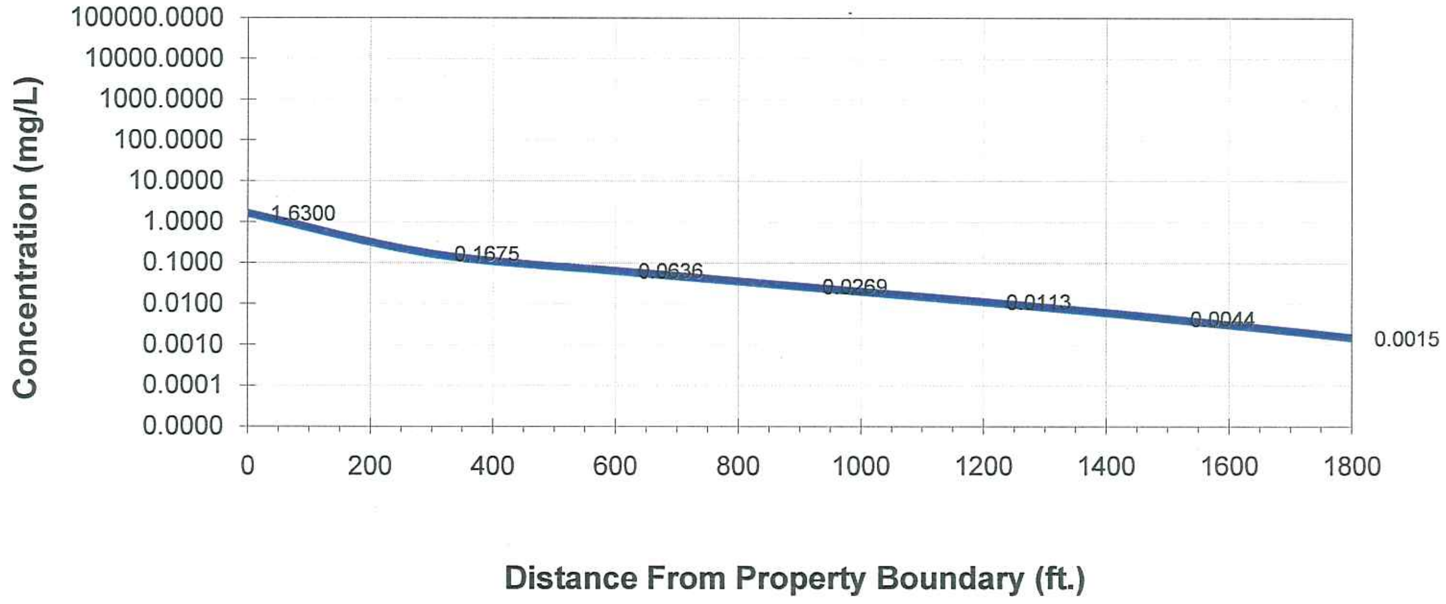

Figure A14
Fate and Transport Modeling for Site Specific CULs
Vinyl Chloride
Precision Engineering, Inc.
Seattle, Washington

