Appendix G
Engineered Cap Chemical Isolation Design Analysis

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ABBREVIATIONS

95% UCL	95 percent upper confidence limit of the mean
BODR	Basis of Design Report
Boeing	The Boeing Company
cfs	cubic feet per second
CIL	chemical isolation layer
COC	contaminant of concern
CUL	cleanup level
EPA	U.S. Environmental Protection Agency
f_{oc}	fraction organic carbon
FNC	Federal Navigation Channel
FS	Feasibility Study
ITRC	Interstate Technology and Regulatory Council
K_d	equilibrium partition coefficient
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
mg/kg	milligram/kilogram
OC	organic carbon
PCB	polychlorinated biphenyl
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RM	river mile
ROD	Record of Decision
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
ZVI	zero valent iron

1   Introduction

This appendix describes chemical transport modeling conducted for Area 18, which is located within the upper reach of the Lower Duwamish Waterway (LDW). As discussed in the Basis of Design Report (BODR), the interim remedy for this area is a partial dredge and cap that will return the finished grade to approximate pre-construction elevations. Area 18 is located between River Mile (RM) 3.7 and RM 3.8, between the Federal Navigation Channel (FNC) and an existing deteriorated bulkhead along the eastern bank of the LDW adjacent to the Boeing Isaacson-Thompson Site and Port of Seattle sliver property (see Figure G-1).

The upland site is currently in the Feasibility Study (FS) phase, and sources may not be sufficiently controlled by the time that upper reach remedial design (RD) is completed. Three options are presented in Section 10.3.2 of the BODR to address the management of contaminated sediments in Area 18. The preferred remedy (Option 1) is to defer in-water remedial work in Area 18 until an interim or final upland remedy is implemented and can integrate the in-water sediment remedy. This integrated approach is judged to be the most effective remedial option, because all remedial construction work in this area could be completed in a single, coordinated effort. An interim partial dredge and capping remedy (Option 2) is presented in Preliminary (30%) RD, since the Option 1 design cannot be completed before the upland cleanup is designed, and the timeline may fall outside the current upper reach design schedule but within the overall timeline of the LDW cleanup. Design for a final cleanup remedy in this transition area (interim capped area within the LDW upper reach and the upland cleanup remedy) will be closely coordinated with The Boeing Company (Boeing).

The modeling was conducted to evaluate a sediment cap at this location to address elevated concentrations of polychlorinated biphenyls (PCBs) and arsenic in sediments. The modeling analyses described herein were performed in accordance with guidance on cap design set forth by the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) (Palermo et al. 1998) and the Interstate Technology and Regulatory Council (ITRC; 2014). The primary goal of this modeling was to simulate the transport of PCBs and arsenic within an engineered cap to identify a chemical isolation layer configuration (i.e., thickness and composition) that will meet remedial action levels (RALs) set forth in the ROD (EPA 2014) for a moderately long period of time (i.e., long enough to allow time to design and construct an integrated remedy between the LDW and the Boeing Isaacson-Thompson upland cleanup site).

Figure G-1
Area 18–Partial Dredge and Cap Area

2   Approach

2.1   Model Framework

The one-dimensional model of chemical transport within sediment caps, Capsim (version 3.8; Reible 2017), was used for this evaluation. This model simulates the time-variable fate and transport of chemicals (dissolved and sorbed phases) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange with the overlying surface water within a sediment cap. This model and its predecessor versions have been used to support the evaluation and design of sediment caps at numerous cleanup sites around the United States and internationally. Details on the model structure and underlying theory and equations are provided in Lampert and Reible (2009), Go et al. (2009), and Shen et al. (2018).

2.2   Simulation Approach

As shown in the schematic on the left of Figure G-2, caps in clamming areas (including intertidal areas of Area 18) need to include a clam habitat layer on top of the cap erosion protection layer, which in turn is on top of the chemical isolation layer. At 30% RD, it has yet to be decided whether these layers will be separate, or whether a combined layer(s) will support more than one function (e.g., chemical isolation and erosion protection requirements can sometimes be met with a single layer of material). Therefore, for the purposes of the 30% RD, the model domain was simplified, such that the entire simulated cap thickness was represented as a layer of granular material having geotechnical properties that are representative of both the chemical isolation material and the erosion protection material[1] (i.e., porosity and dry bulk density; see schematic on the right of Figure G-2). As the design progresses, this simplified assumption will be revisited.

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[1] The key geotechnical parameters for cap design, porosity and bulk density, do not vary significantly between the typical materials that are used for chemical isolation and erosion protection.

Figure G-2
Cap Layer Configuration and Processes Modeled
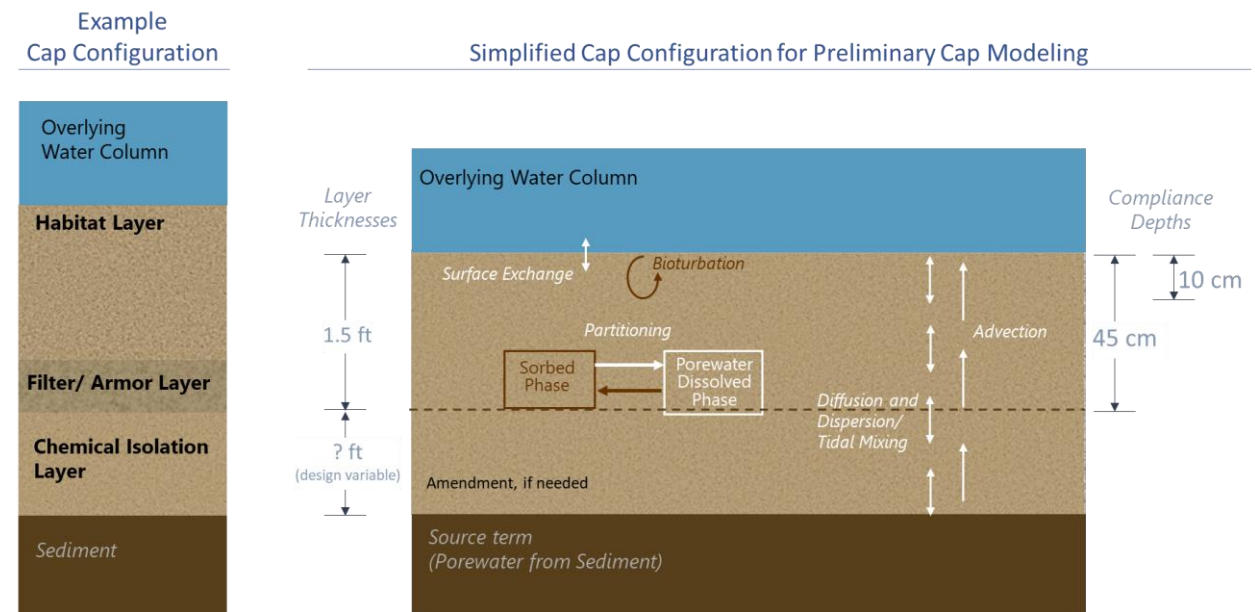
Notes:
The modeling approach conservatively ignored net sedimentation.
Consolidation of underlying sediments was not simulated; consolidation was assumed to be minimal where dredging occurs before material placement. This assumption will be revisited in future phases of design.

According to the ROD, LDW contaminants of concern (COCs) include four chemicals based on risk to human health, and 39 chemicals based on risk to benthic invertebrates. In Area 18, total PCBs and arsenic were evaluated as the driver COCs based on observed exceedances of RALs in this area.[2] PCBs were simulated as individual PCB homologs[3] in the model to account for the differences in homolog mobility. Model simulations were conducted to identify the cap thickness and composition (i.e., sorptive amendment content, if any, in the portion of the cap beneath the 45-cm depth) required to maintain PCB and arsenic concentrations less than performance target concentrations in surface sediment, as discussed subsequently.

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[2] RAL exceedances in surface (0-10 cm) sediment were also reported for each of the following: benzo(a,h)anthracene, total benzofluoranthenes, cPAHs, benzo(a)pyrene, chrysene, total HPAHs, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and butyl benzyl phthalate. The remedy that addresses PCBs will also address these chemicals.

[3] PCB concentrations were measured using an Aroclor-based method. To account for the range in mobility of the PCB congeners that make up an Aroclor, reported Aroclor PCB concentrations in sediment were converted to homolog concentrations based on the average fraction of each homolog group associated with each Aroclor developed from several published studies (Rushneck et al. 2004; Schulz-Bull et al. 1989; Frame et al. 1996; EPA 1995).

2.2.1   Performance Target Concentrations

For the purposes of this evaluation, performance targets for the cap design evaluation were set to the RALs. Consistent with Table 28 of the ROD, the RALs are dependent on the location, elevation type (i.e., intertidal vs. subtidal), recovery category (e.g., erosion potential), and depth interval in the sediment. The cap in Area 18 is located within the Recovery Category 2 area, and fully within the intertidal zone. Therefore, the performance of the cap in Area 18 was evaluated based on meeting the PCB and arsenic RALs that apply to sediment in the intertidal portion of Area 18 and within Recovery Category 2 as follows:

- PCBs: 12 mg/kg organic carbon (OC) total PCB in 0-10 cm; 65 mg/kg OC in 0-45 cm
- Arsenic: 57 mg/kg in 0-10 cm; 28 mg/kg in 0-45 cm

2.2.2   Cap Thickness and Compliance Intervals Considered

Four total cap thicknesses were evaluated: 2 ft, 2.5 ft, 3.5 ft, and 4.5 ft. For each cap thickness evaluated, compliance with performance targets was assessed in the top 10 cm and top 45 cm of the simulated cap material as per the targets discussed in the previous section. If necessary to meet performance targets, the lower portion of the cap (i.e., the cap material below a depth of 45 cm) was simulated to contain an amendment. The amendment content was considered a design variable in such cases. The upper 10 cm of the model domain was used for the bioturbation zone, where mixing by benthic activity was simulated.

3 Model Inputs

The Capsim model uses several input parameters that describe chemical-specific properties, cap material properties, and chemical mass transfer rates. These input parameters were developed based on Site-specific data, information from literature, and experience with cap design at other similar sites. A list of model input parameters, values used for this modeling assessment, and source(s) from which they were derived is provided in Table G-1. More details describing certain key model inputs are provided in Sections 3.1 through 3.3.

Table G-1
Input Parameter Values for the Chemical Isolation Cap Model

Model Input Parameter	Value	Data Source
Chemical-Specific Properties		
PCB porewater concentration	See Table G-3	Based on bulk sediment PCB concentrations from Samples SD-507-0020 and SD-507-0060[1], which represent the maximum and 95% UCL total PCB concentrations from Area 18, respectively. Homolog concentrations were estimated from individual Aroclor concentrations based on composition reported in literature. Porewater concentrations were calculated based on bulk sediment PCB and TOC concentrations and equilibrium partition coefficients. The model assumes a fixed concentration at the bottom boundary of the model (i.e., infinite source). See Sections 3.1 and 3.2 for more detail.
Arsenic porewater concentration	See Table G-3	Based on the maximum and 95% UCL arsenic concentrations in sediment from Area 18.[1] Porewater concentrations were calculated based on bulk sediment arsenic concentrations and partition coefficients. The model assumes a fixed concentration at the bottom boundary of the model (i.e., infinite source). See Sections 3.1 and 3.2 for more detail.
OC partition coefficients for PCB homologs, log K_{OC} (log L/kg)	See Table G-2	Based on partition coefficients developed as part of the Pre-Design Studies (Windward 2020). See Section 3.1 for more detail.
Partition coefficient for arsenic, log K_d (log L/kg)	See Table G-2	Values based on literature; separate values used for sorption to sand material versus sand amended with ZVI, with K_d calculated as a function of ZVI content for the latter. See Section 3.1 for more detail.

Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

Model Input Parameter	Value	Data Source
Molecular diffusivity (cm^2/s)	PCBs: 3.3E-06 to 6.5E-06 Arsenic: 1.2E-05	For PCB homologs, calculated based on molecular weight using correlation from Schwarzenbach et al. (1993). For arsenic, calculated based on molar volume using correlation from Hayduk and Laudie (1974). The model calculates an effective diffusion coefficient using this chemical-specific input value for the molecular diffusivity and an empirical equation based on the cap material porosity using the approach developed by Millington and Quirk (1961).
Chemical biodegradation rate (per year)	0	Assumed no biodegradation.
Upper Portion of Cap (Top 45 cm)		
Thickness (cm)	45	Based on the depth interval used for target sediment concentration.
Total porosity	0.4	Typical value for sand (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.56	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.4 for sand.
Fraction OC of bioturbation zone (%)	1%	Assumed 1% within the 10-cm bioturbation zone based on experience from other sites and the assumption that over time, the f_{OC} will increase toward levels similar to (but lower than) that of the current surface sediment, which is 1.6%.
Fraction OC of cap material below bioturbation zone	0.1%	Represents the sorptive capacity of the cap material within the 10- to 45-cm depth interval. A lower-bound estimate typically used to represent quarry sand where sorption to mineral fractions can also occur (Karickhoff 1984 and EPA 2000).
Lower Portion of Cap (Below 45 cm)		
Thickness (cm)	15 to 120 cm	Design variable. Multiple cap thicknesses evaluated, ranging from 2 ft (60 cm) to 4.5 ft (137 cm). Thickness of the lower portion of the cap (below 45 cm) ranged from 15 cm to 90 cm.
Total porosity	0.4	Typical value for sand (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.56	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.4 for sand. Value adjusted to account for quantity of ZVI added to address arsenic, as necessary. Dry bulk density of ZVI was 2.92 g/cm^3.
Fraction OC of cap material (%)	Design variable	Represents sorptive capacity of the cap material. Started with a nominal value of 0.1%. If the PCB RAL was not met with sand alone, this value was increased as necessary to represent an OC amendment to meet the PCB RAL.

Model Input Parameter	Value	Data Source
Mass Transport Properties		
Boundary layer mass transfer coefficient (cm/hr)	0.3	Midpoint of range of values compiled from laboratory and field site measurements reported in the literature (e.g., Thibodeaux et al. 2001; Martinez et al. 2010; Erickson et al. 2005) and values calibrated as part of models (1D and system-wide) of sediment/water exchange at other sites (e.g., Anchor QEA and GZA 2015; Connolly et al. 2000; EPA 2006).
Groundwater seepage rate (cm/yr)	400 and 800	Range of values estimated from MODFLOW model predictions developed by Fabritz et. al. (1998). See Section 3.3 for detail. This value may be refined in 60% RD based on additional evaluations.
Net sedimentation rate (cm/yr)	0	Conservatively assumed no future net sedimentation.
Dispersion length (cm)	Variable	Based on 20% of the model domain length (cap thickness). See Section 3.3 for detail.
Bioturbation zone thickness (cm)	10	The RI (Windward 2010) concluded that 10 cm can be reasonably estimated as depth of bioturbation in the LDW.
Particle biodiffusion coefficient (cm^2/yr)	1	Parameter represents bioturbation rate applied to the particulate phase; order of magnitude estimate represents midpoint between freshwater rivers and intertidal areas (Thibodeaux and Mackay 2011).
Porewater biodiffusion coefficient (cm^2/yr)	100	Parameter represents bioturbation rate applied to dissolved phase. Typical cap modeling approach is to use 100 times the particle biodiffusion coefficient (see row above) (Reible 2012).
Consolidation (cm)	0	Consolidation not simulated in this phase of design; parameter may be updated in the 60% RD phase.

Notes:

1. These data are included in the design dataset, which is described in detail in the DER (Anchor QEA and Windward 2022).

95% UCL: 95 percent upper confidence limit of the mean
f_{OC}: fraction organic carbon
K_d: equilibrium partition coefficient
K_{OC}: organic carbon partition coefficient
LDW: Lower Duwamish Waterway
OC: organic carbon
PCB: polychlorinated biphenyl
RAL: remedial action level
RD: remedial design
RI: Remedial Investigation
TOC: total organic carbon
ZVI: zero valent iron

3.1   Partitioning Coefficients

Partitioning of chemicals between the dissolved and sorbed (i.e., cap material) phases is described in the model by the chemical-specific equilibrium partition coefficient (K_d). This approach assumes sorption follows a linear isotherm and is instantaneous (not rate-limited) and reversible. For organic compounds, such as PCBs, the partition coefficient is calculated in the model based on the customary K_d = fraction organic carbon (f_{OC})*organic carbon partition coefficient (K_{OC}) approach (e.g., Karickhoff 1984), where K_{OC} is the compound's OC partition coefficient and f_{OC} is the OC fraction of the solid phase (i.e., cap material). For arsenic, K_d values were defined for two potential cap materials.

Site-specific partitioning data were not available for arsenic. Arsenic partitioning onto sand or sediment was based on the mean log K_d value reported for sediment by Allison and Allison (2005) of 2.4 log L/kg. As necessary, the modeling evaluation considered amendment of sand cap material to limit transport of arsenic, which was represented in the model as a sorption term. For the purposes of this evaluation, zero valent iron (ZVI) was the assumed amendment. The log K_d value used to simulate the sorption of arsenic onto ZVI was set to 3.6 log L/kg (Nikolaidis et al. 2003). When simulating sand amended with ZVI, a weighted average K_d to represent the effective strength of sorption to ZVI, accounting for the percent by weight ZVI in the bulk mixture, was used in the model.

For PCBs, model simulations were performed at the homolog level to represent the range of chemical mobility associated with the congeners that make up the total. Log K_{OC} values for each homolog group were calculated from the empirical relationship developed from the data collected as part of the Pre-Design Studies (log K_{OC} = 0.77 × Log K_{OW} + 1.5) using the K_{OW} values from Hawker and Connell (1988) (Windward 2020). Windward (2020) confirmed that effects from black carbon on partitioning within site-sediments were minimal; therefore, these Site-specific partition coefficients were used to represent partitioning onto sediments as well as sand cap material. Log K_{OC} values by homolog group are shown in Table G-2.

Table G-2
Partitioning Coefficients Used in the Cap Model

Chemical Name	OC Partition Coefficient, Log K$_{OC}$ (log L/kg)	Partition Coefficient, Log K$_d$ (log L/kg)
Arsenic (Sand)	--	2.4
Arsenic (ZVI)	--	3.6
PCB-Mono	5.1	--
PCB-Di	5.4	--
PCB-Tri	5.8	--
PCB-Tetra	6.1	--
PCB-Penta	6.4	--
PCB-Hexa	6.7	--
PCB-Hepta	7.0	--
PCB-Octa	7.3	--
PCB-Nona	7.5	--
PCB-Deca	7.8	--

Notes:
--: Not relevant
K$_d$: equilibrium partition coefficient
K$_{OC}$: organic carbon partition coefficient
OC: organic carbon
PCB: polychlorinated biphenyl
ZVI: zero valent iron

3.2 Porewater Concentrations

The porewater concentration input defines the source term in the cap model and corresponds to the contaminant concentrations present in the porewater immediately beneath the cap. Porewater was not sampled in Area 18; therefore, PCB and arsenic concentrations in sediment porewater were calculated from vertical core interval sediment concentrations collected from Area 18 using the equilibrium partitioning coefficients discussed in Section 3.1. For this evaluation, all data collected from within Area 18 were used. Simulations were conducted using both the maximum and 95% UCL concentrations, which were calculated using ProUCL.

3.2.1   Arsenic

For arsenic, the maximum sediment concentration (1,100 mg/kg from Sample LDW-SS114-010 [0 to 10 cm]) and the 95% UCL of the mean (347 mg/kg[4] [sample count = 59]) were selected for modeling. These sediment concentrations were converted to porewater using the log K_d of 2.4 log L/Kg listed in Table G-2. Because of the uncertainty in arsenic species present at the Site (i.e., dissolved or precipitated form), the porewater concentration derived from literature partition coefficients was compared to the range in dissolved groundwater concentrations measured in monitoring wells on the adjacent Boeing Isaacson-Thompson Site and Port of Seattle Sliver property (Landau Associates 2020).

The estimated porewater concentration of arsenic in Area 18 sediments was within the range measured in groundwater from monitoring wells located along the shoreline (note, dissolved concentrations in groundwater are greater in monitoring wells further from shore in the upland direction, suggesting attenuation is occurring as groundwater moves towards the LDW). As presented in the Boeing Isaacson-Thompson Site FS, alkaline conditions in groundwater may increase arsenic mobility. Arsenic concentrations in porewater depend on multiple factors, including pH, dissolved oxygen, redox conditions, and other geochemical characteristics. This means the arsenic concentrations in porewater may be different from those reported in groundwater for adjacent upland wells.

Pathway or geochemical studies of arsenic have not been performed in Area 18, so it is not known whether the arsenic precipitates out of solution before entering the BAZ of the sediments. Because of large tidal variations in the LDW, it is reasonable to assume that dissolved oxygen is present in the surface sediment porewater, which could cause arsenic to precipitate out of solution and become immobile. That said, because supporting data are not available, this evaluation conservatively assumed the arsenic is mobile throughout the full thickness of the sediment layer (and within the simulated cap). Until additional data can be collected to better characterize the geochemical conditions and porewater concentrations of arsenic at the Site, the concentrations used in this evaluation are considered representative (but are recognized as uncertain).

3.2.2   PCBs

For PCBs, the sediment samples with OC-normalized PCB concentrations equal to the maximum (Sample SD-507-0020 [61 to 91 cm depth interval], with a total PCB concentration of 110 mg/kg OC) and 95% UCL (23.6 mg/kg OC[5] [sample count = 63]) were selected for use in the model. The total PCB concentration associated with sample SD-507-0060 was equal to the 95% UCL; therefore, the

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[4] ProUCL selected statistic for arsenic: 95% Chebyshev (Mean, Sd) UCL
[5] ProUCL selected statistic for total PCBs: 95% KM Approximate Gamma UCL

Aroclor composition of this sample was used to represent the 95% UCL. PCB concentrations were measured using an Aroclor-based method. To account for the range in mobility of the PCB congeners that make up an Aroclor, reported Aroclor PCB concentrations in sediment were converted to homolog concentrations based on the average fraction of each homolog group associated with each Aroclor developed from several published studies (Rushneck et al. 2004; Schulz-Bull et al. 1989; Frame et al. 1996; EPA 1995). The sediment PCB homolog concentrations were then converted to porewater concentrations using the log K_{OC} values listed in Table G-2.

The porewater concentrations used in the model evaluations are provided in Table G-3.

Table G-3
Porewater Concentrations Used in the Cap Model

Chemical Name	Maximum (µg/L)	95% UCL (µg/L)
Arsenic	4.3E+03	1.4E+03
PCB-Mono	1.3E-04	3.3E-05
PCB-Di	1.9E-03	4.7E-04
PCB-Tri	1.2E-02	3.2E-03
PCB-Tetra	2.1E-02	4.5E-03
PCB-Penta	1.6E-02	2.7E-03
PCB-Hexa	4.6E-03	9.7E-04
PCB-Hepta	6.5E-04	2.2E-04
PCB-Octa	5.4E-05	2.1E-05
PCB-Nona	3.0E-06	1.2E-06
PCB-Deca	1.2E-07	4.9E-08
Total PCB[1]	5.6.E-02	1.2.E-02

Note:

2. Total PCB is included for reference only; total PCB was not simulated with the model. PCBs were simulated by homolog group, and results were summed to calculate total PCBs for comparison with RALs.

95% UCL: 95 percent upper confidence limit of the mean
PCB: polychlorinated biphenyl
RAL: remedial action level

3.3 Groundwater Seepage and Dispersion

Direct measurements of groundwater seepage rates in the project area were not available. Therefore, seepage rates were estimated from the groundwater flow modeling study documented by Fabritz et. al. (1998). In this study, a three-dimensional model of the Duwamish River Basin was developed using the US Geological Survey MODFLOW framework. As part of that study, predicted cumulative discharge to LDW was presented as a function of location along 12 miles of river (see Figure G-3,

which is adapted from Figure 11 of Fabritz et al. [1998]). To estimate the seepage rate in Area 18, the change in cumulative discharge with distance in the project area, as shown in Figure G-3, was reviewed. The increase in discharge with distance appears to differ somewhat among three sections of the river. Discharge is predicted to be the greatest from the river outlet to RM 2.75, as illustrated by the steeper slope shown in Figure G-3. The slope becomes flatter from RM 2.75 to RM 5; Area 18 is located between RM 3.6 and RM 3.7 (identified by a star on Figure G-3). The flatter slope from RM 6 to 9.5 suggests lower discharge to the LDW in this area.

Figure G-3
Cumulative Discharge to the Lower Duwamish Waterway Predicted by MODFLOW Model
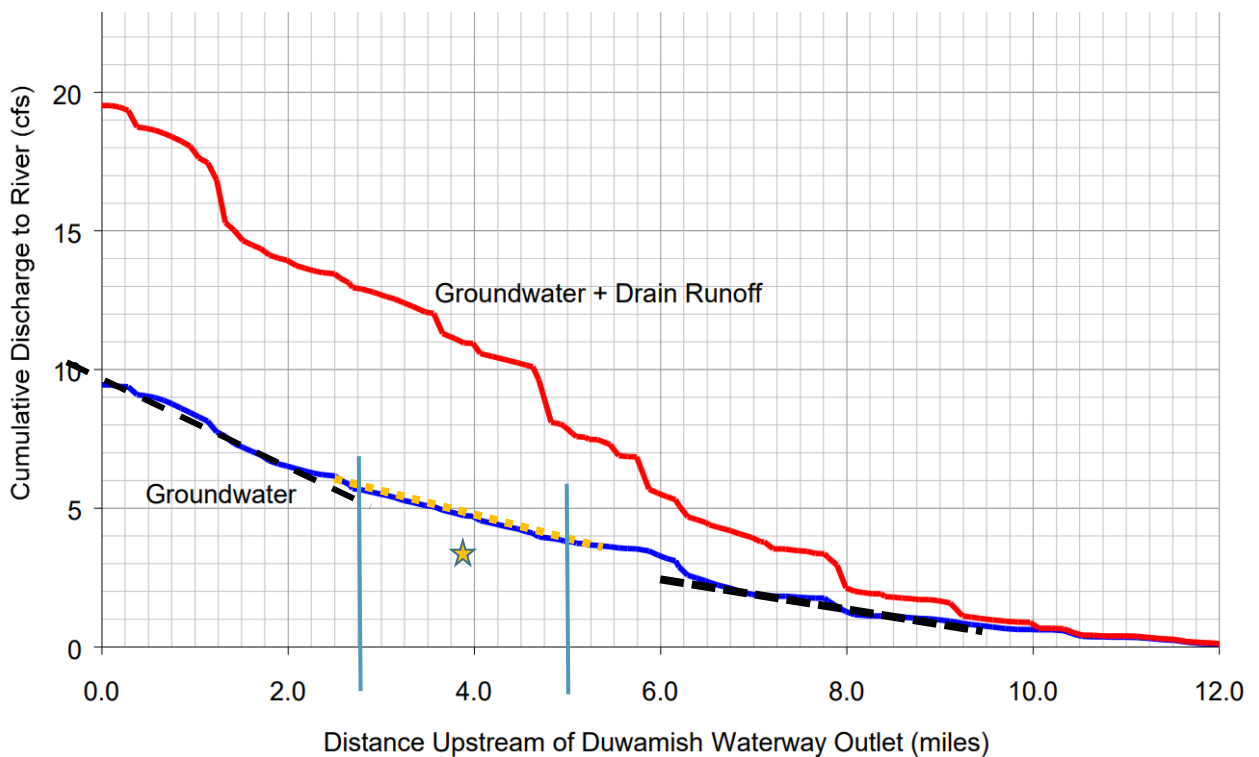
Notes:
Source: Figure 11 from Fabritz, J., J. Massmann, and D. Booth, 1998. Development of a Three-Dimensional, Numerical Groundwater Flow Model for the Duwamish River Basin
The dashed lines, vertical blue lines, and star were not part of original figure.
Dashed lines represent the three general discharge patterns observed in the river (based on change in slope). The yellow dashed line represents the consistent change in discharge over the portion of the river where Area 18 is located. Area 18 is represented by the star. Seepage was calculated as the change in cumulative discharge between the two vertical blue lines (2.25 miles).

Within the portion of the waterway where Area 18 is located, discharge changes by 2 cubic feet per second (cfs) over 2.25 miles (11,880 ft), as illustrated by the yellow dotted line on Figure G-3. The LDW is approximately 400 ft wide in this section. The Darcy flux can therefore be calculated as the

change in discharge over a specified distance (2 cfs), divided by surface area, which equals the specified distance (11,880 ft) multiplied by the width of the river (400 ft). The resulting Darcy flux is approximately 400 cm/yr.

This calculation assumes the flow to the river is distributed evenly across its width. Figure G-4, which is adapted from Figure 8 of Fabritz et. al. (1998), shows a cross section view of the river near Area 18, with model-predicted groundwater flow paths. Based on this figure, the majority of the flow is expected to discharge in the nearshore areas. Thus, the Darcy flux closer to the center of the channel could be closer to 100 cm/yr or less whereas closer to shore within Area 18, the Darcy flux could be closer to 800 cm/yr (assuming the majority of flow discharges to half the area along shore). Model simulations were therefore conducted using values of 400 and 800 cm/yr, both of which are considered equally valid in the absence of Site-specific measurements. Site-specific measurements are recommended for refining this value in the future.

Figure G-4
Flow Paths to Lower Duwamish Waterway Predicted by MODFLOW Model
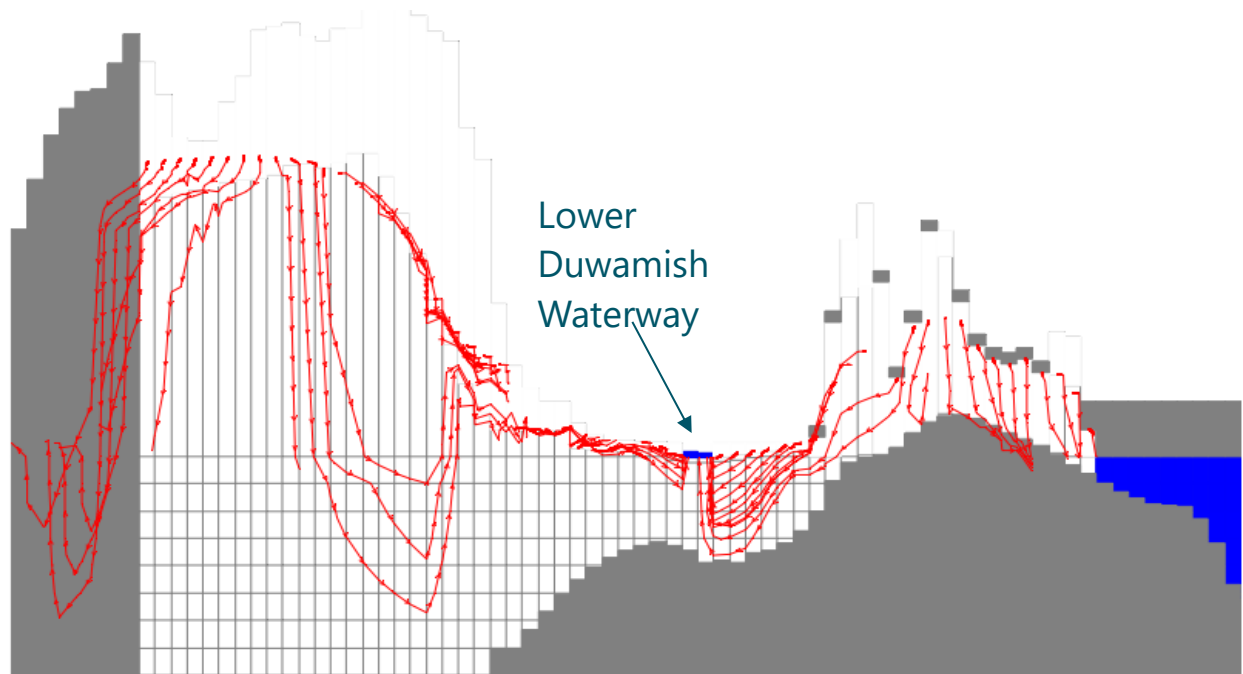
Cross-Section View – Row 57

Notes:
Source: Figure 8 from Fabritz, J., J. Massmann, and D. Booth, 1998. Development of a Three-Dimensional, Numerical Groundwater Flow Model for the Duwamish River Basin
Area 18 is located to the right of the LDW in this diagram.

Darcy fluxes assumed in cap design evaluations in other portions of the LDW range from 56.8 to 590 cm/yr, as shown in Table G-4, which are generally consistent with the range considered here.

Table G-4
Seepage Rates Assumed for Modeling Conducted for Cap Design at Other Nearby Sites

Site	Assumed Seepage Rate (cm/yr)	Reference
EMJ Jorgensen	250	USACE 2016
Duwamish Diagonal	56.8	June 2003
Slip 4 100% Design	312	Integral Consulting Inc. 2007
LDW FS	250 (106 – 590)	AECOM 2010

Dissolved phase transport within the cap may also be influenced by tidal fluctuations in the LDW, which can result in daily reversals in hydraulic gradient and advective flow. Representing tidal mixing with a dispersion coefficient is a common approach in groundwater modeling (e.g., La Licata et al. 2011). Dispersivity values for flow in porous media over relatively short distances are typically in the range of 1% of the domain length (consistent with typical value used in cap modeling [Reible 2012]), whereas those associated with large-scale groundwater plumes are on the order of 10% (Gelhar et al. 1992; Neuman 1990).

In this capping evaluation, the hydrodynamic dispersivity was set to a higher value of 20% of the cap thickness to represent hydraulic gradient variations and reversals from tidal fluctuations as a dispersion process. This dispersivity value (i.e., 20% of domain length) is consistent with values used in the final cap designs conducted at other tidally influenced sites, such as the Former Portland Gas Manufacturing Site (located on the Lower Willamette River just upstream of Portland Harbor, Oregon), where dispersivity was estimated based on the comparative strengths of tidal signals in hourly seepage meter measurements (Appendix C of Anchor QEA 2020), and Gloucester Harbor, Massachusetts, where dispersivity was derived from model calibrations to vertical profiles of salinity in porewater (Anchor QEA and GZA 2015; Reidy et al. 2015).

4   Model Results

Modeling was conducted to evaluate the effectiveness of four cap configurations in meeting the RALs that apply to Area 18. Cap thicknesses of 2 ft (Scenario 1), 2.5 ft (Scenario 2), 3.5 ft (Scenario 3) and 4.5 ft (Scenario 4) were considered. The caps were evaluated under two seepage rates—400 cm/yr and 800 cm/yr—and for two porewater concentrations—maximum and 95% UCL—for both PCBs and arsenic.

Model-predicted concentrations over the 100-year simulation period are provided in the attached Figures G-5 though G-20 for each scenario simulated. These figures show predicted increases in concentrations in the 0-10 cm (top panel) and the 0-45 cm (bottom panel of the cap) over time in some cases. For PCBs, in addition to total PCB, the individual homologs that contribute to the total PCB concentration are shown.

Model-predicted concentrations for the 100-year simulation period were compared to the RALs to evaluate the performance of the cap, including whether concentrations were predicted to exceed the RALs (and if so, when). Table G-5 shows the results with respect to which scenarios resulted in a predicted RAL exceedance and the time at which the RAL was predicted to be exceeded, if applicable.

Table G-5
Model-Predicted Time to Exceed the RALs for Four Cap Thicknesses Evaluated

Depth of Interest (cm)	RAL	Predicted Time to Exceed RALs (Years)[1]							
		Scenario 1 2 ft Cap (0.5 ft CIL)		Scenario 2 2.5 ft Cap (1 ft CIL)		Scenario 3 3.5 ft Cap (2 ft CIL)		Scenario 4 4.5 ft Cap (3 ft CIL)	
		400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr
PCBs – 95% UCL									
0 to 10	12 mg/kg OC	100+	100+	100+	100+	100+	100+	100+	100+
0 to 45	65 mg/kg OC	100+	100+	100+	100+	100+	100+	100+	100+
PCBs– Maximum									
0 to 10	12 mg/kg OC	100+	100+	100+	100+	100+	100+	100+	100+
0 to 45	65 mg/kg OC	100+	100+	100+	100+	100+	100+	100+	100+
Arsenic – 95% UCL									
0 to 10	57 mg/kg	29	14	40	18	62	27	88	37
0 to 45	28 mg/kg	8	4	14	7	25	13	37	19
Arsenic – Maximum									
0 to 10	57 mg/kg	18	9	24	12	35	17	47	22
0 to 45	28 mg/kg	4	2	9	5	17	9	26	13

Notes:
1.100+ indicates predicted concentrations were lower than RAL throughout the 100 year simulation.
95% UCL: 95 percent upper confidence limit of the mean
CIL: chemical isolation layer
OC: organic carbon
RAL: remedial action level

For simulations of PCBs using both the 95% UCL and the maximum concentrations, model results indicate that concentrations in the cap surface were not predicted to exceed the RALs within the 100-year simulations. Thus for PCBs, a 2-ft sand cap was predicted to be sufficient to meet the RALs for more than 100 years for each Darcy flux evaluated (see Table G-5 and Figures G-5a G-5b, G-9a, and G-9b).

For arsenic, the RAL of 28 mg/kg in the 0- to 45-cm depth interval is the more stringent of the two criteria. For simulations using the 95% UCL concentration as the source term, arsenic concentrations were predicted to exceed the RAL within 4 to 37 years, depending on cap thickness and Darcy flux (see Figures G-13 through G-16). For simulations using the maximum concentration as the source term, arsenic concentrations were predicted to exceed the RAL within 2 to 26 years, depending on cap thickness and Darcy flux (see Figures G-17 through G-20).

As previously stated, the cap within this portion of Area 18 is intended to be an interim remedy until dredging can be completed in coordination with the future upland remedy, which may entail bulkhead demolition, repair, or replacement. The estimated timeframe for when upland cleanup activities could commence is assumed to be about 10 years. Thus, the cap is assumed to need to protect against RAL exceedances for a minimum of 10 years. Conservatively, cap configurations under which the arsenic RAL was predicted to be exceeded in 25 years or less were simulated with the addition of 10% by weight ZVI in the lower portion of the cap (below 45 cm). Table G-6 shows the predicted times for arsenic RAL exceedances in these scenarios with the simulated ZVI amendment. Temporal profiles of arsenic within the top 10 cm and top 45 cm of the cap for these scenarios are shown in Figures G-21 through G-28.

Table G-6
Model-predicted Time to Exceed the RALs for Four Cap Thicknesses Evaluated Assuming 10% by Weight ZVI in Lower Portion of the Cap

Depth of Interest (cm)	RAL	Time to Exceed RALs (Years)							
		Scenario 1 2 ft Cap (0.5 ft CIL)		Scenario 2 2.5 ft Cap (1 ft CIL)		Scenario 3 3.5 ft Cap (2 ft CIL)		Scenario 4 4.5 ft Cap (3 ft CIL)	
		400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr	400 cm/yr	800 cm/yr
Arsenic – 95% UCL									
0 to 10	57 mg/kg	39	18	63	29	NA	53	NA	79
0 to 45	28 mg/kg	13	7	26	13	NA	27	NA	42
Arsenic – Maximum									
0 to 10	57 mg/kg	24	12	38	18	68	32	NA	47
0 to 45	28 mg/kg	8	4	18	9	39	20	NA	30

Notes:
NA = not applicable. Cap configuration with no ZVI amendment predicted to meet RALs for more than 25 years.
95% UCL: 95 percent upper confidence limit of the mean
CIL: chemical isolation layer
RAL: remedial action level
ZVI: zero valent iron

Model results indicate that a 2.5-ft cap with 10% by weight ZVI in the lower 1 ft of the cap is predicted to be needed to meet the RALs for 10 years, based on the 95% UCL arsenic concentration in sediment beneath the cap and considering both values for seepage rate. Using the maximum arsenic concentration in sediment beneath the cap, a 3.5-ft cap (Scenario 3) with 10% ZVI by weight is predicted to be needed to meet RALs for more than 10 years for both seepage rates.

5   Summary

Chemical transport modeling was conducted to evaluate the performance of a range of cap thicknesses considered for the nearshore portion of Area 18 at the Site. Modeling indicates that for PCBs, a 2-ft sand cap is predicted to meet the PCB RALs for more than 100 years. For arsenic, cap thicknesses of 3.5 ft and 4.5 ft without amendment are predicted to be needed to meet the RALs for more than 10 years, for the 95% UCL and maximum porewater concentrations, respectively. Thinner caps of 2.5 ft and 3.5 ft, amended with 10% ZVI by weight in the lower portion, are predicted to be needed to meet the arsenic RALs for more than 10 years, for the 95% UCL and maximum porewater concentrations, respectively. These simulations are conservative and ignored net sedimentation, which would enhance the performance of the cap.