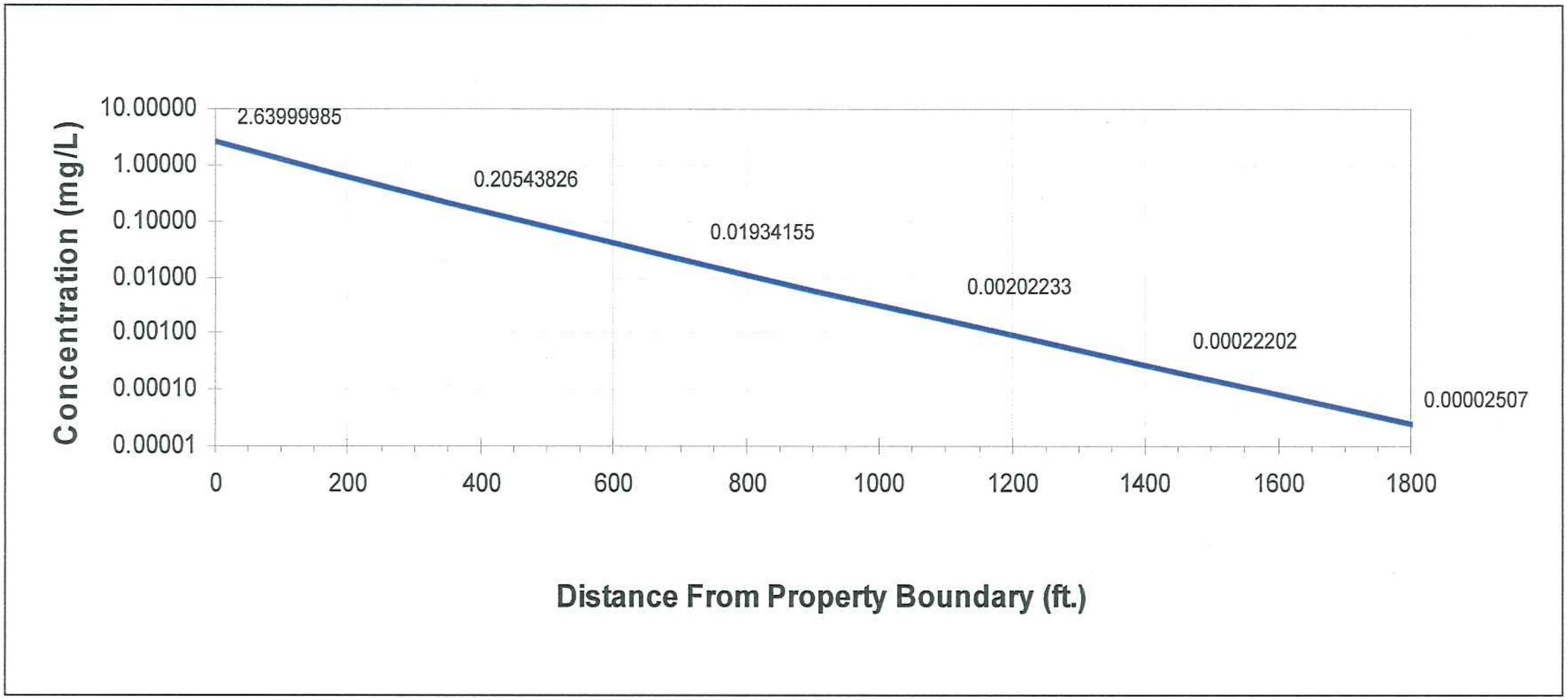

Figure A15
Fate and Transport Modeling for Site Specific CULs
Benzo(a)anthracene
Precision Engineering, Inc.
Seattle, Washington

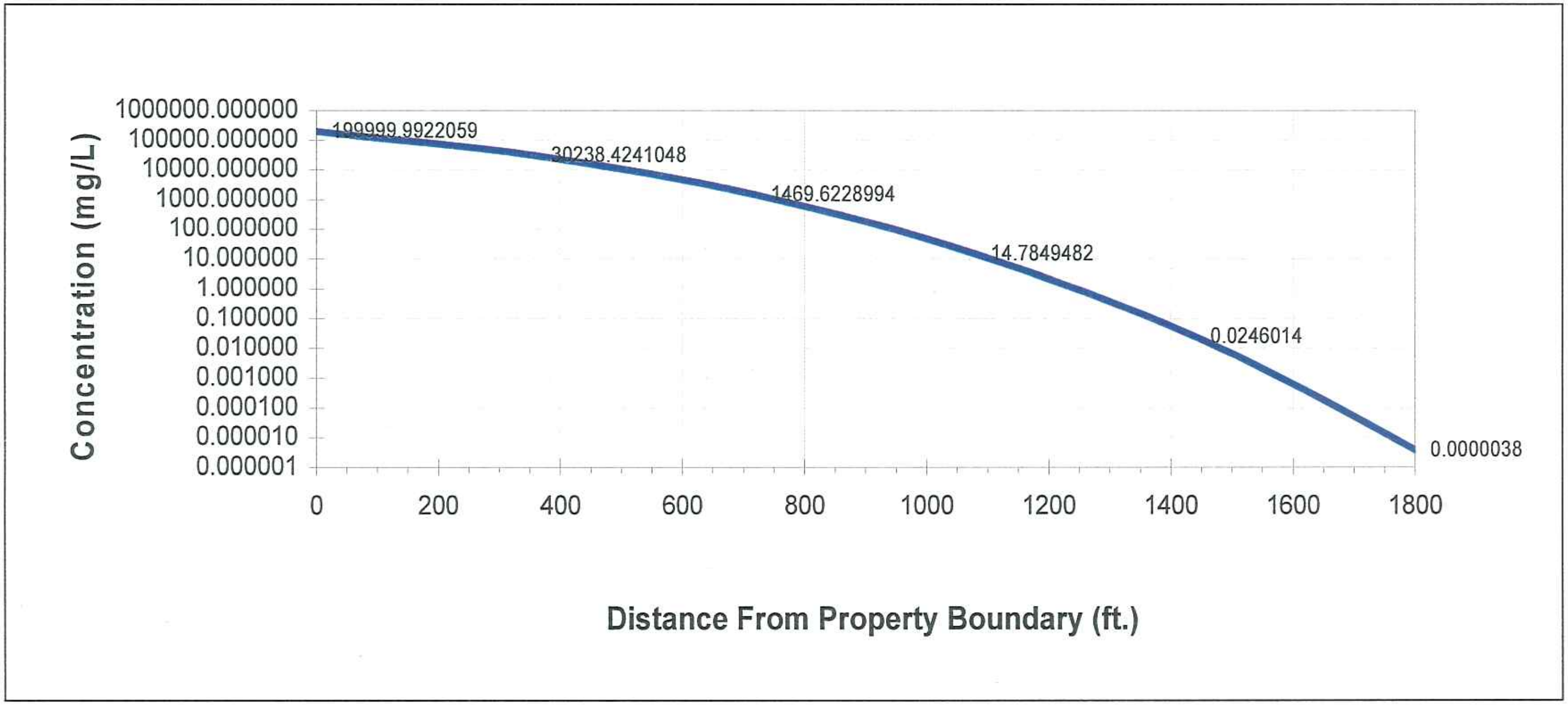

Figure A16
Fate and Transport Modeling for Site Specific CULs
Benzo(b)fluoranthene
Precision Engineering, Inc.
Seattle, Washington