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Figures G-5 to G-20

Average over top 10 cm

Concentration @ 100 years: 0.39 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 5.86 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-5a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 1.61 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 11.17 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
- PCB-mono
- PCB-di
- PCB-tri
- PCB-tetra
- PCB-penta
- PCB-hexa
- PCB-hepta
- PCB-octa
- PCB-nona
- PCB-deca
- TPCB

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Figure G-5b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(800 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.24 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC) vs Time (years)

Average over top 45 cm

Concentration @ 100 years: 2.74 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC) vs Time (years)

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
- PCB-mono
- PCB-di
- PCB-tri
- PCB-tetra
- PCB-penta
- PCB-hexa
- PCB-hepta
- PCB-octa
- PCB-nona
- PCB-deca
- TPCB

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Figure G-6a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 1.15 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 6.86 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-6b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(800 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.1 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Average over top 45 cm

Concentration @ 100 years: 0.84 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-7a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.64 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 3.0 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
PCB-mono | PCB-penta | PCB-nona
PCB-di | PCB-hexa | PCB-deca
PCB-tri | PCB-hepta | TPCB
PCB-tetra | PCB-octa

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Figure G-7b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(800 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.05 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Average over top 45 cm

Concentration @ 100 years: 0.33 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

— PCB-mono	— PCB-penta	— PCB-nona
— PCB-di	— PCB-hexa	— PCB-deca
— PCB-tri	— PCB-hepta	— TPCB
— PCB-tetra	— PCB-octa	

File Path: \\athena\Syracuse\Projects\Lower Duwamish Waterway\MODEL\BODR\CapSim_3-8\python\CapSim_Plots_Batch.py

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Figure G-8a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and 95% UCL PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.39 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 1.53 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
- PCB-mono
- PCB-di
- PCB-tri
- PCB-tetra
- PCB-penta
- PCB-hexa
- PCB-hepta
- PCB-octa
- PCB-nona
- PCB-deca
- TPCB

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Figure G-8b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(800 cm/yr Darcy Flux and 95% UCL PCB Concentration)
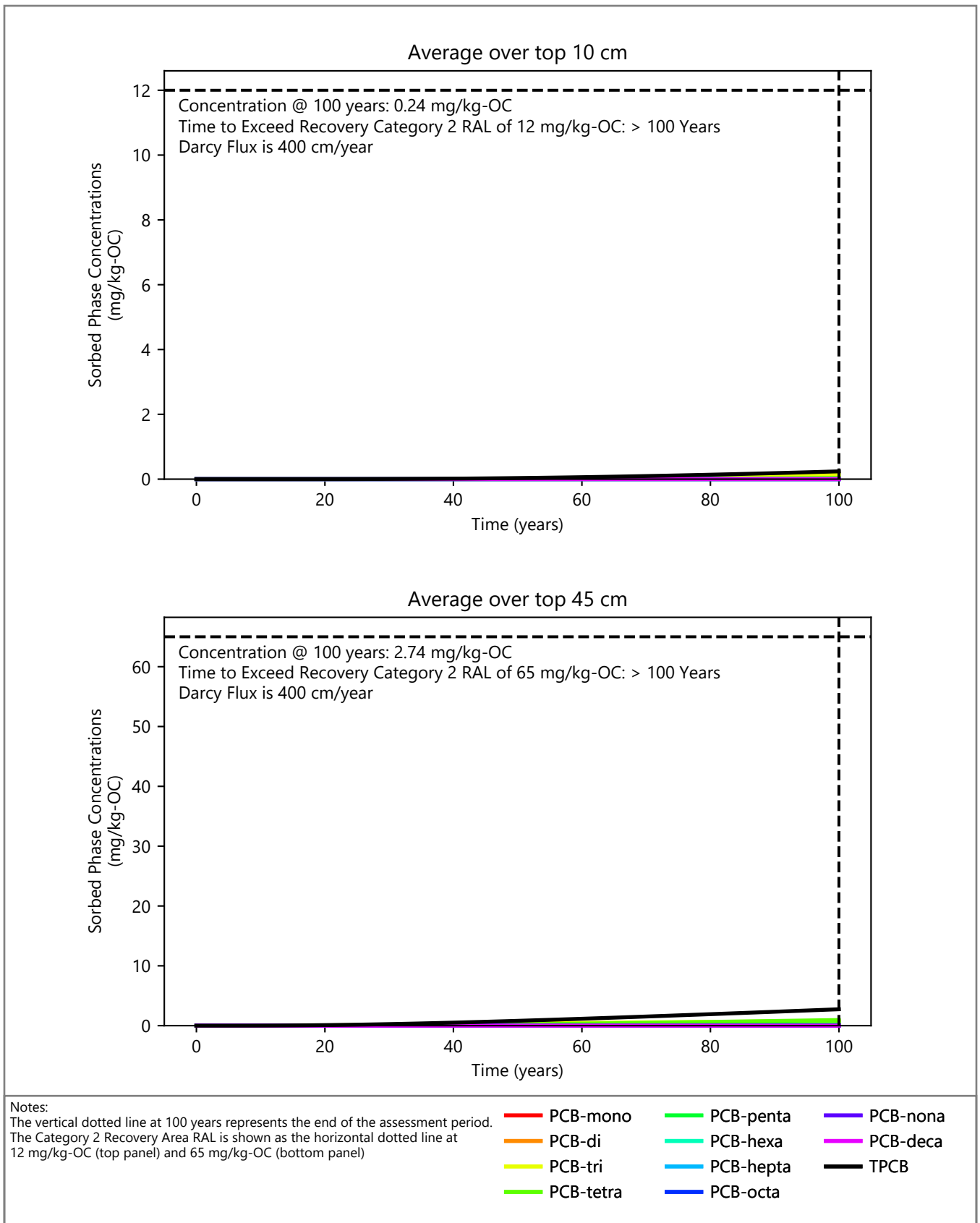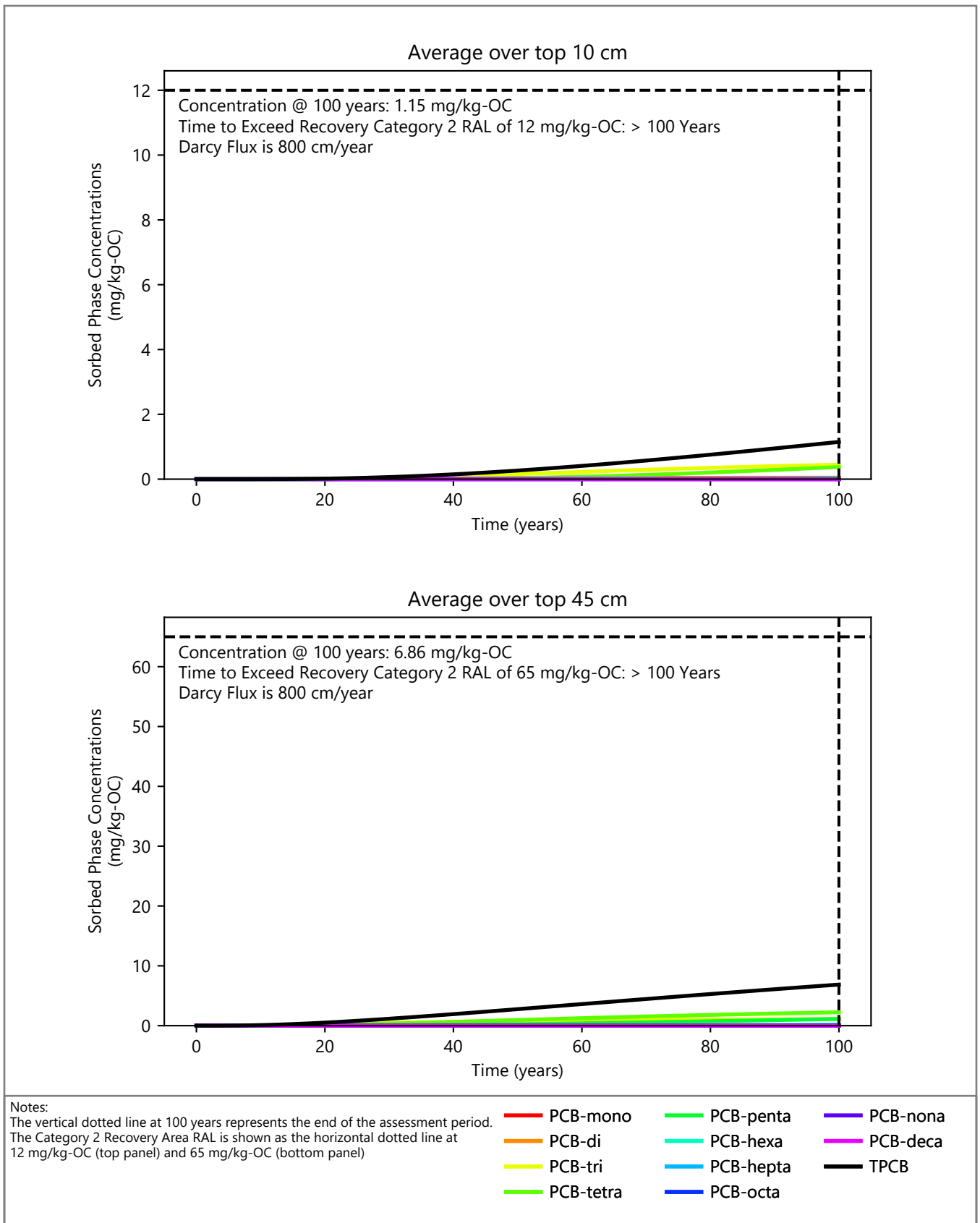
Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Figure G-9a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and Maximum PCB Concentration)
Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 7.18 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 55.07 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
PCB-mono, PCB-di, PCB-tri, PCB-tetra, PCB-penta, PCB-hexa, PCB-hepta, PCB-octa, PCB-nona, PCB-deca, TPCB

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Figure G-9b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
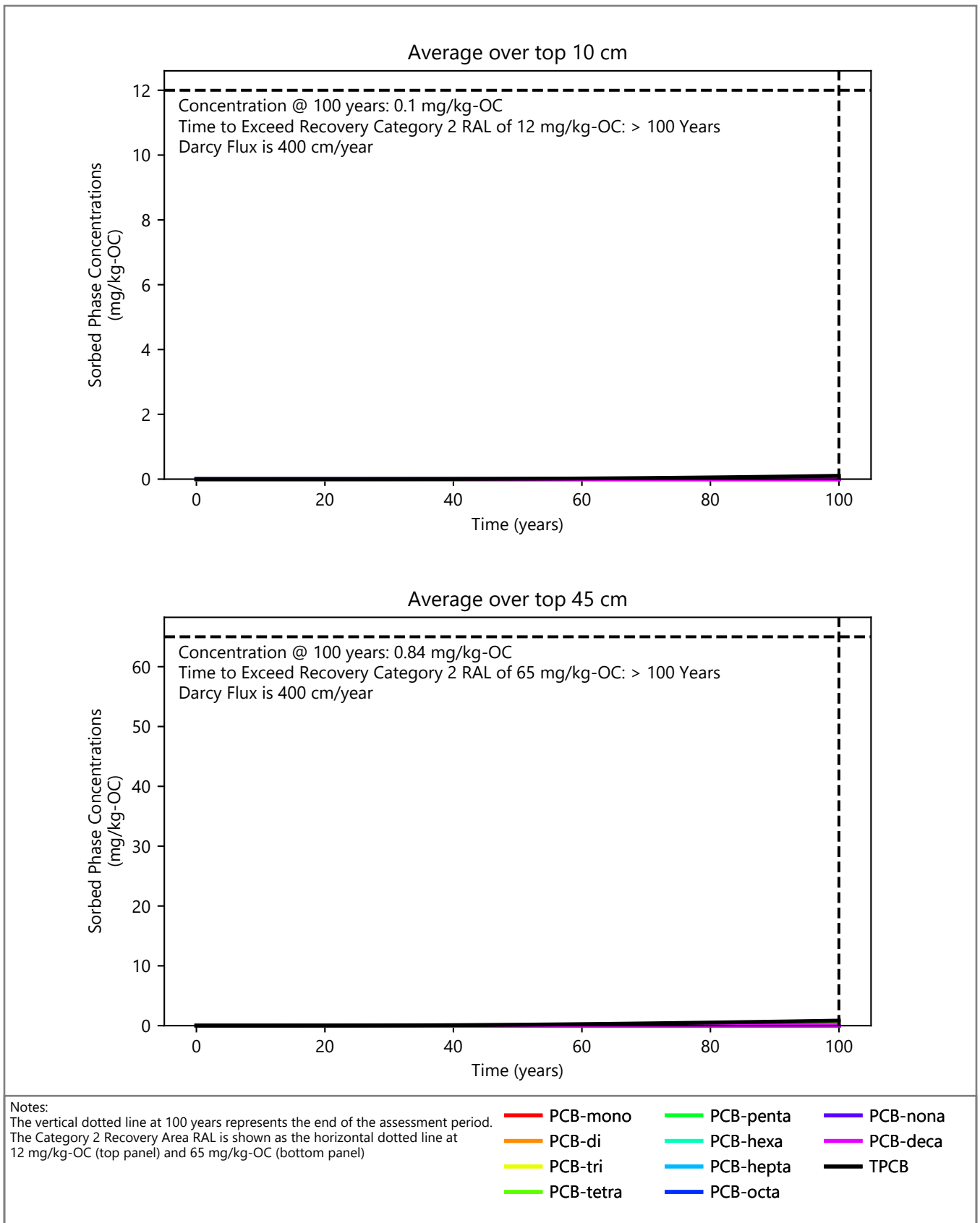**(800 cm/yr Darcy Flux and Maximum PCB Concentration)**

Engineered Cap Chemical Isolation Design Analysis
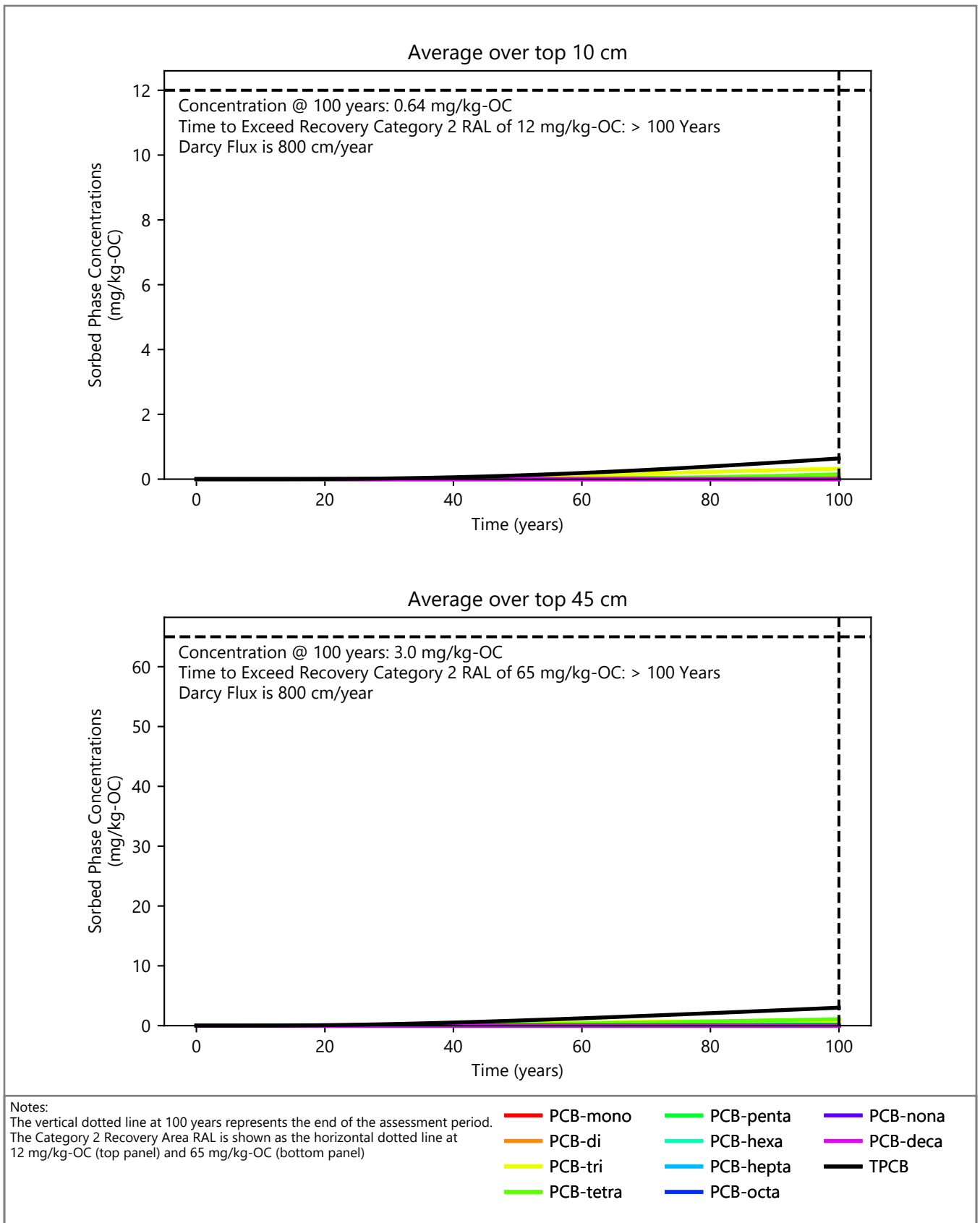Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.97 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 12.47 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-10a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and Maximum PCB Concentration)

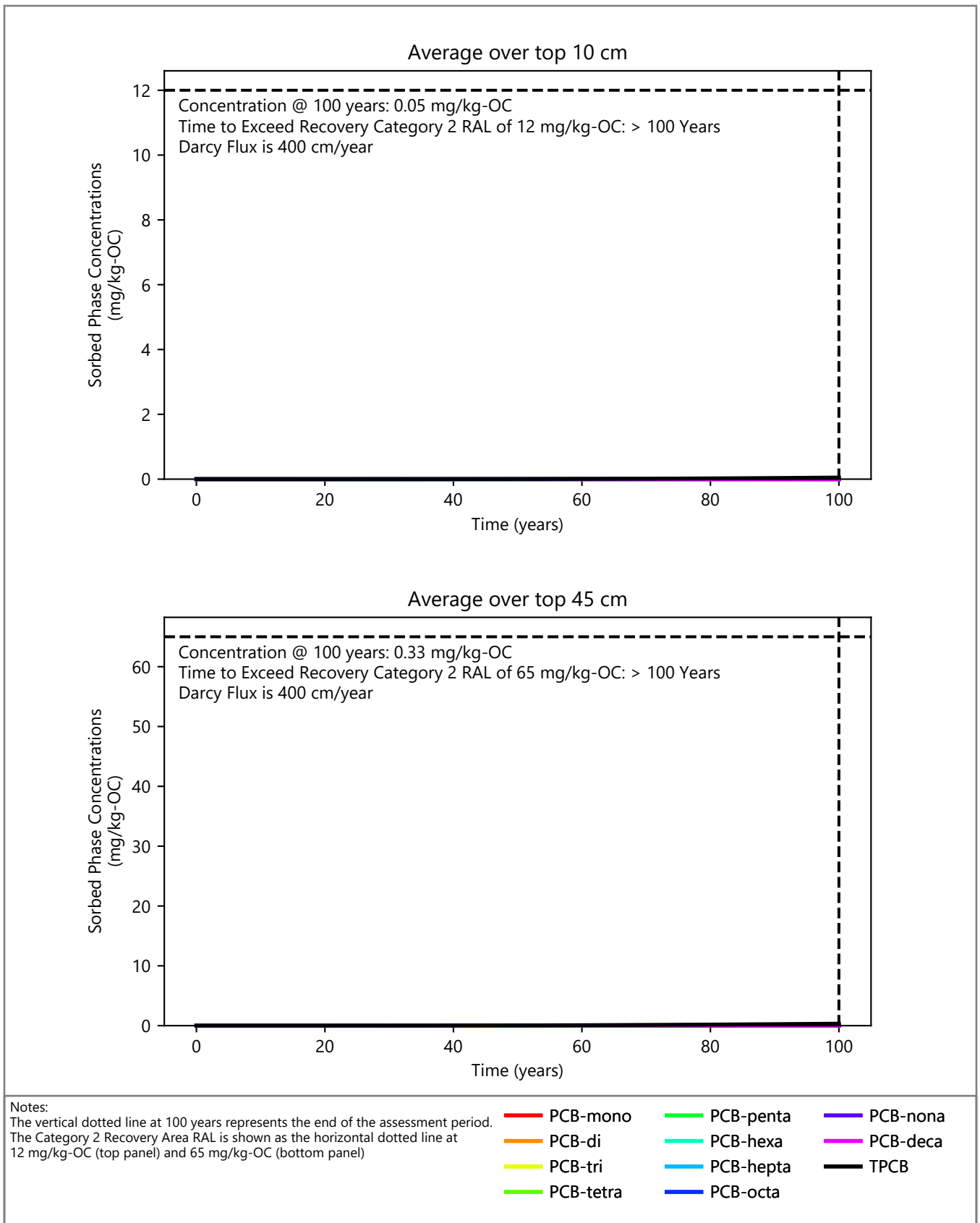Engineered Cap Chemical Isolation Design Analysis
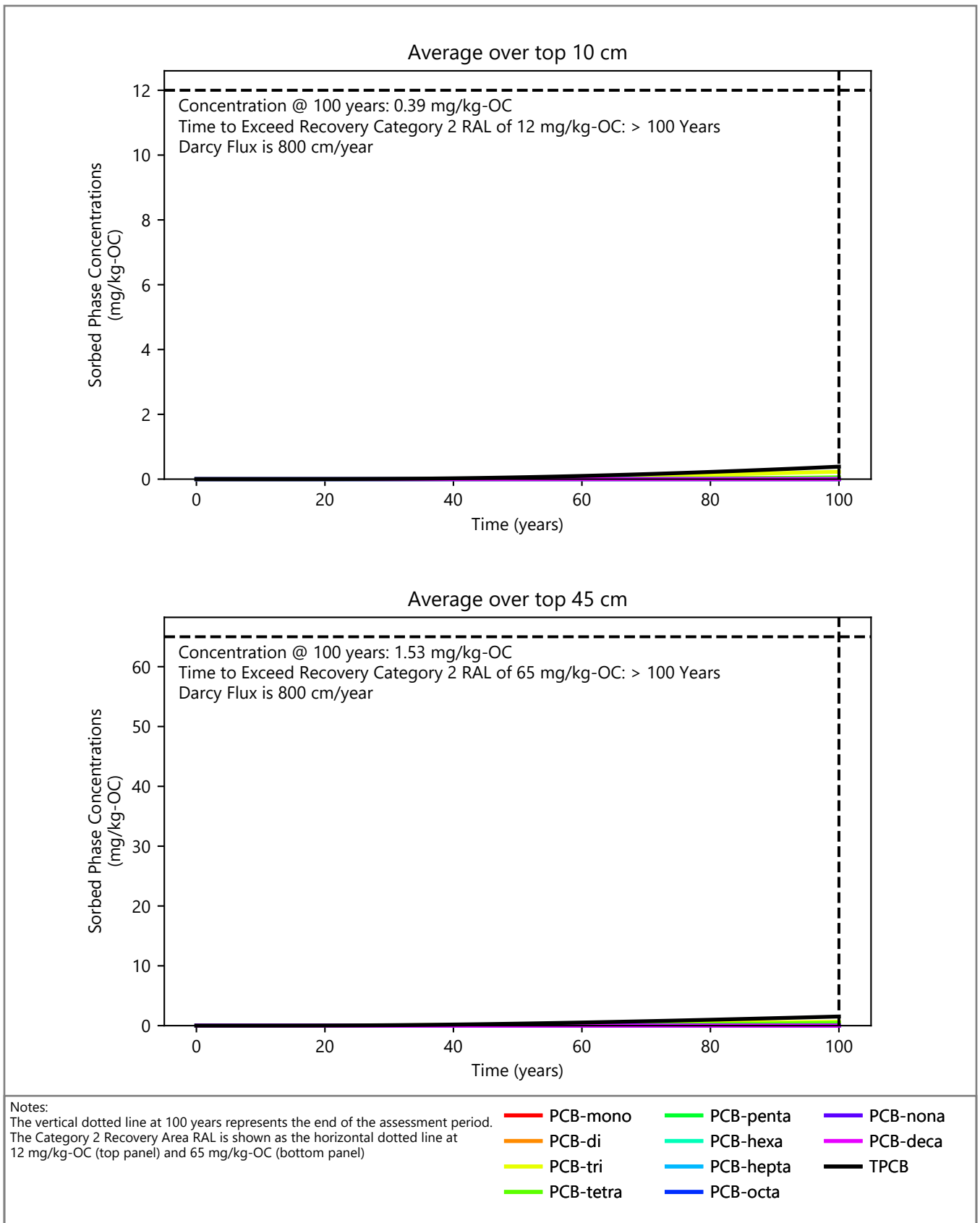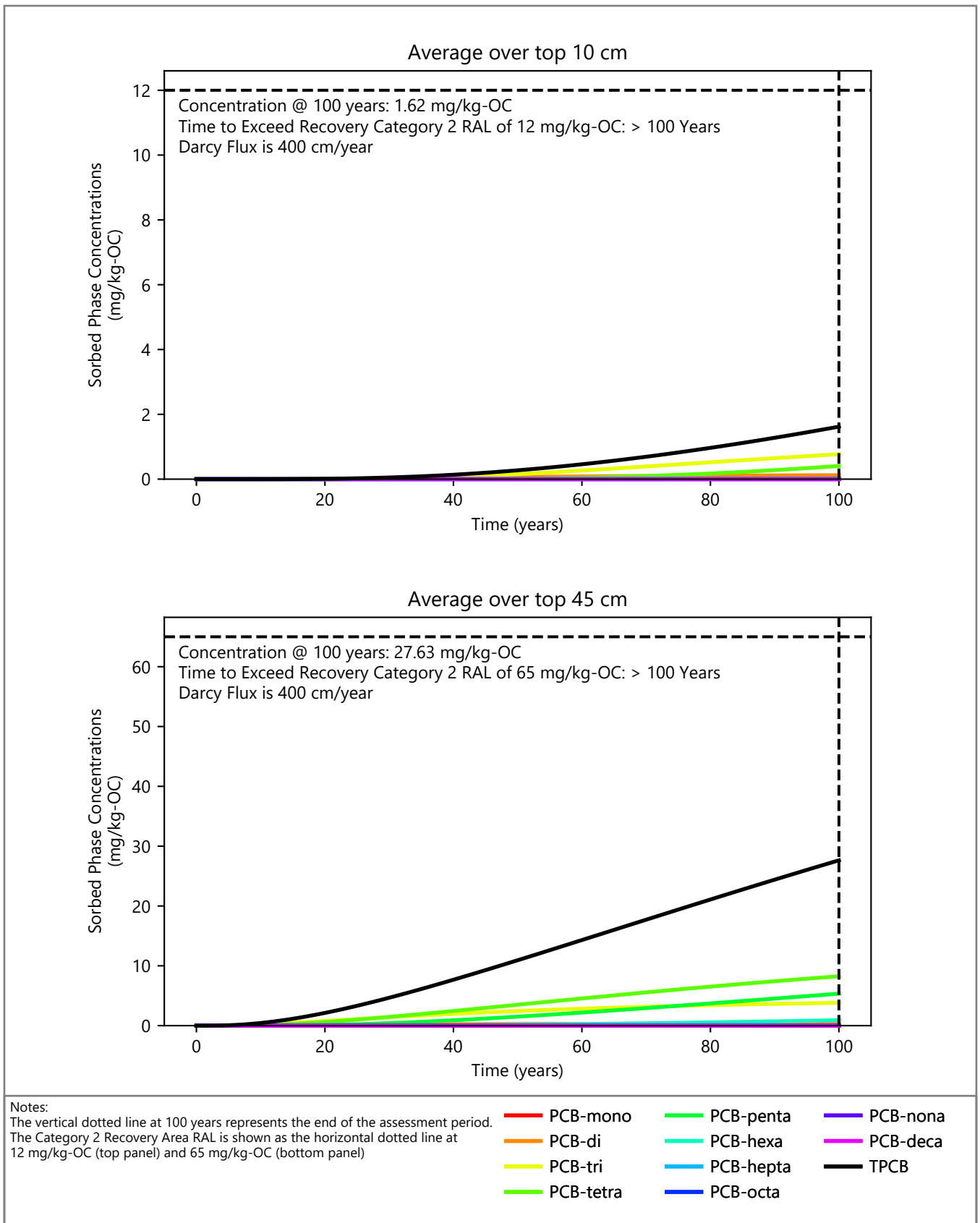Lower Duwamish Waterway Upper Reach