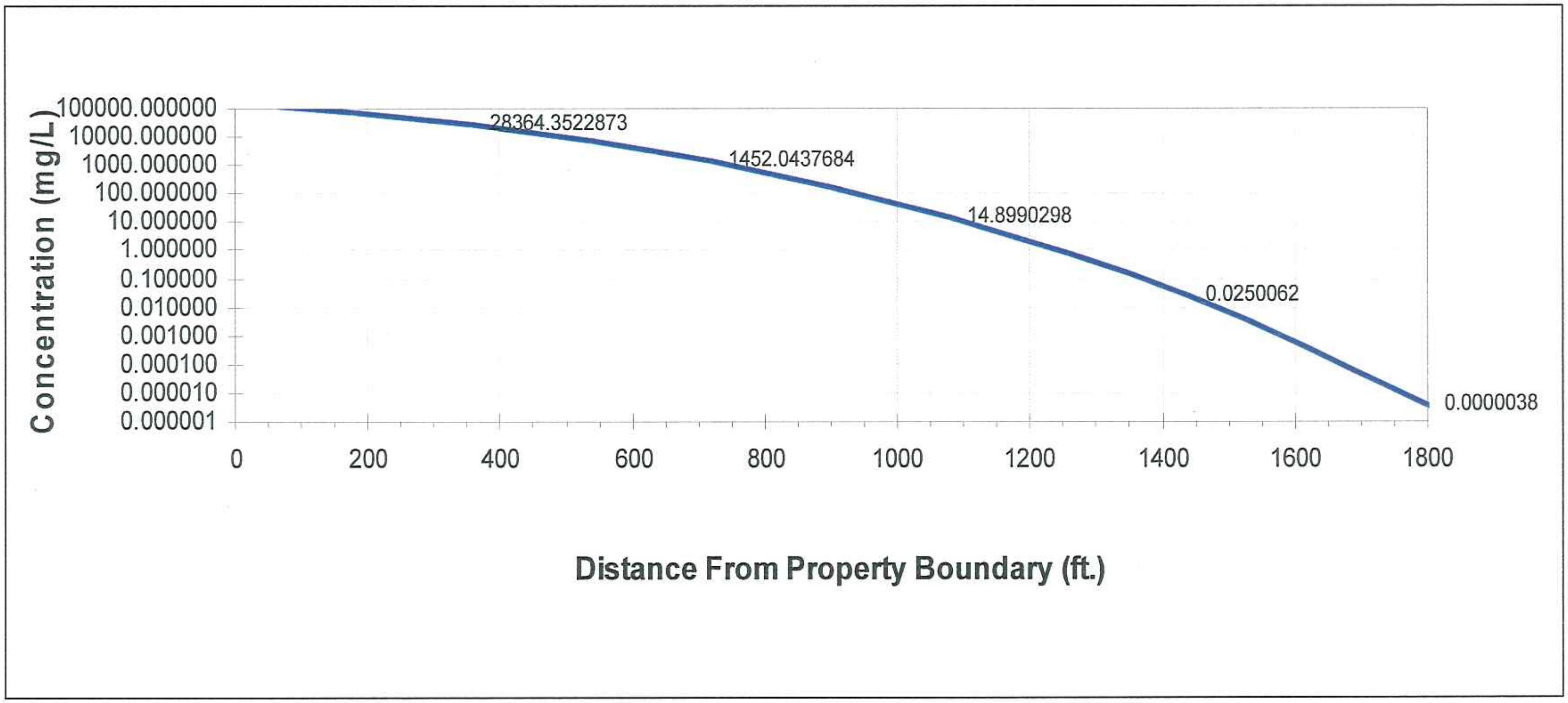

Figure A17
Fate and Transport Modeling for Site Specific CULs
Benzo(k)fluoranthene
Precision Engineering, Inc.
Seattle, Washington