Figure G-10b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(800 cm/yr Darcy Flux and Maximum PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.41 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Average over top 45 cm

Concentration @ 100 years: 3.52 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Sorbed Phase Concentrations (mg/kg-OC)

Time (years)

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-11a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and Maximum PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Figure G-11b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
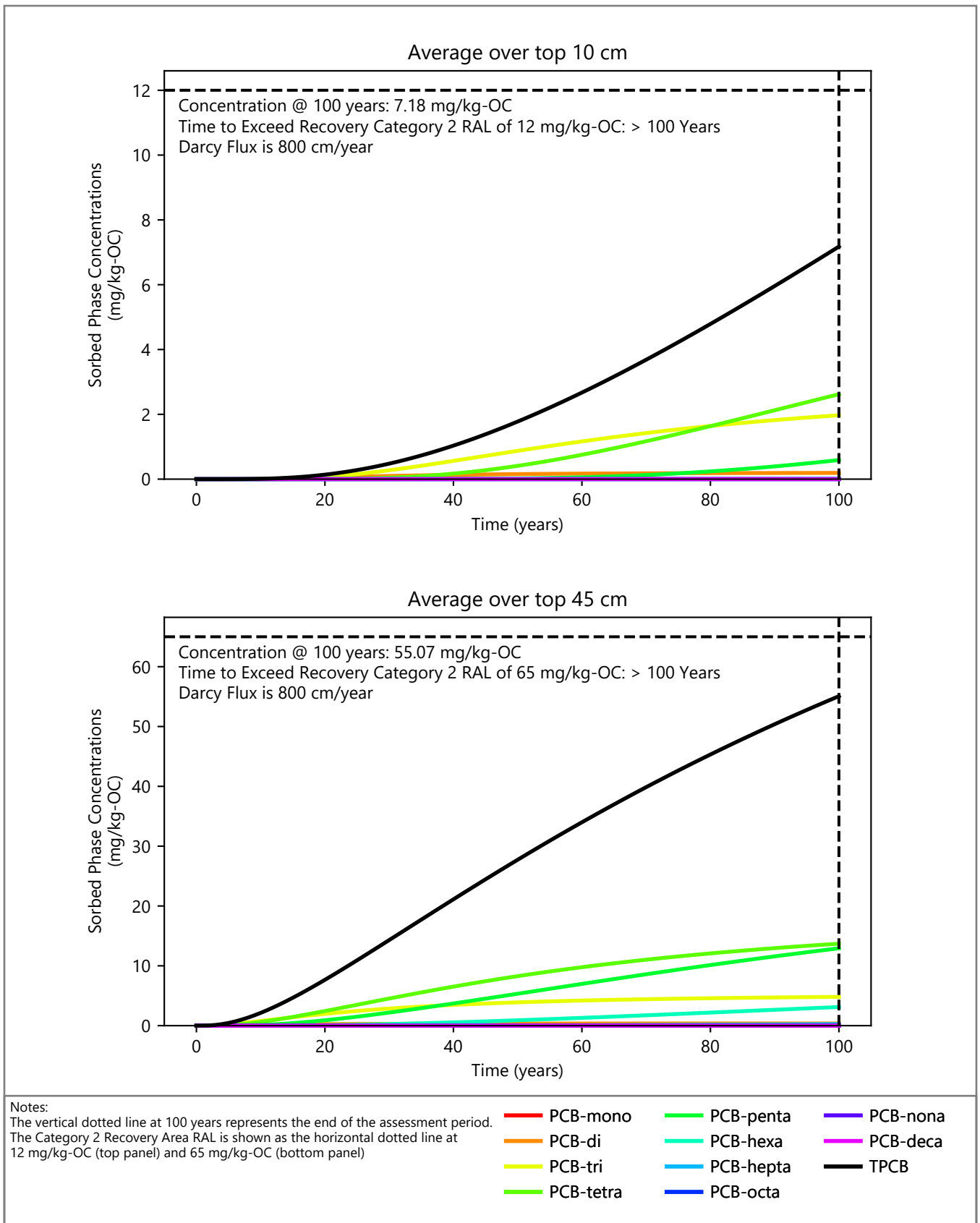**(800 cm/yr Darcy Flux and Maximum PCB Concentration)**

Engineered Cap Chemical Isolation Design Analysis
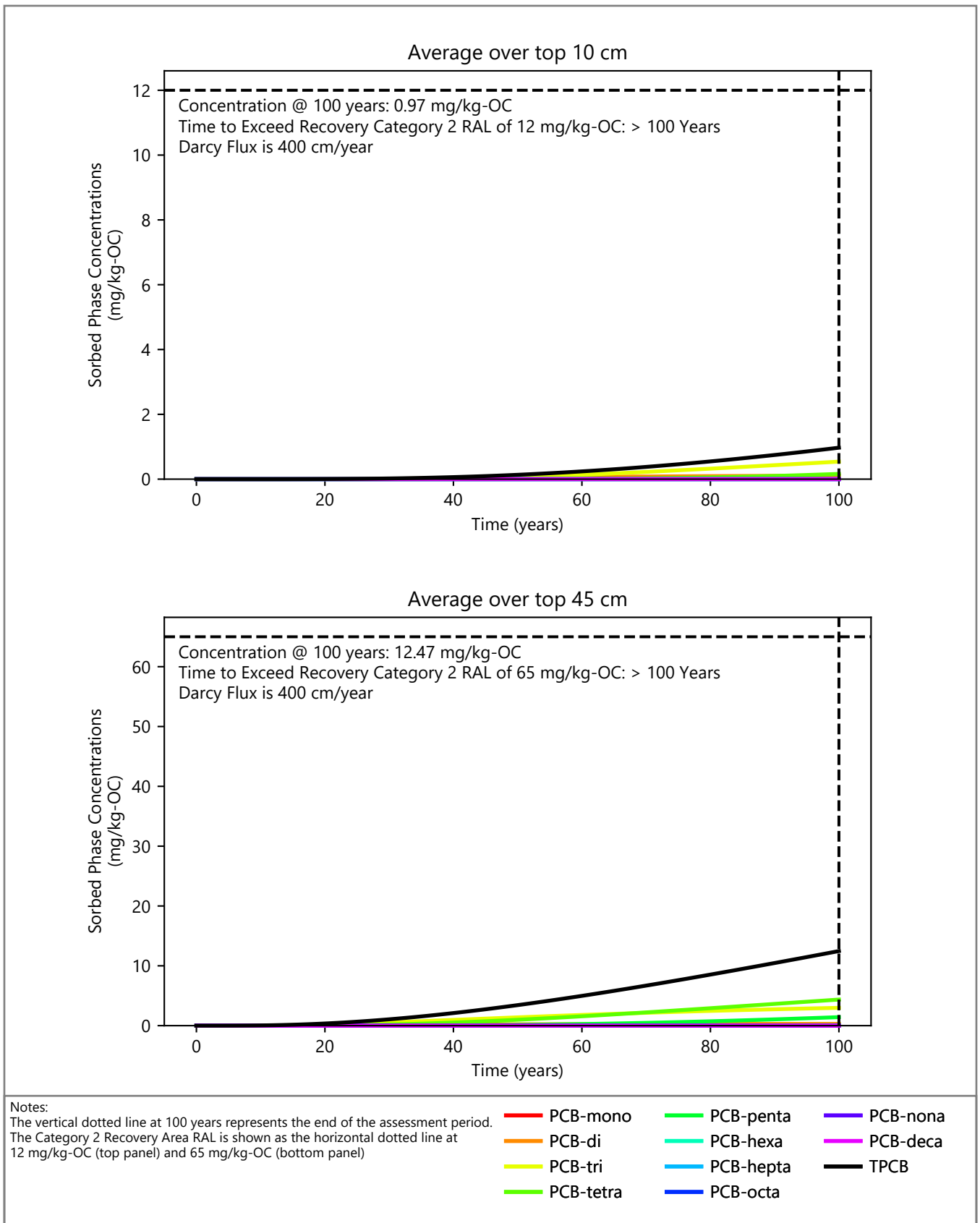Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 0.2 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Y-axis: Sorbed Phase Concentrations (mg/kg-OC)
X-axis: Time (years)

Average over top 45 cm

Concentration @ 100 years: 1.32 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 400 cm/year

Y-axis: Sorbed Phase Concentrations (mg/kg-OC)
X-axis: Time (years)

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

Legend:
- PCB-mono
- PCB-di
- PCB-tri
- PCB-tetra
- PCB-penta
- PCB-hexa
- PCB-hepta
- PCB-octa
- PCB-nona
- PCB-deca
- TPCB

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Figure G-12a
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
(400 cm/yr Darcy Flux and Maximum PCB Concentration)

Engineered Cap Chemical Isolation Design Analysis
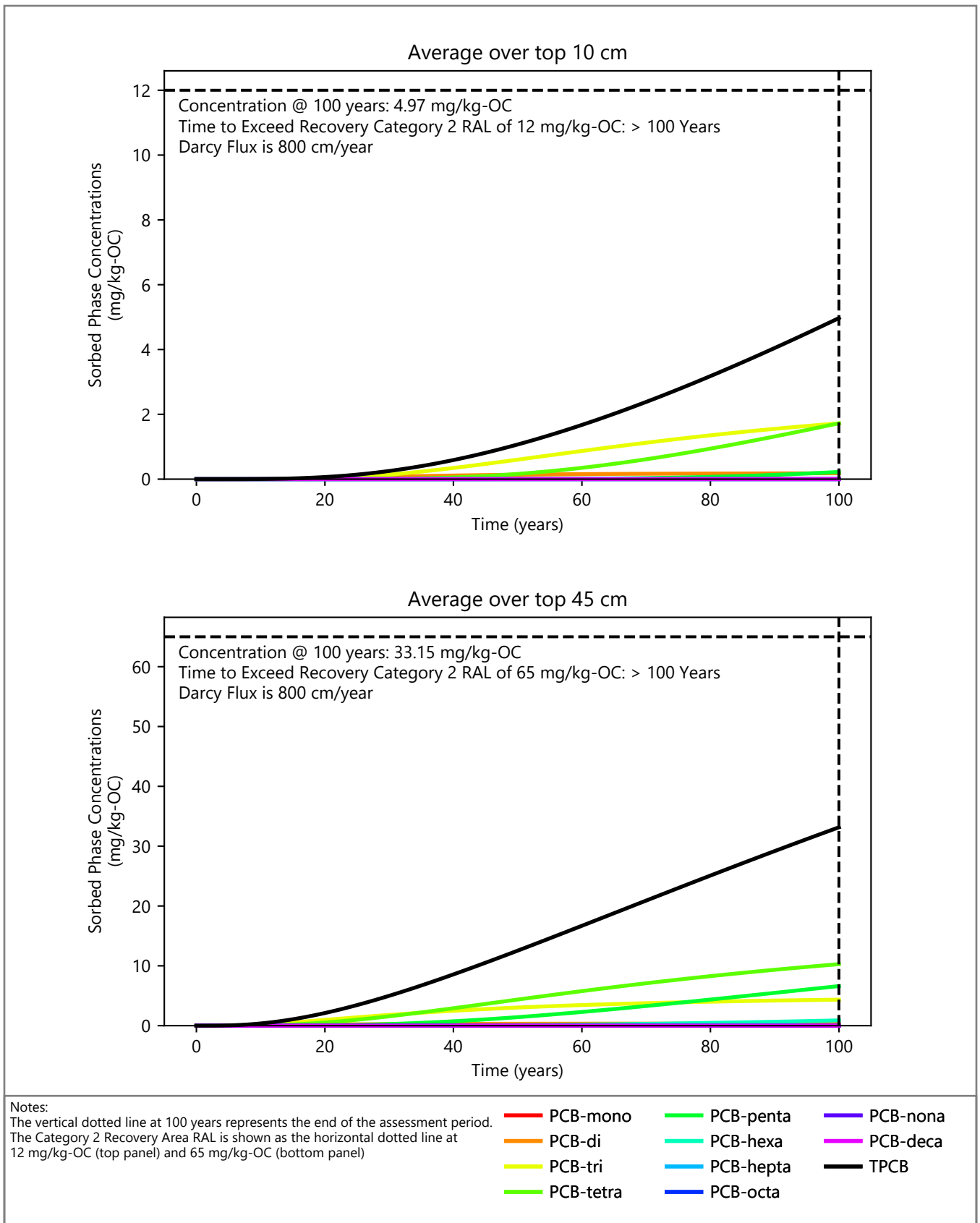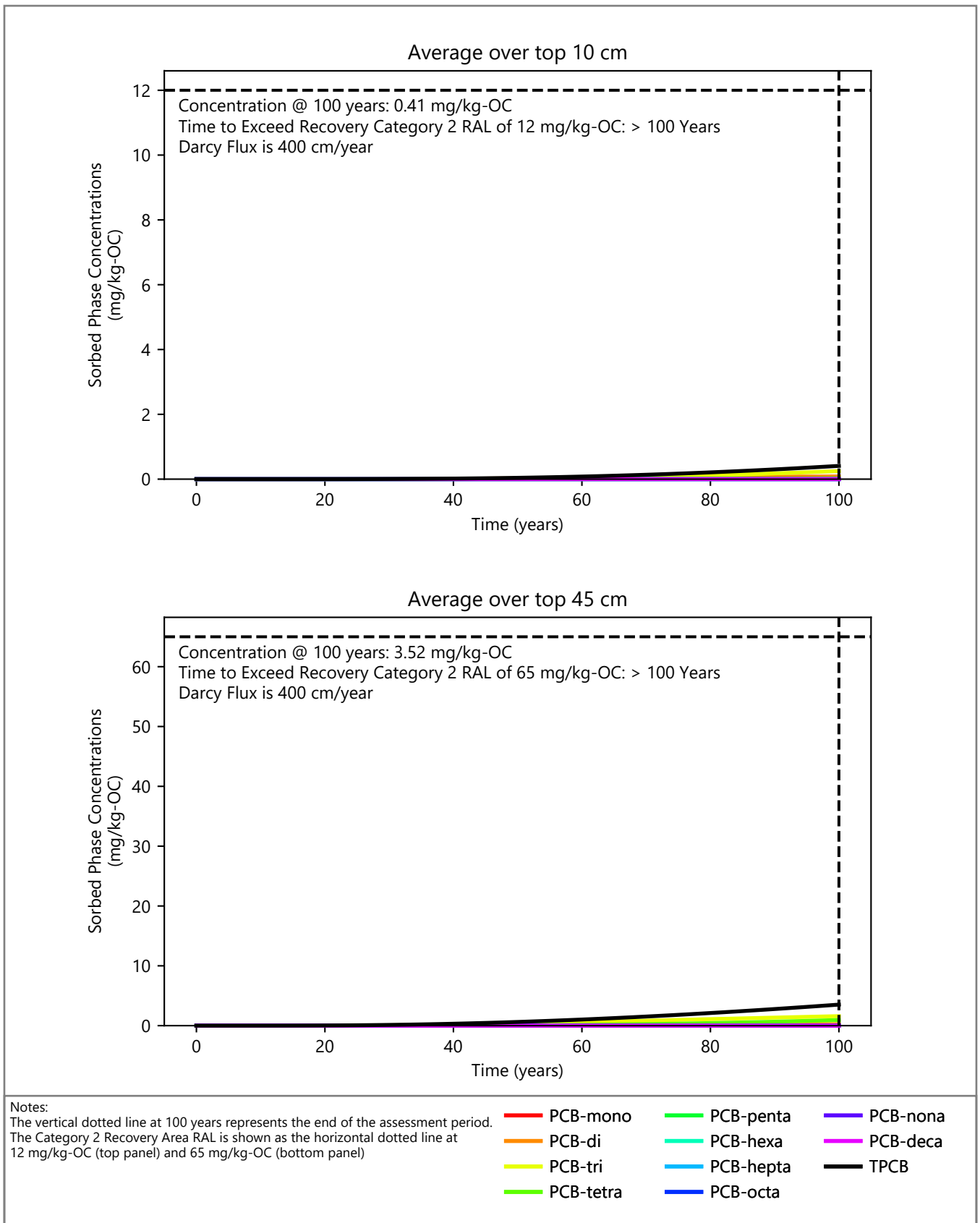Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 1.56 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 12 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 6.55 mg/kg-OC
Time to Exceed Recovery Category 2 RAL of 65 mg/kg-OC: > 100 Years
Darcy Flux is 800 cm/year

Notes:
The vertical dotted line at 100 years represents the end of the assessment period.
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
12 mg/kg-OC (top panel) and 65 mg/kg-OC (bottom panel)

PCB-mono	PCB-penta	PCB-nona
PCB-di	PCB-hexa	PCB-deca
PCB-tri	PCB-hepta	TPCB
PCB-tetra	PCB-octa	

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Figure G-12b
Temporal Profile of PCBs Within the Surface of the Scenario Area 18 Cap
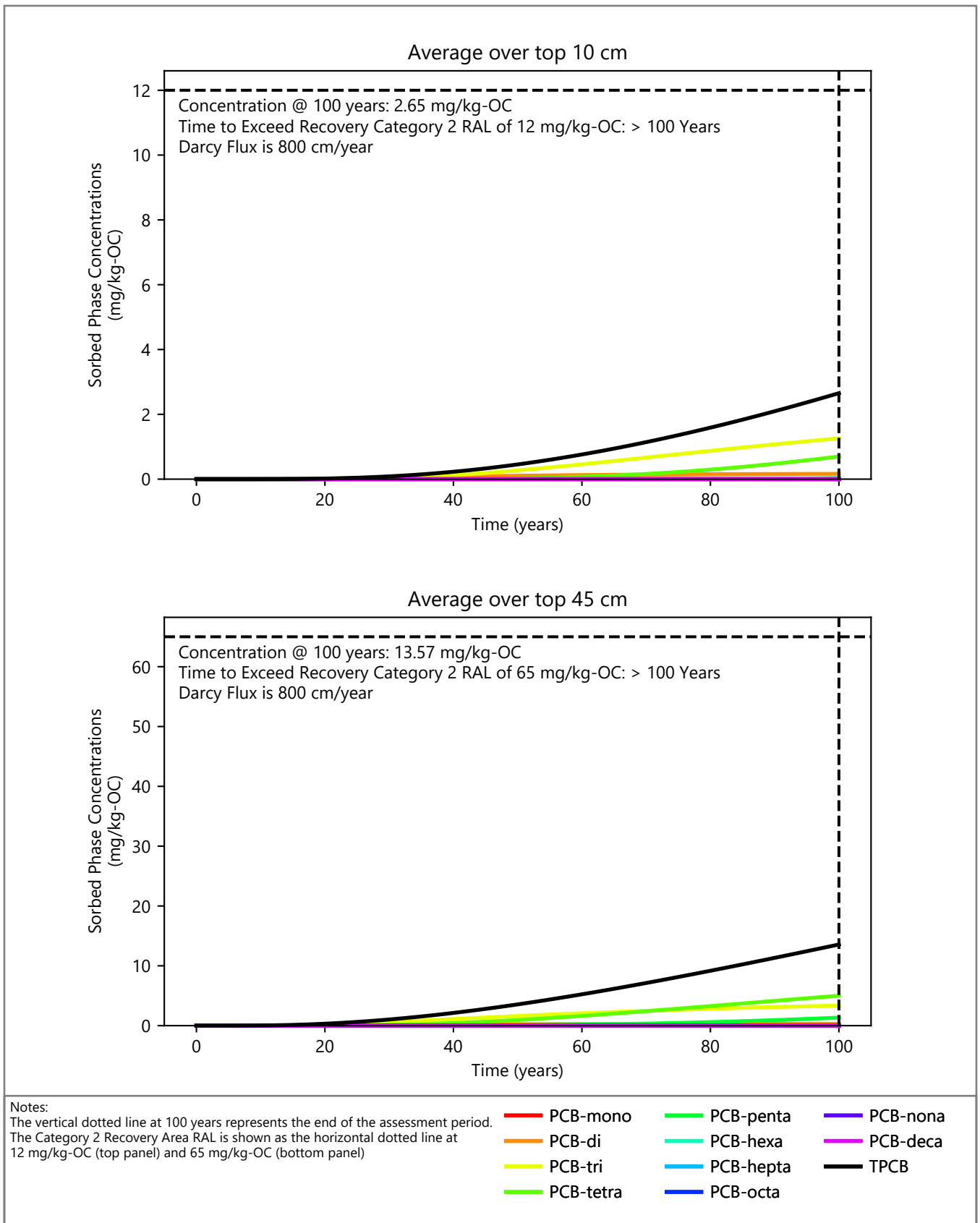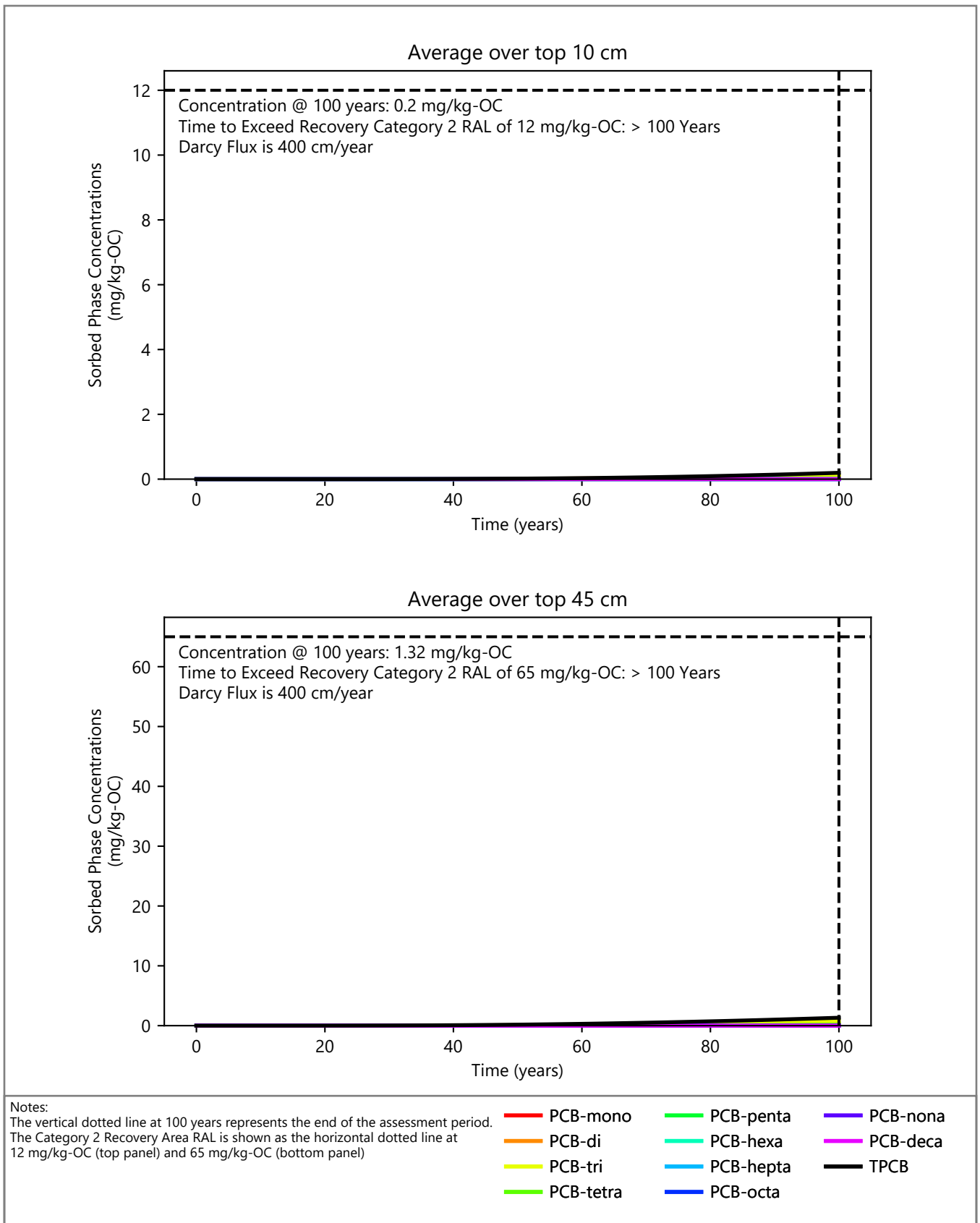**(800 cm/yr Darcy Flux and Maximum PCB Concentration)**