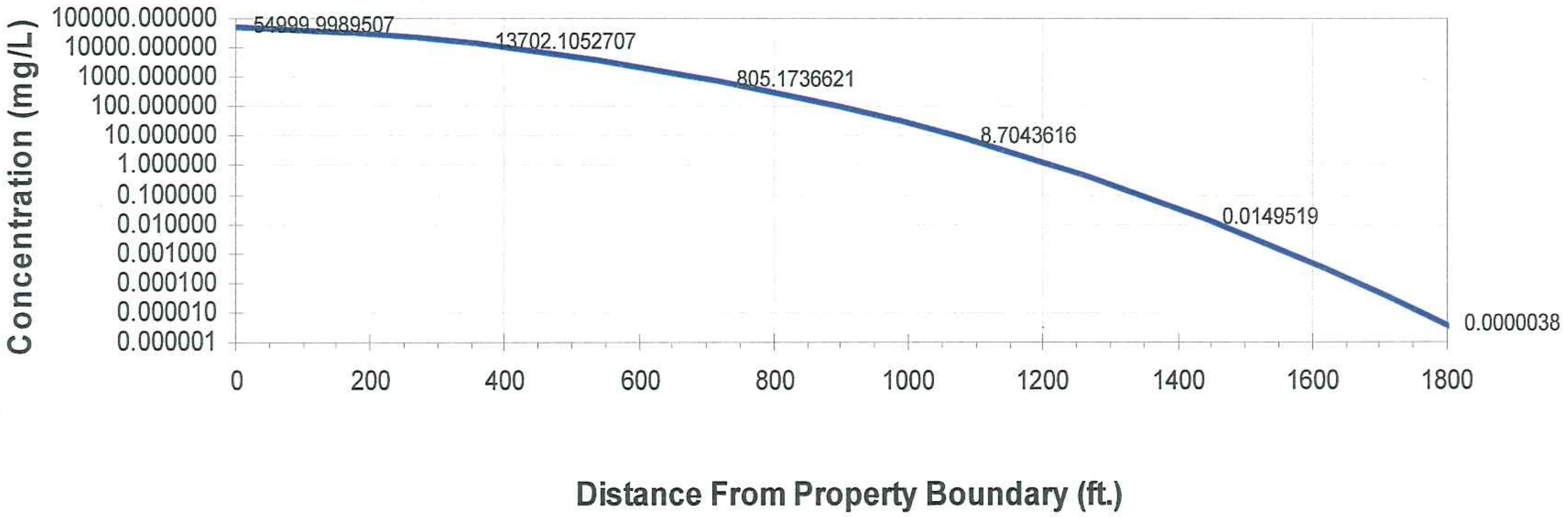

Figure A18
Fate and Transport Modeling for Site Specific CULs
Chrysene
Precision Engineering, Inc.
Seattle, Washington

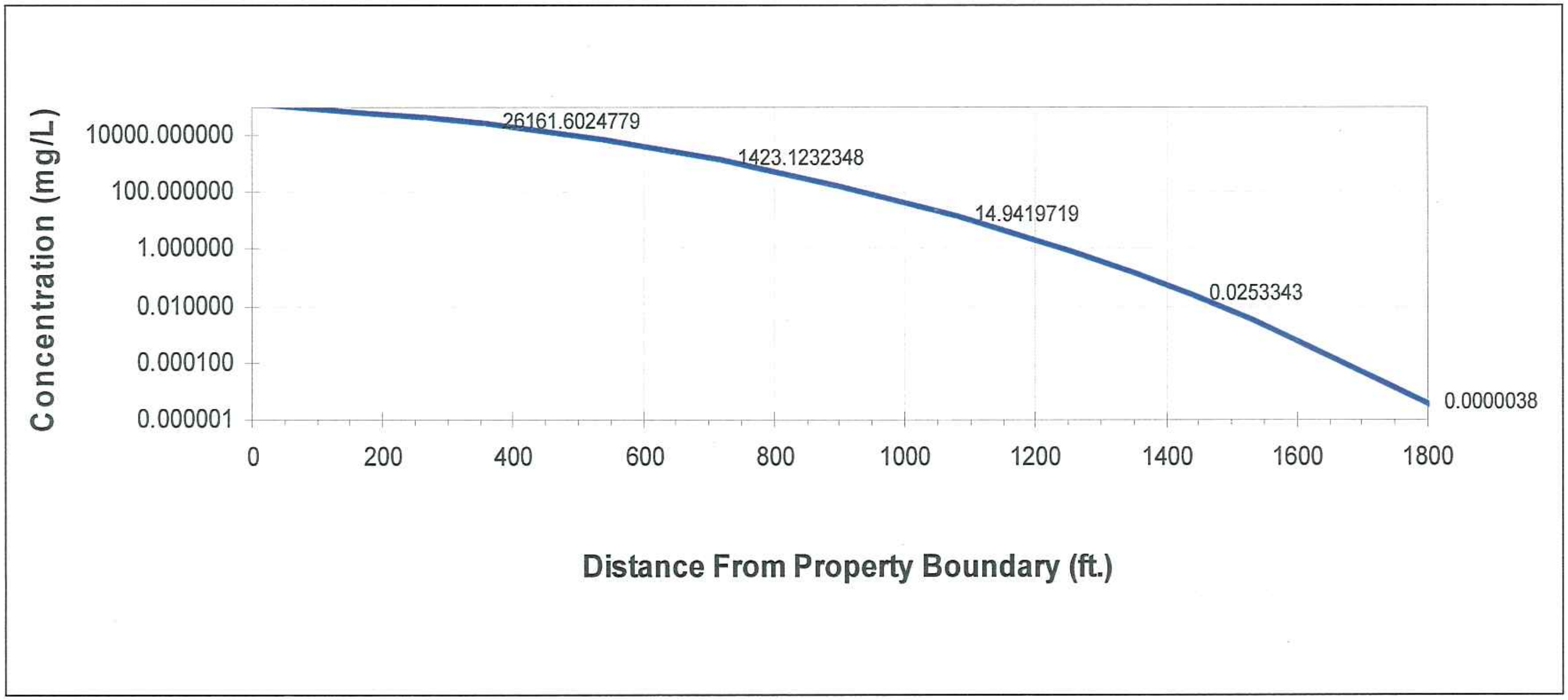

Figure A19
Fate and Transport Modeling for Site Specific CULs
Dibenzo(a,h)anthracene
Precision Engineering, Inc.
Seattle, Washington