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 124 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 29 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 256 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 8 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-13a
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 154 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 14 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 271 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 4 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-13b
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 109 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 40 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 235 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 14 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-14a
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 143 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 18 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 256 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 7 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
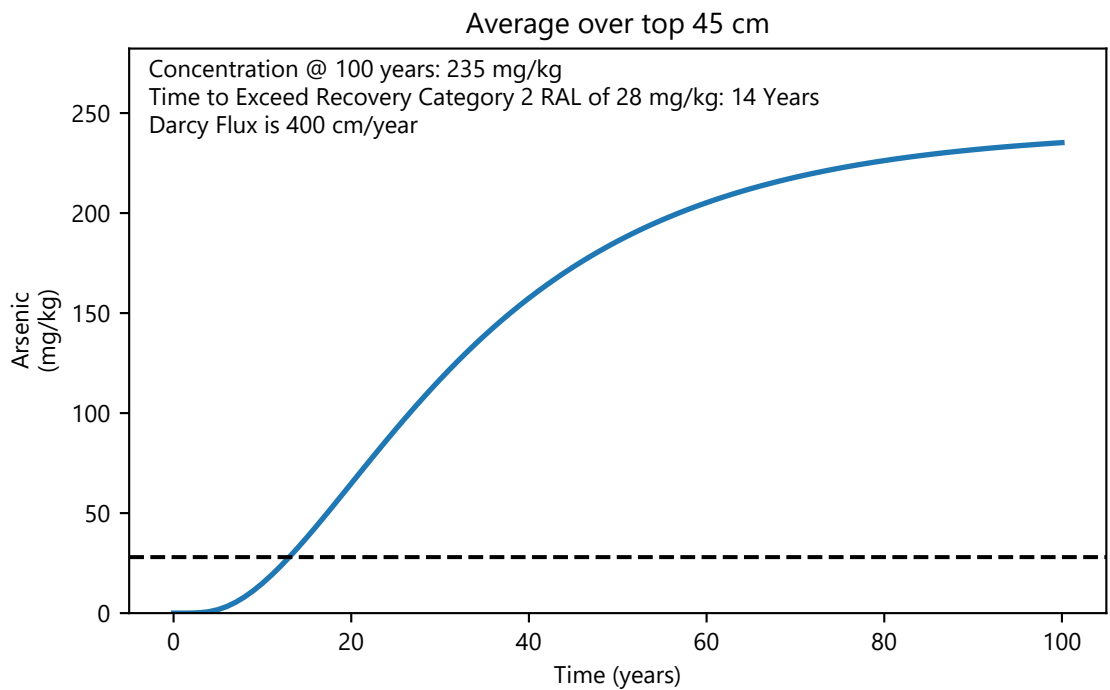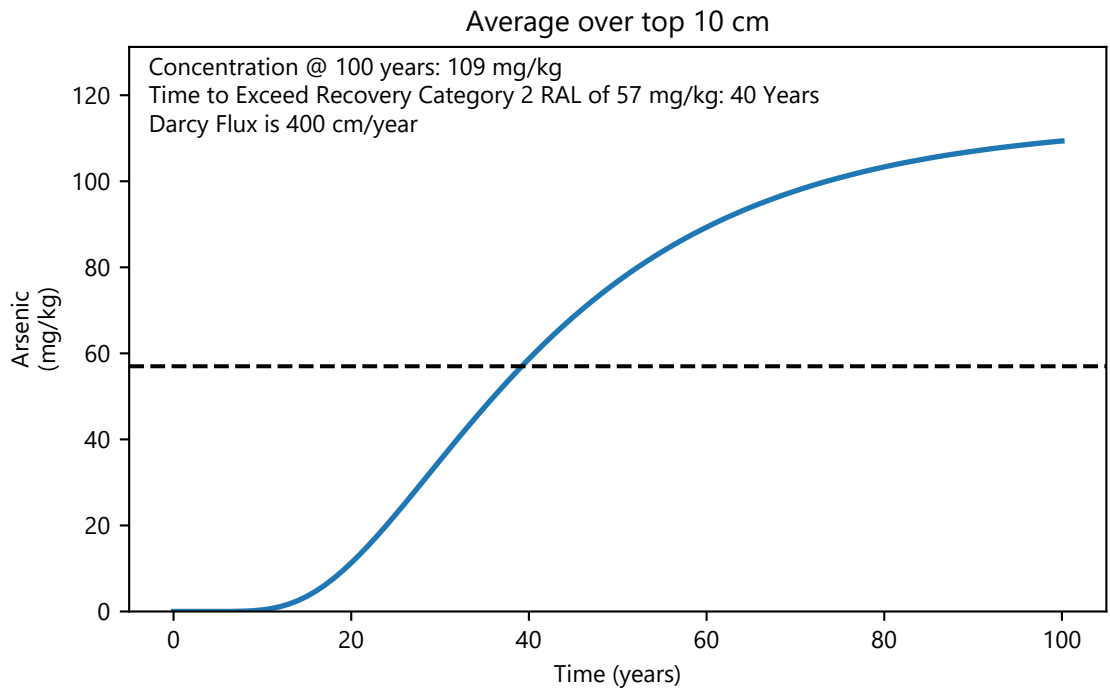57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-14b
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 85 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 62 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 191 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 25 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
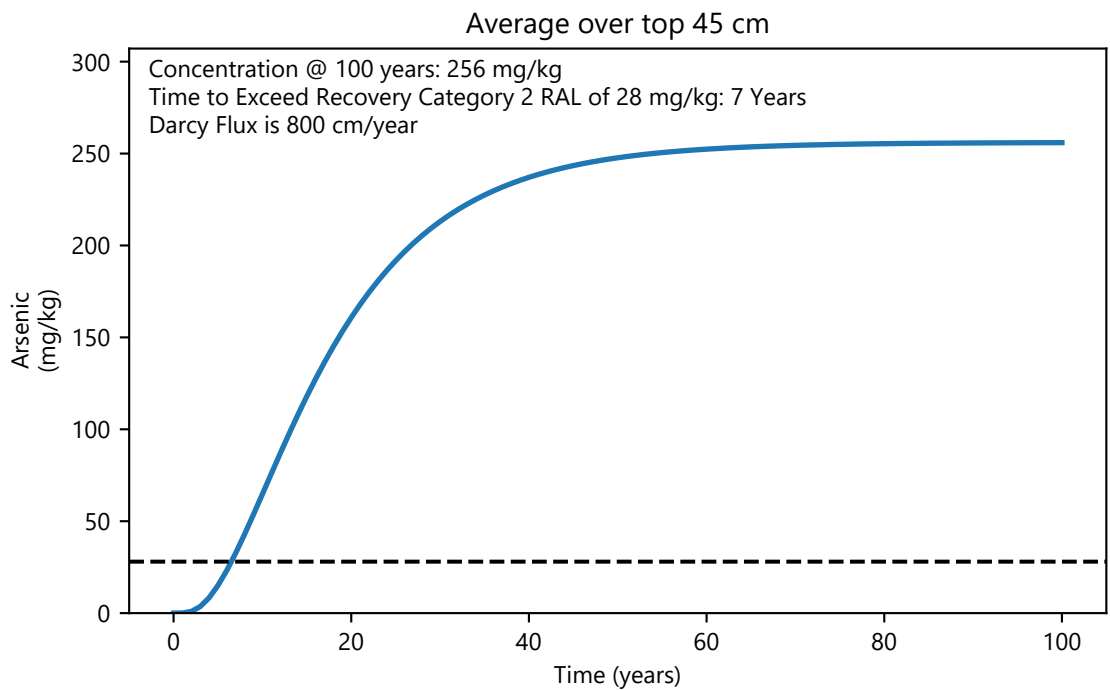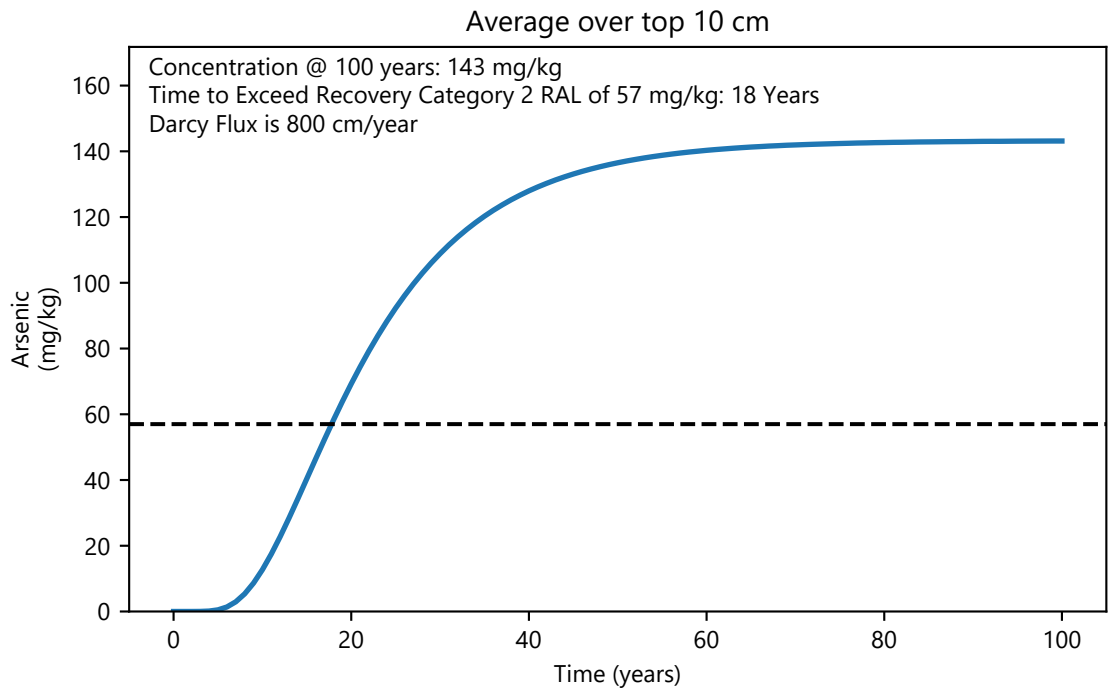57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-15a
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 128 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 27 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 230 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 13 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
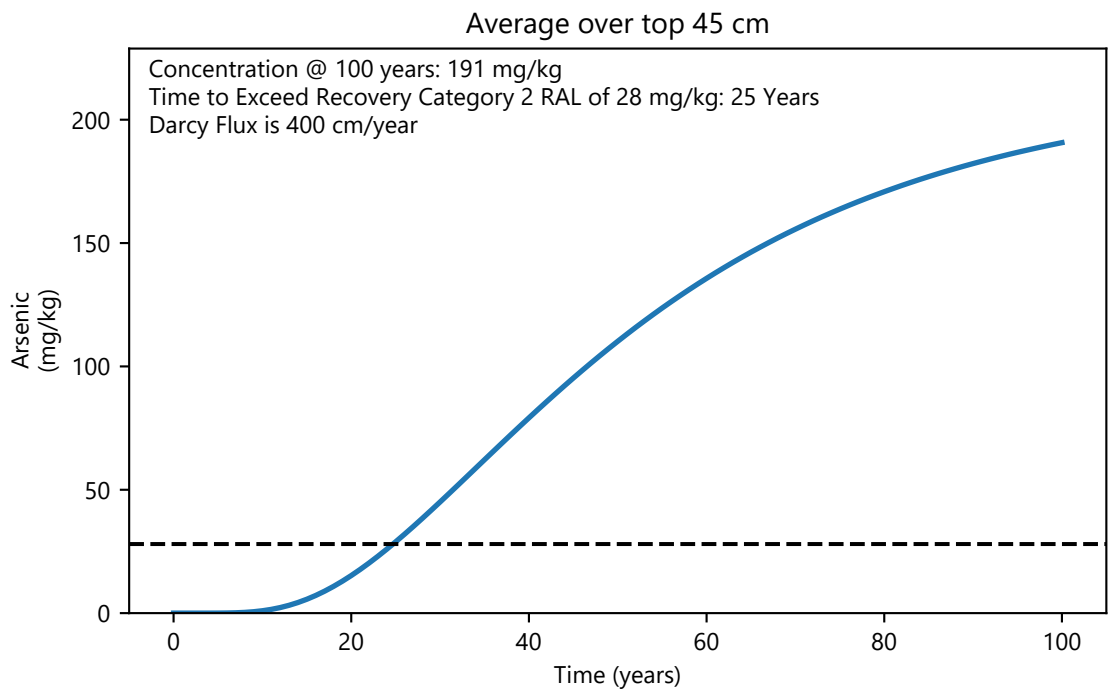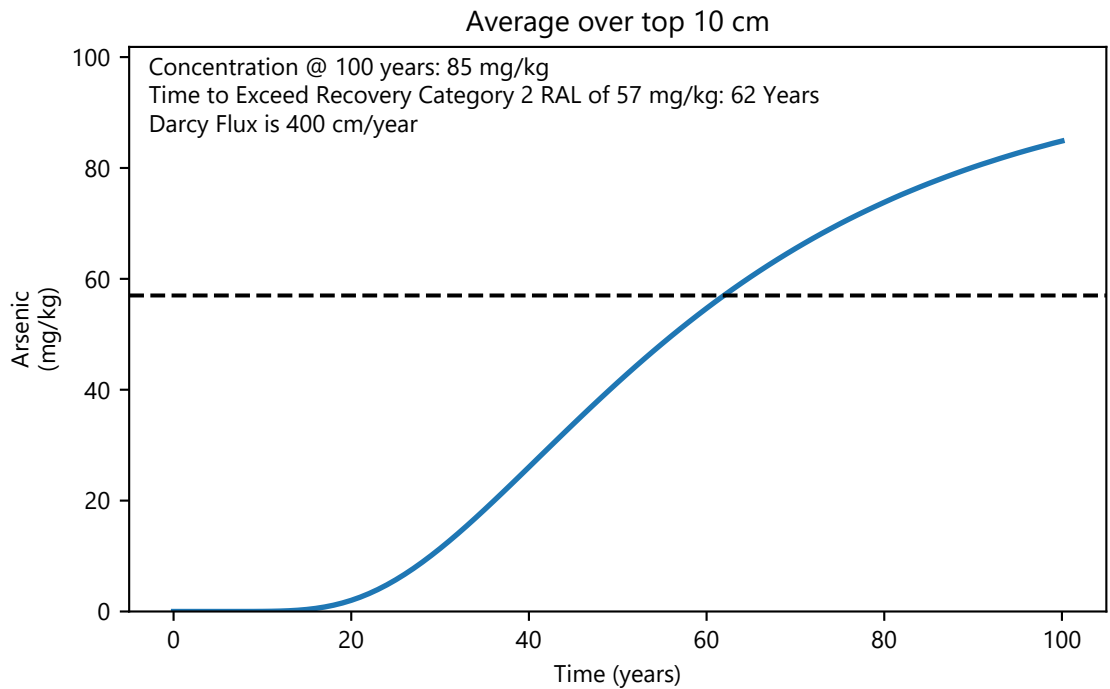57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-15b
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 65 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 88 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 148 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 37 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-16a
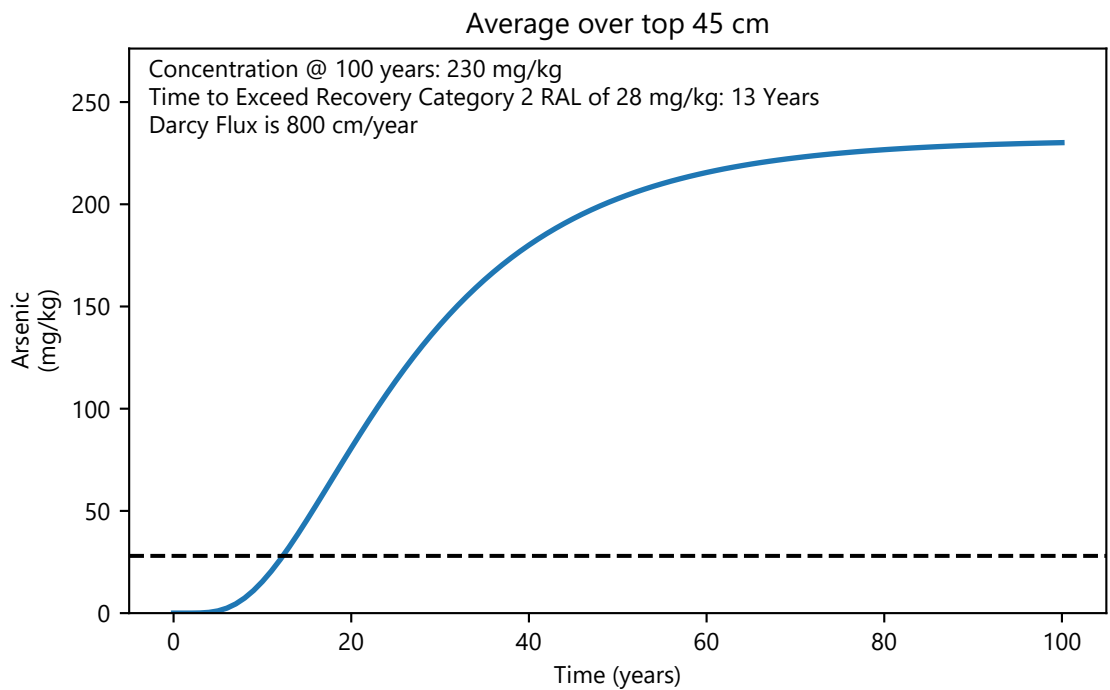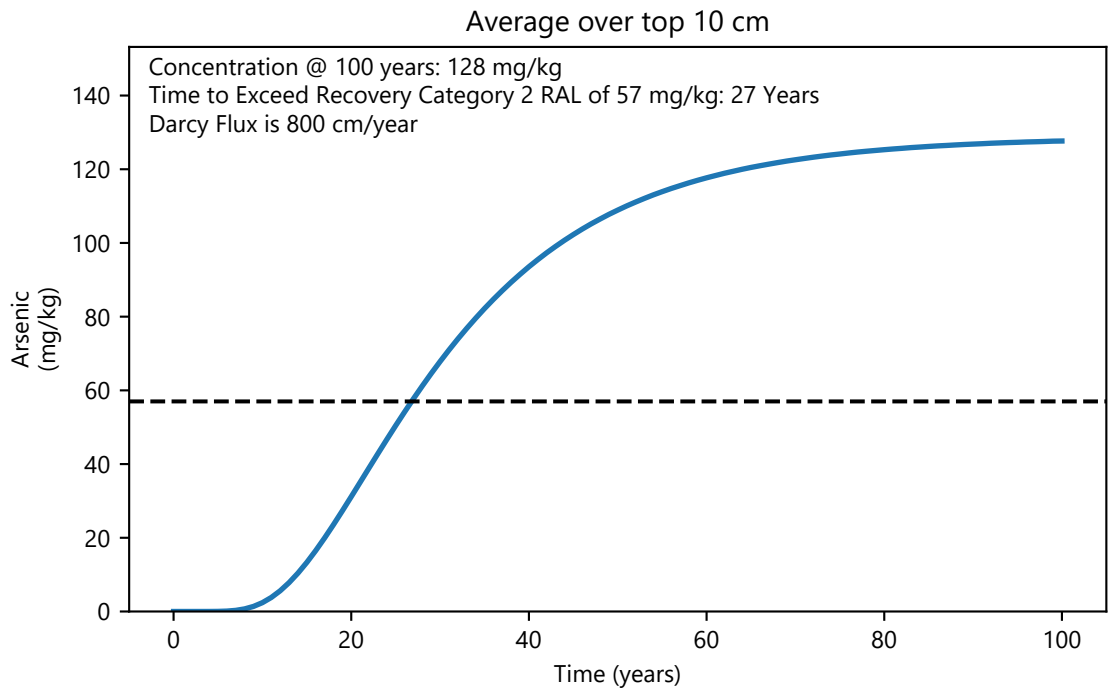**Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap**
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 116 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 37 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 207 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 19 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-16b
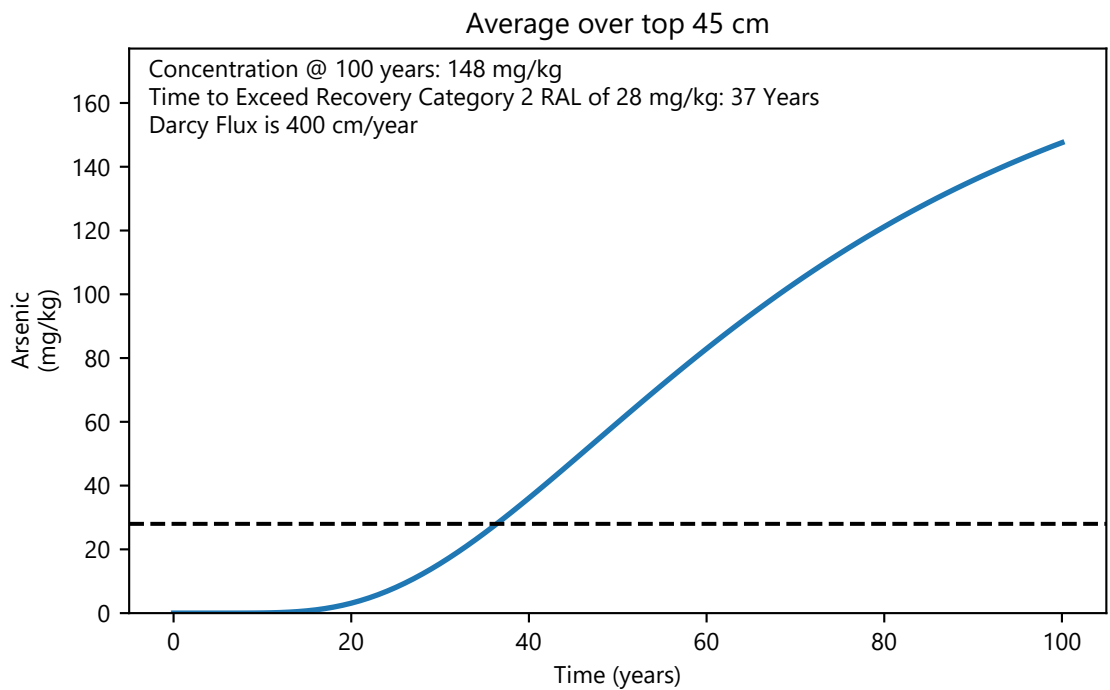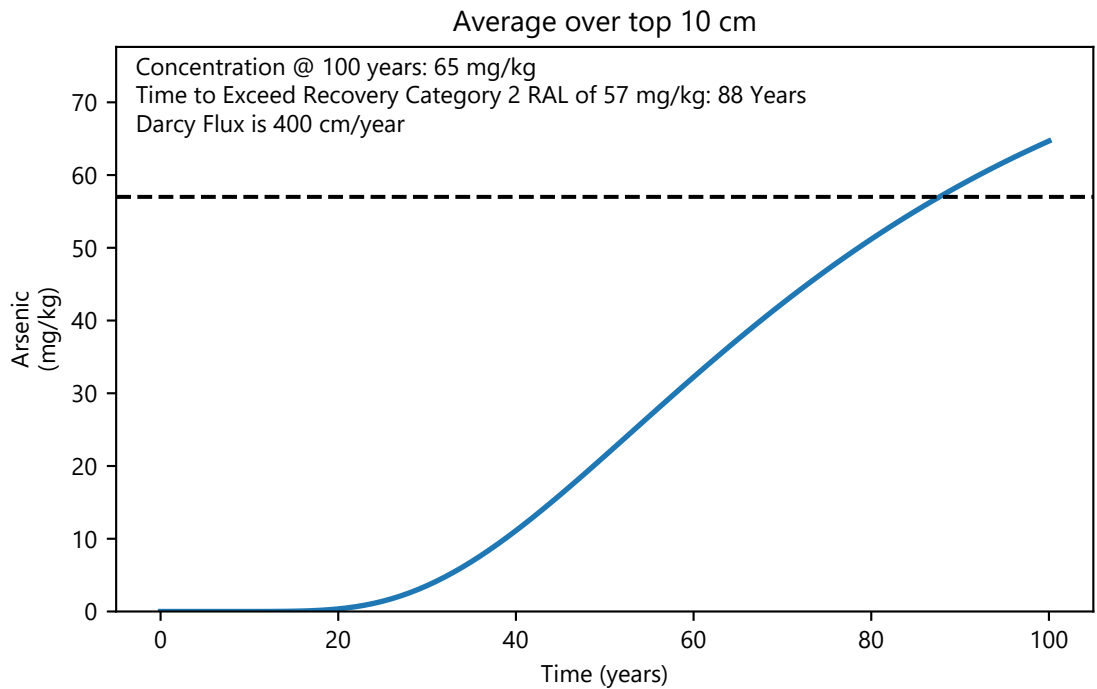**Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap**
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 393 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 18 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 812 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 4 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
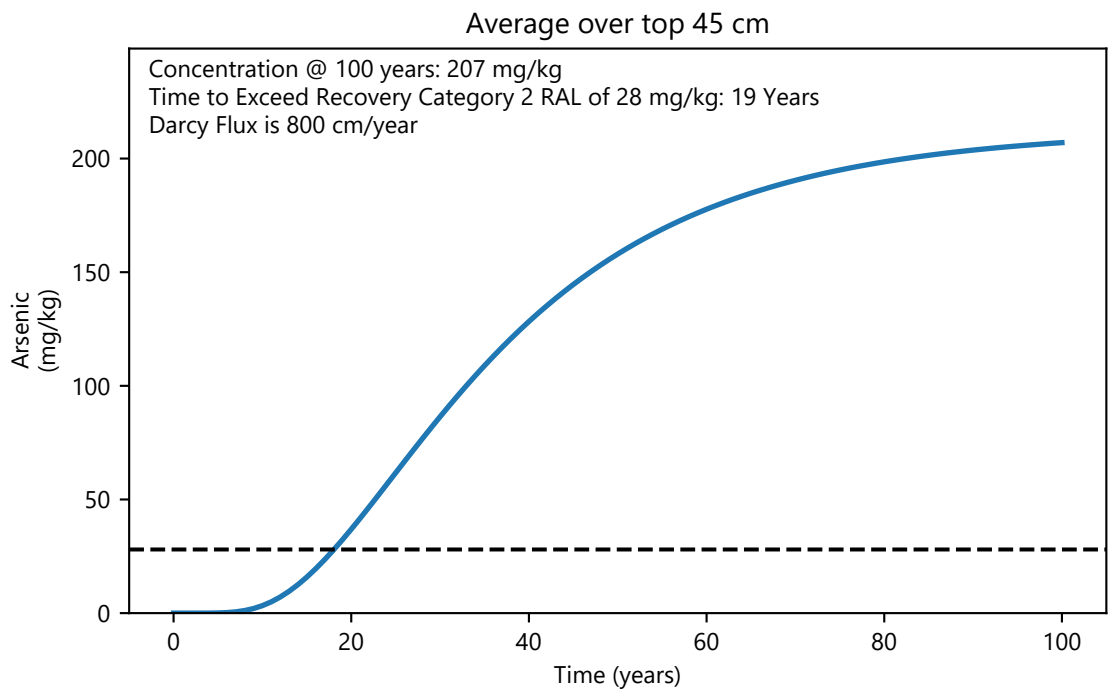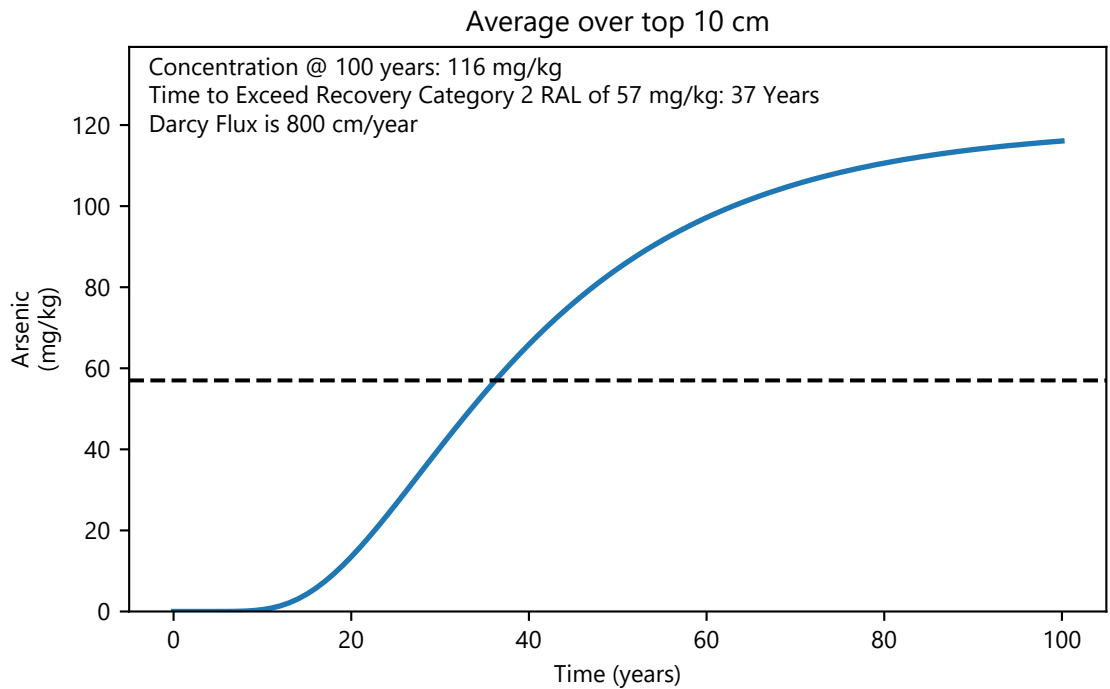57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-17a
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 489 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 9 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 858 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 2 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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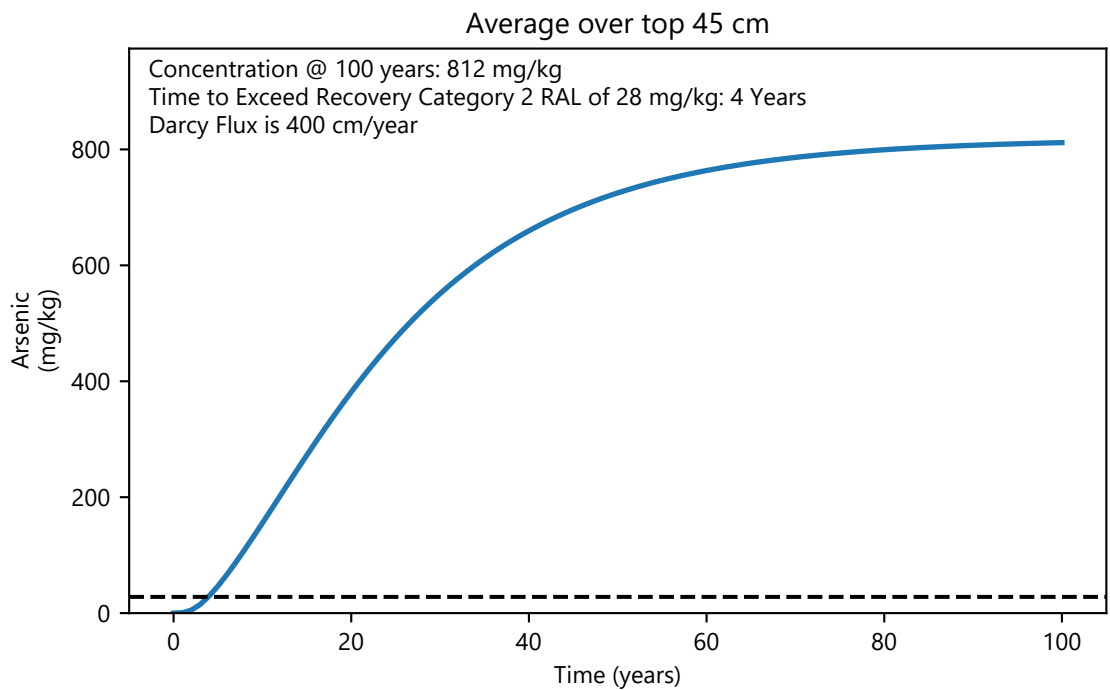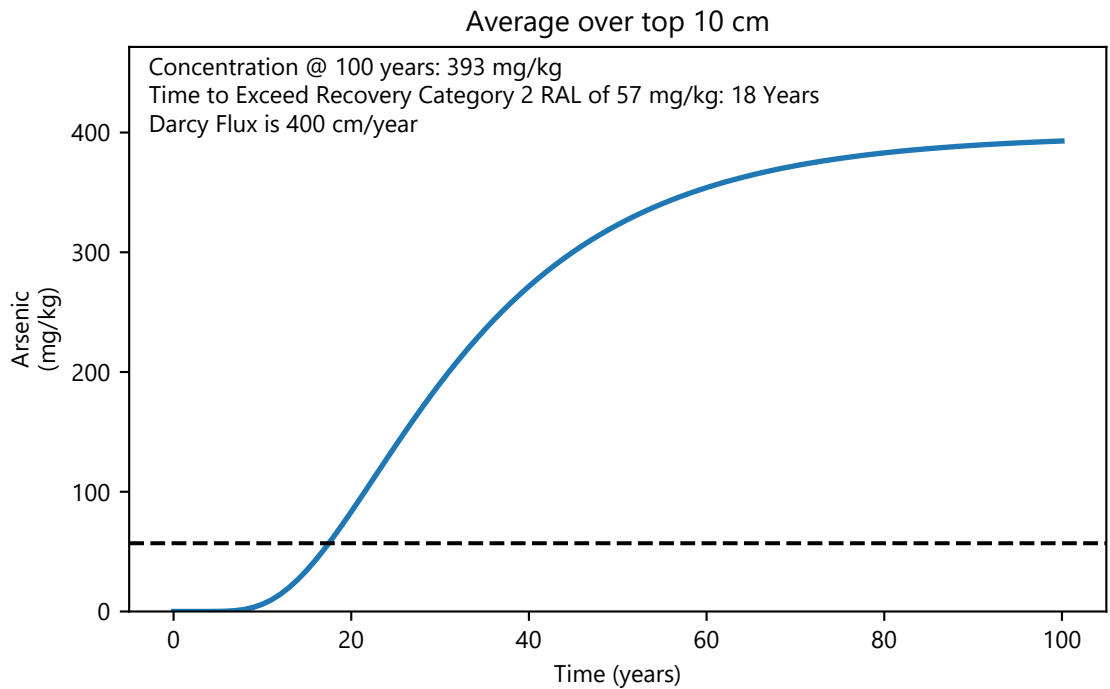
Figure G-17b
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 347 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 24 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 746 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 9 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
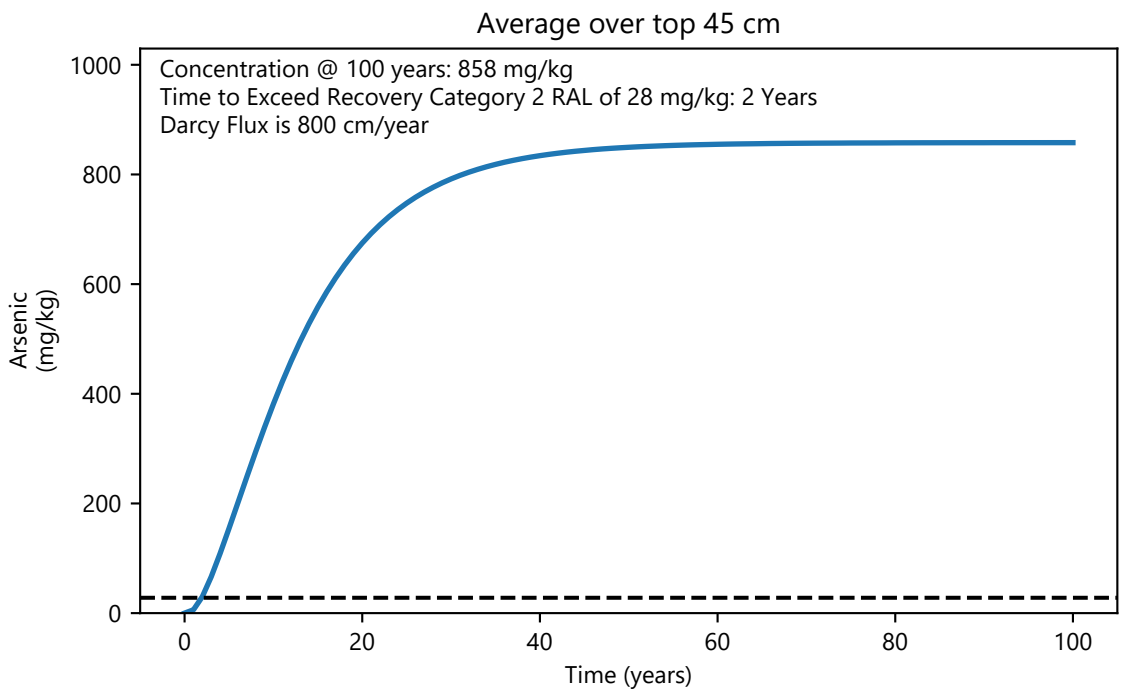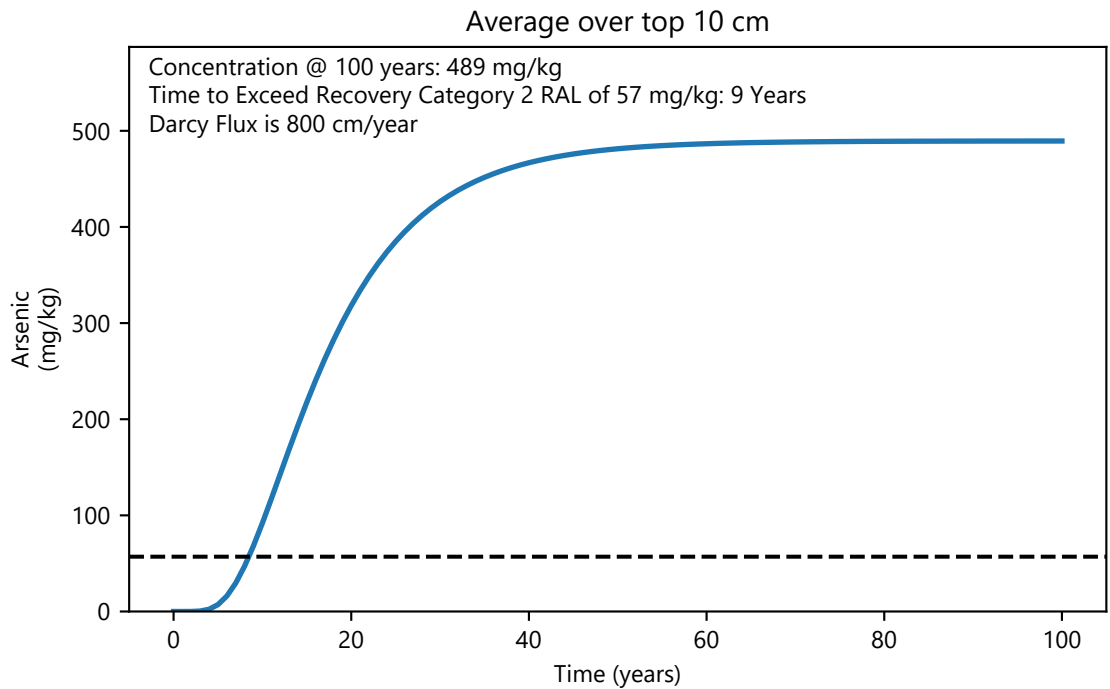57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-18a
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 454 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 12 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 811 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 5 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
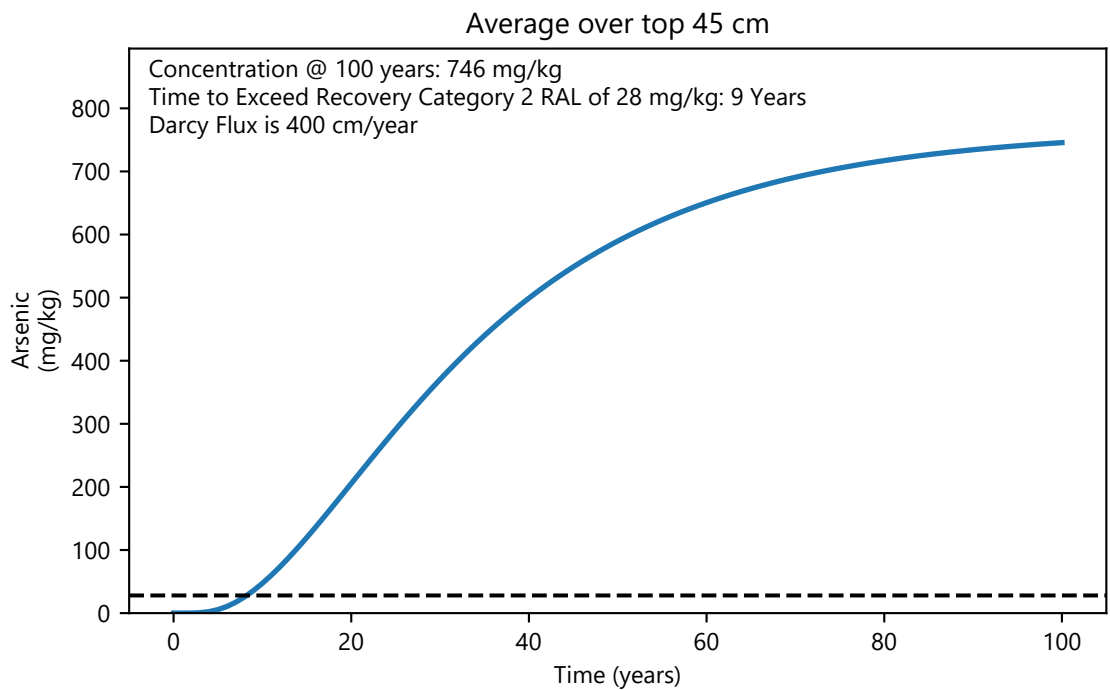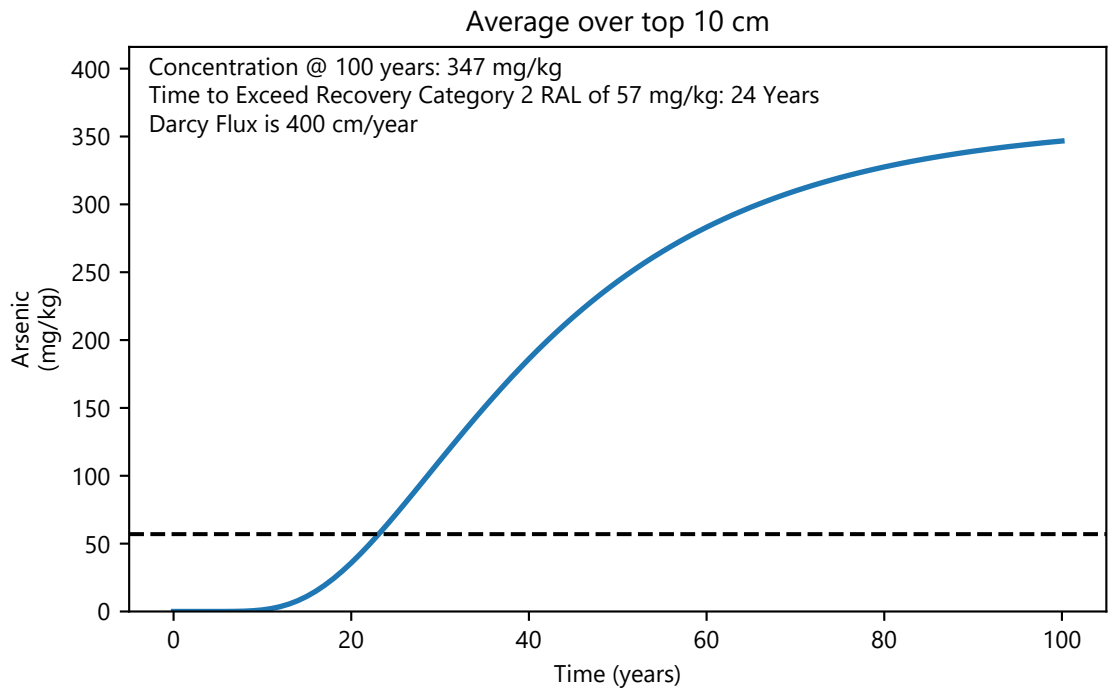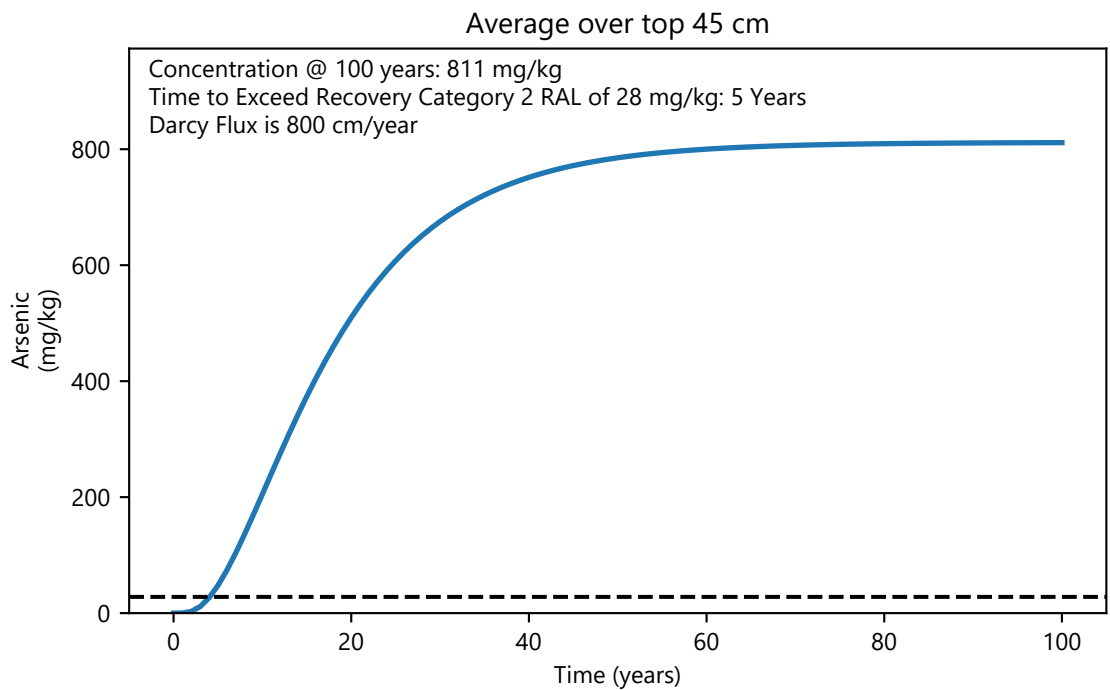57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-18b
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 269 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 35 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 605 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 17 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
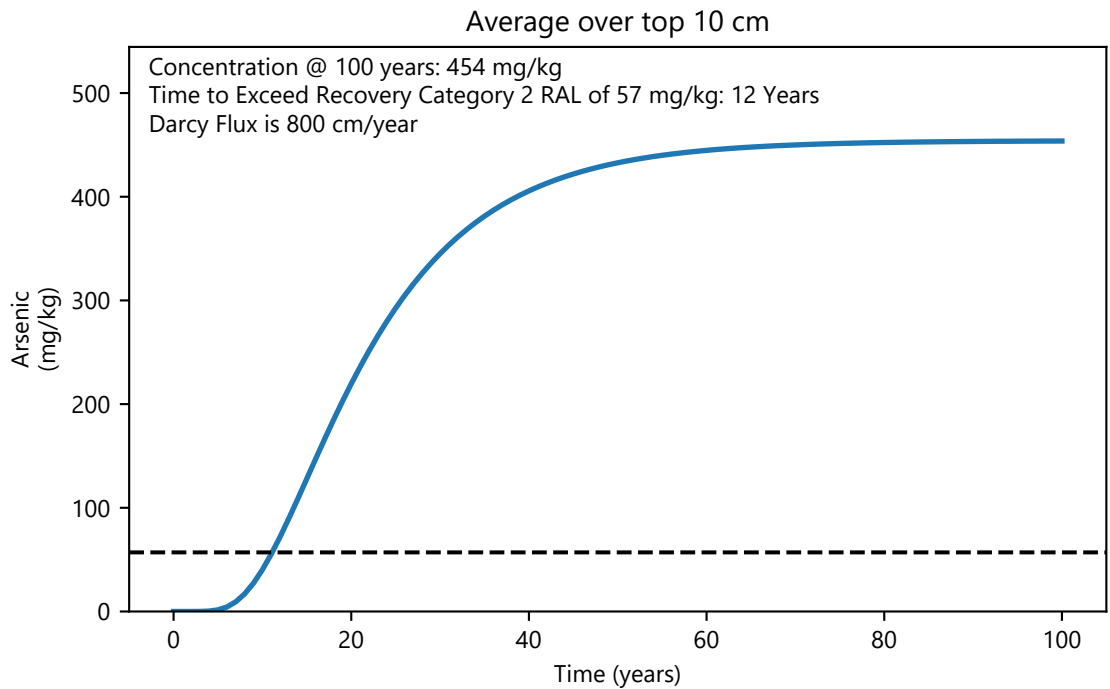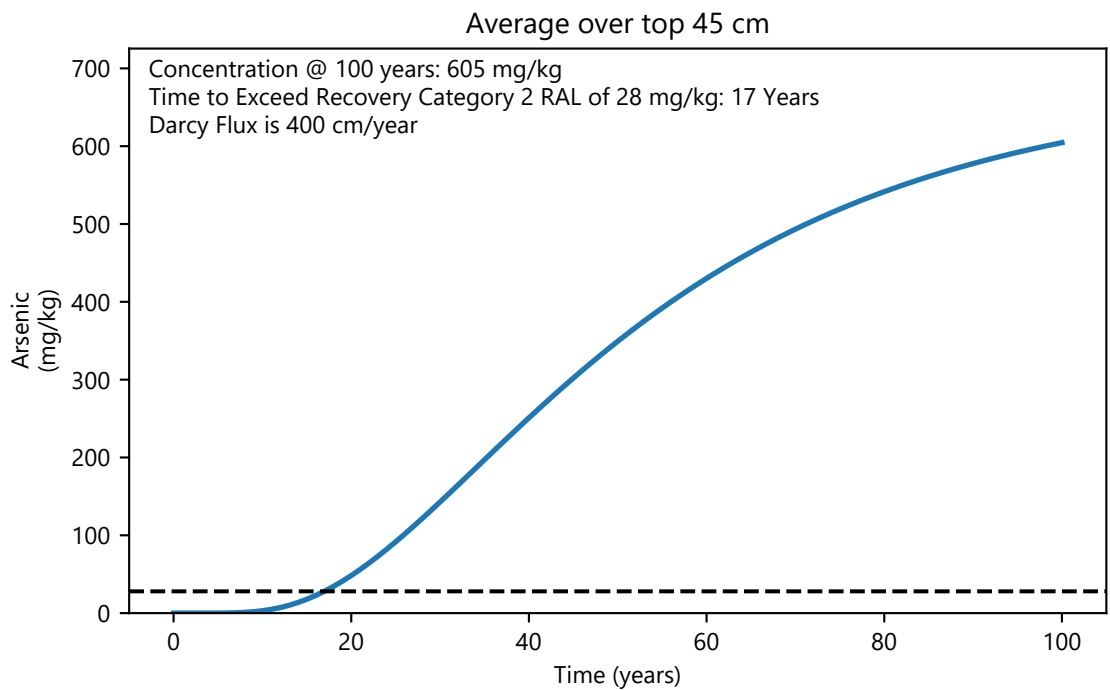57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-19a