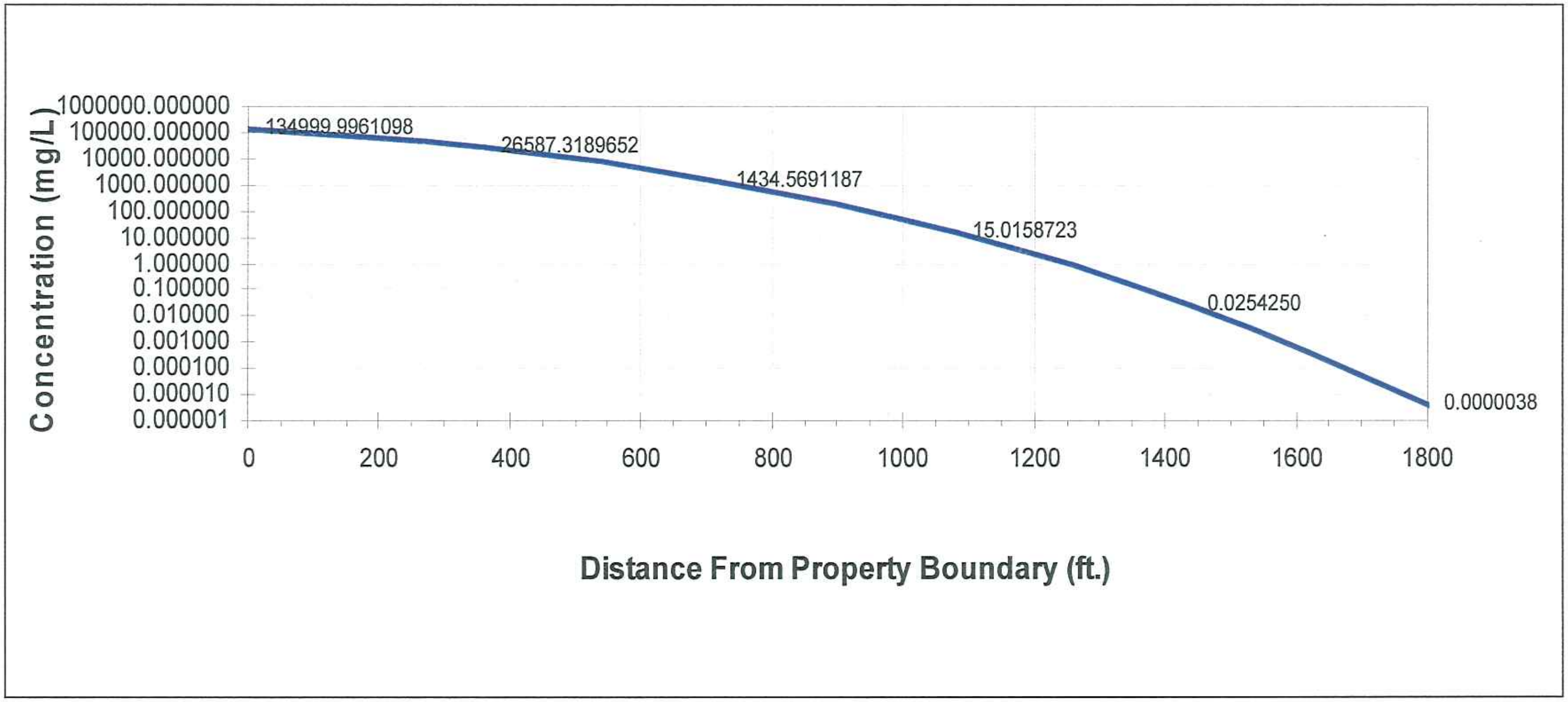

Figure A20
Fate and Transport Modeling for Site Specific CULs
Indeno(1,2,3-cd)pyrene
Precision Engineering, Inc.
Seattle, Washington