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 405 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 17 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 730 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 9 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
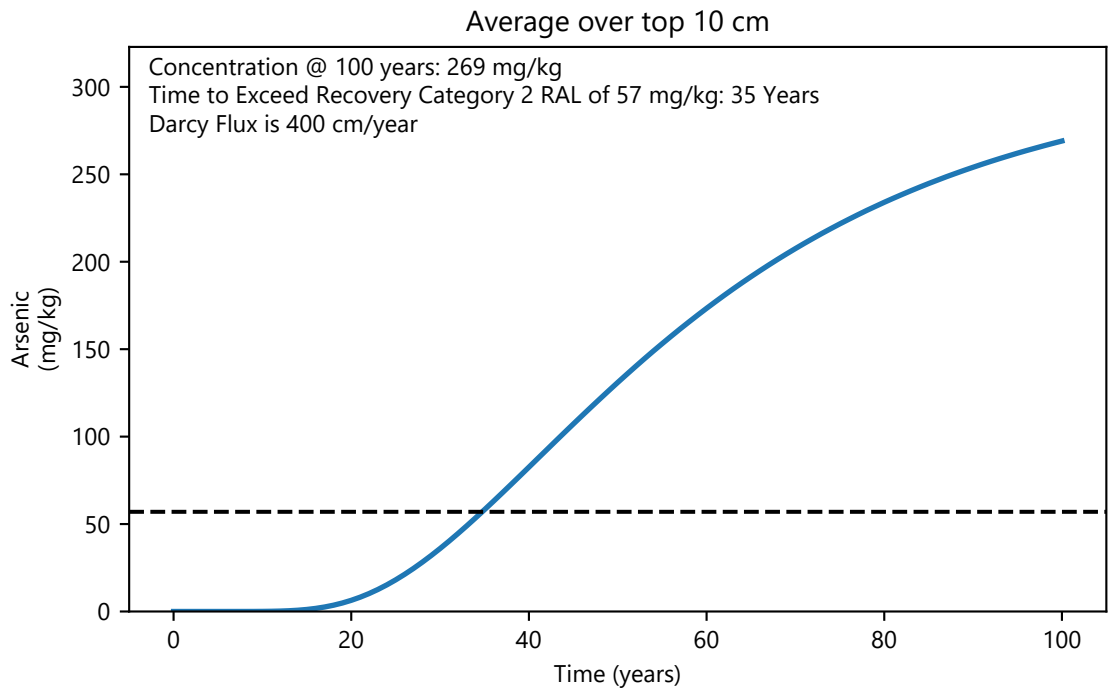57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
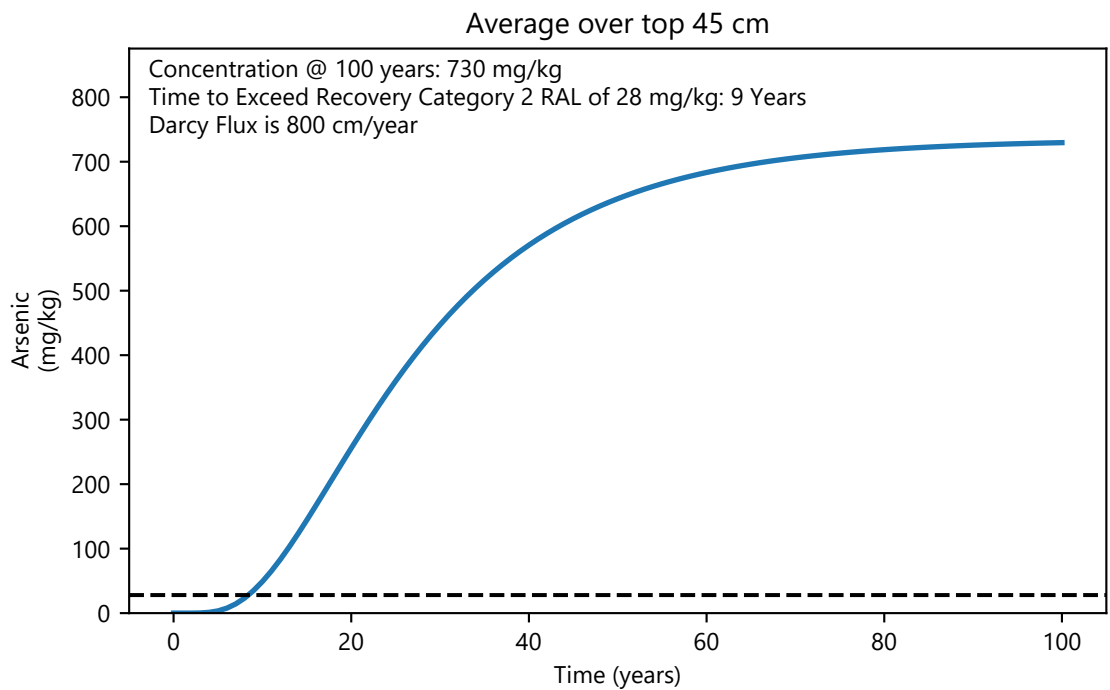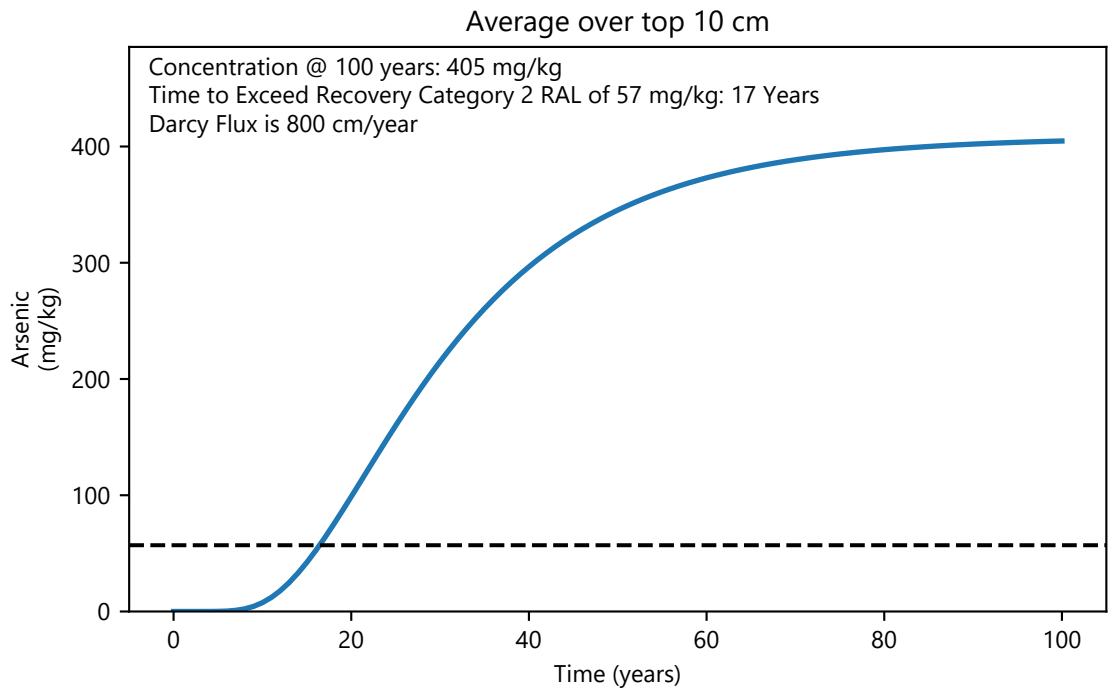
Figure G-19b
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 205 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 47 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 468 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 26 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-20a
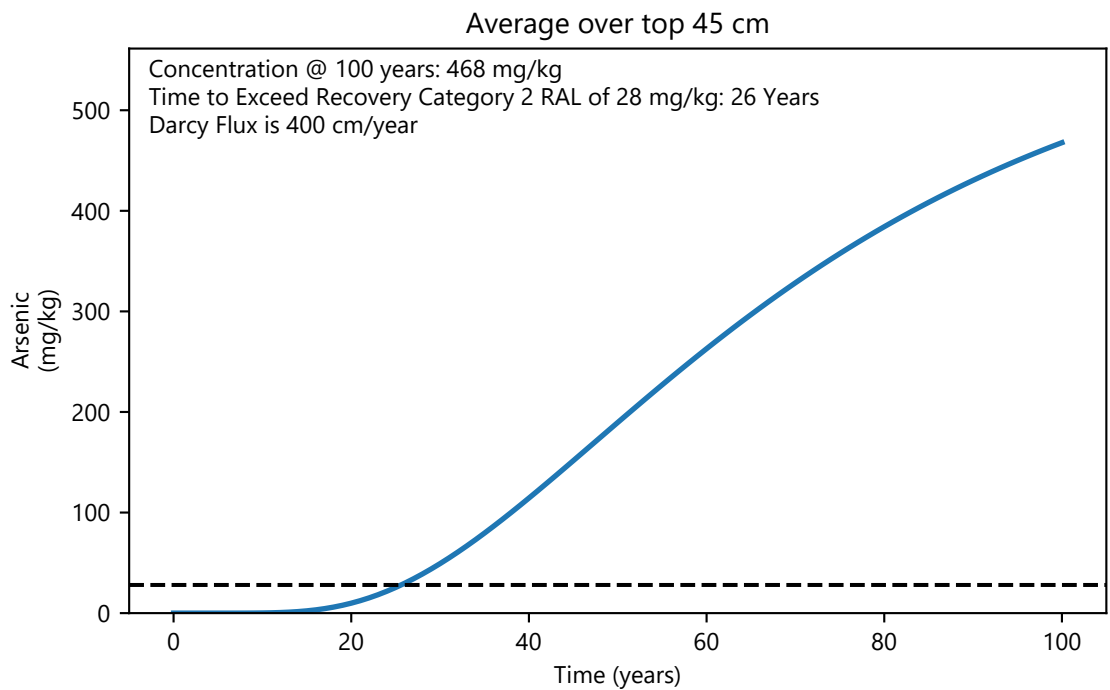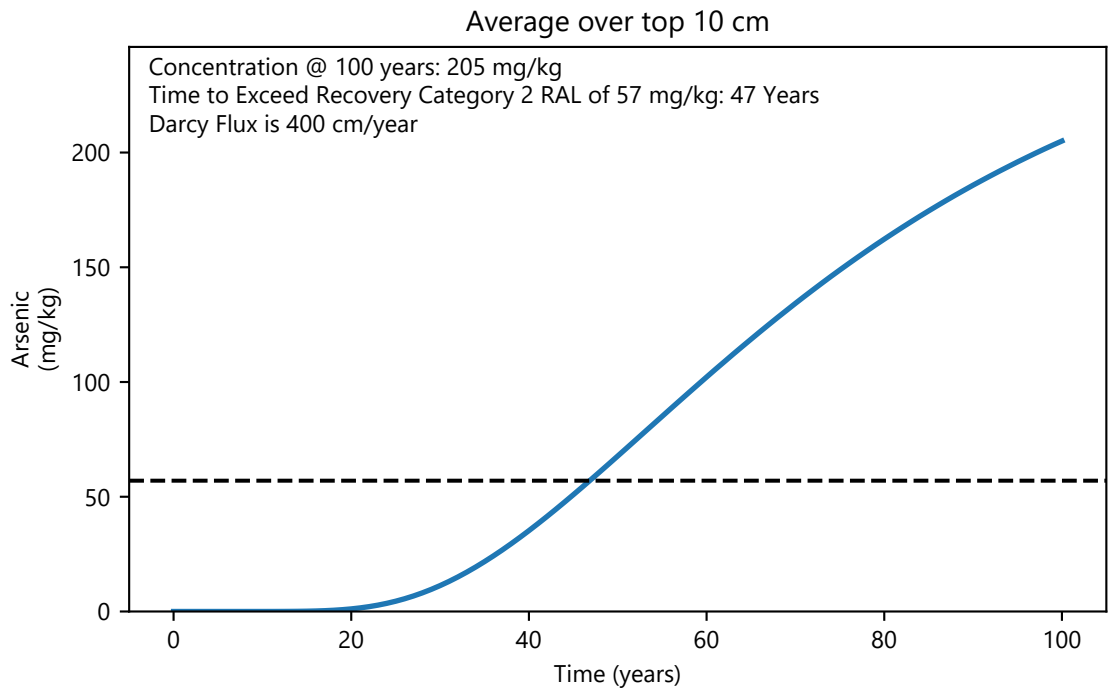**Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap**
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 368 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 22 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 656 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 13 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
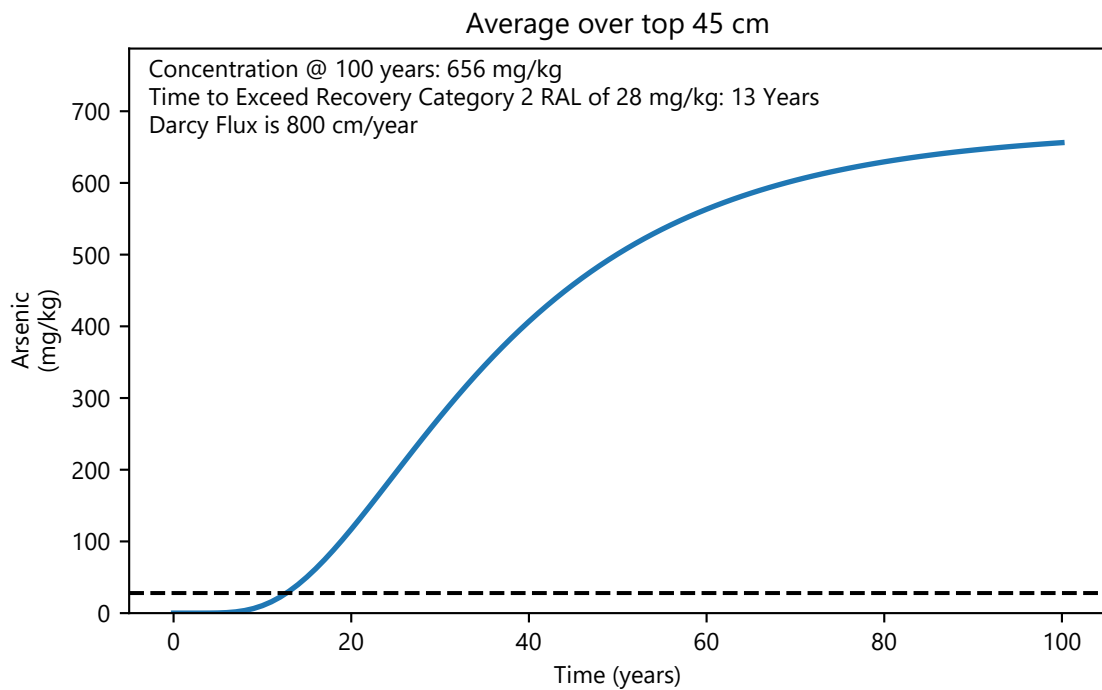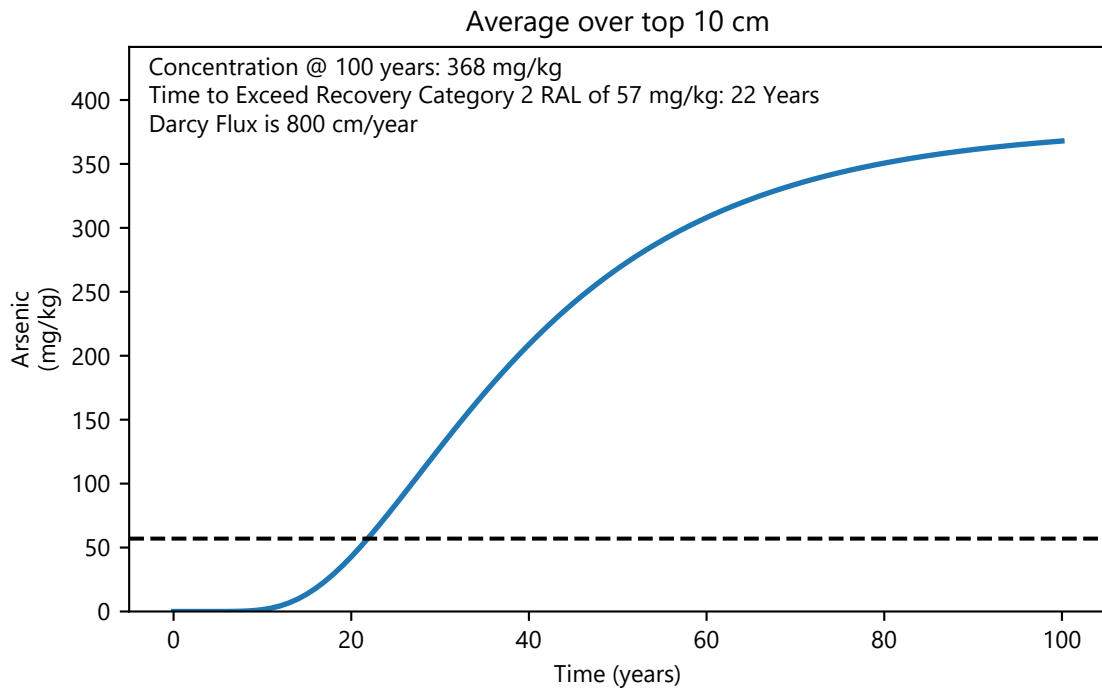
Figure G-20b
Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 121 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 39 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 251 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 13 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-21a
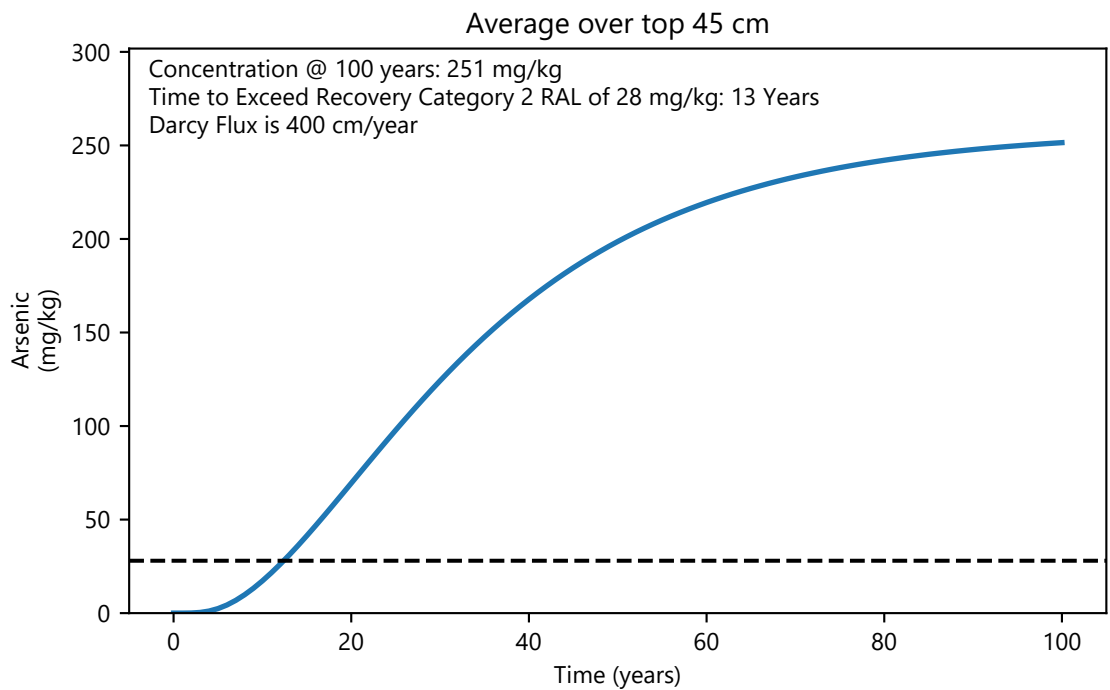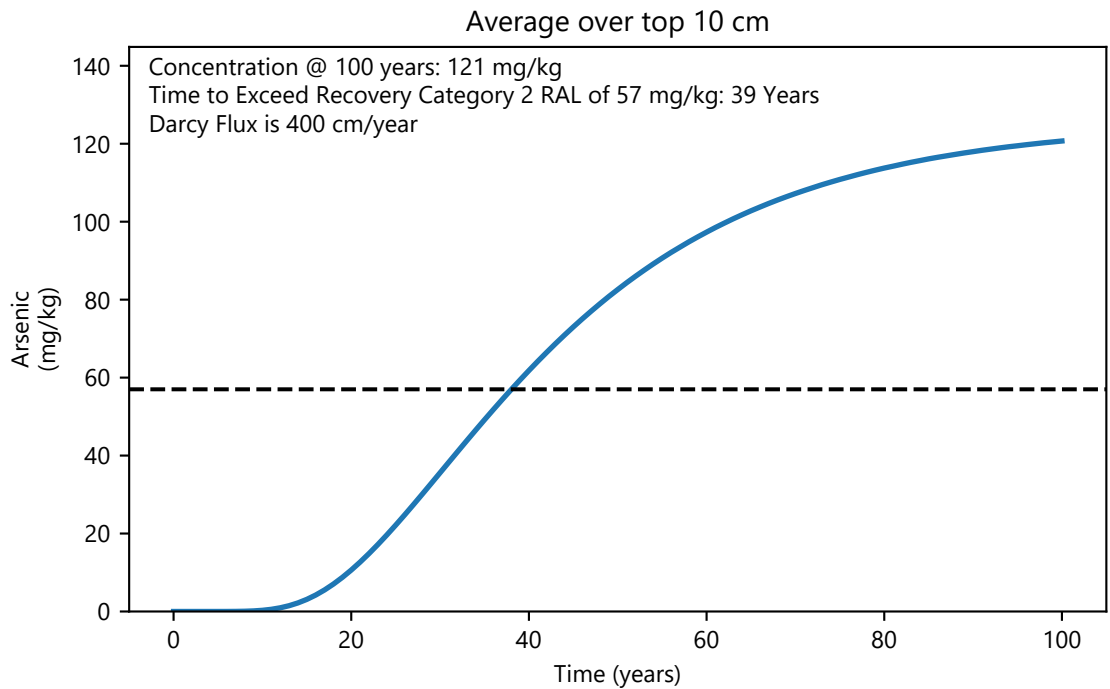**Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap with 10% ZVI**
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 154 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 18 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 271 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 7 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
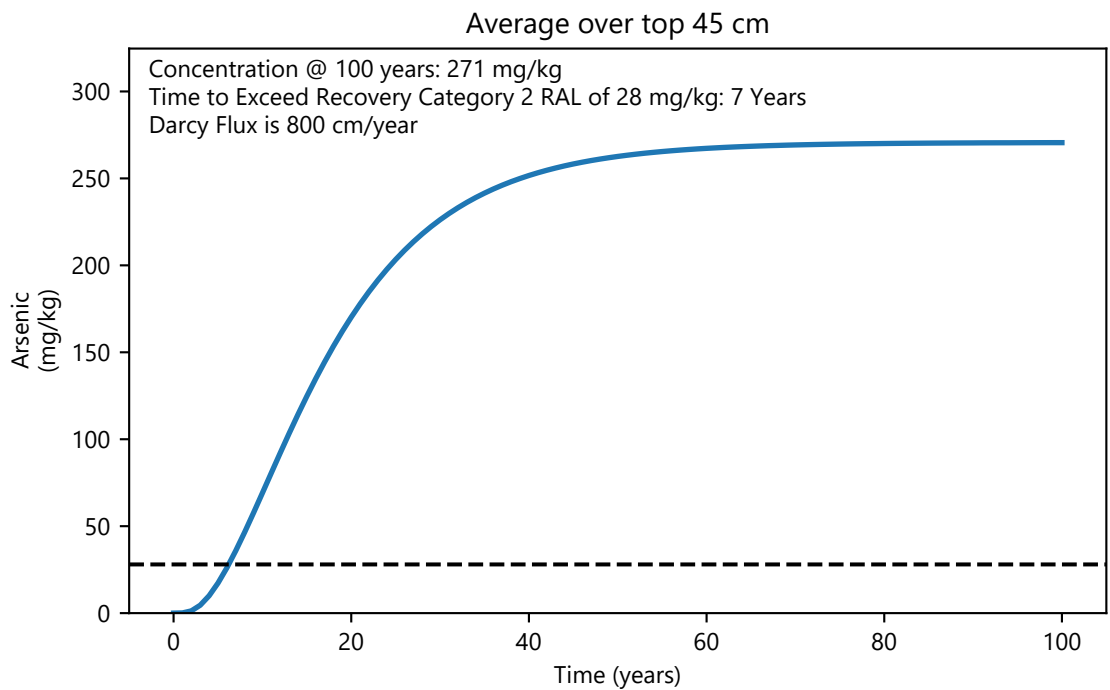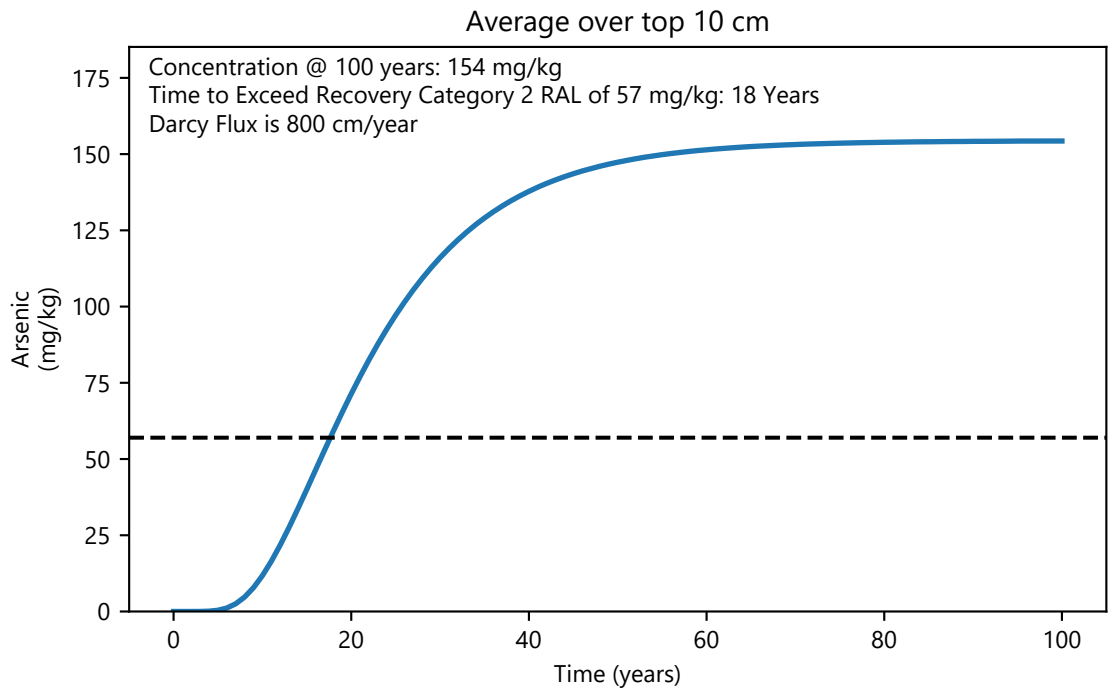
Figure G-21b
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap with 10% ZVI
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 91 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 63 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 203 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 26 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
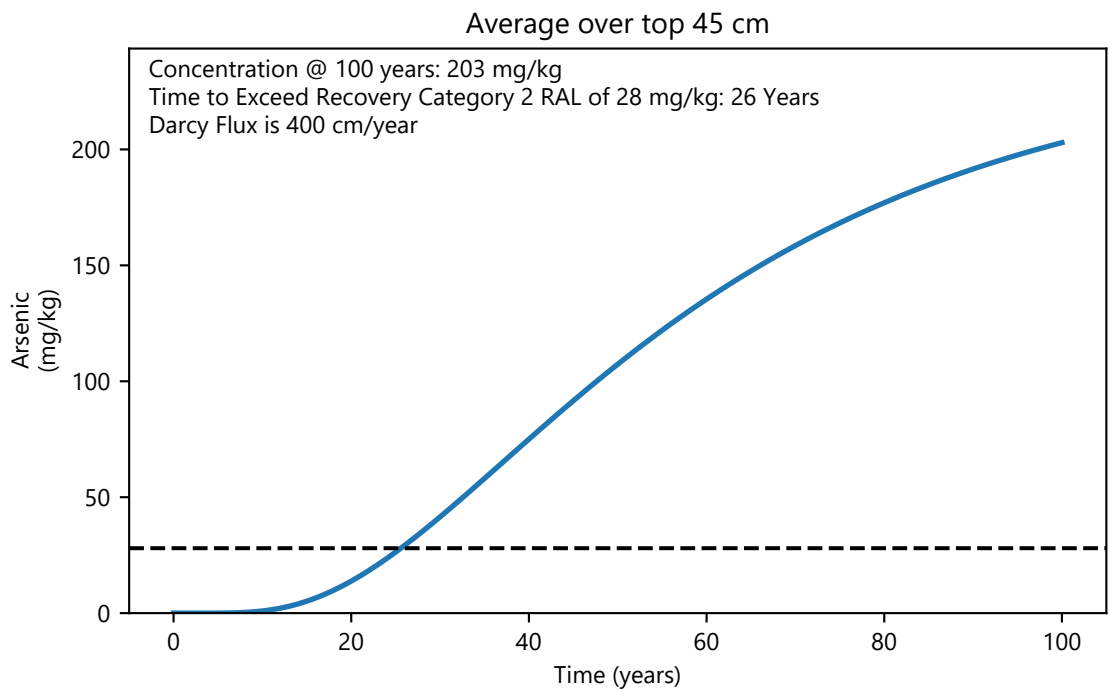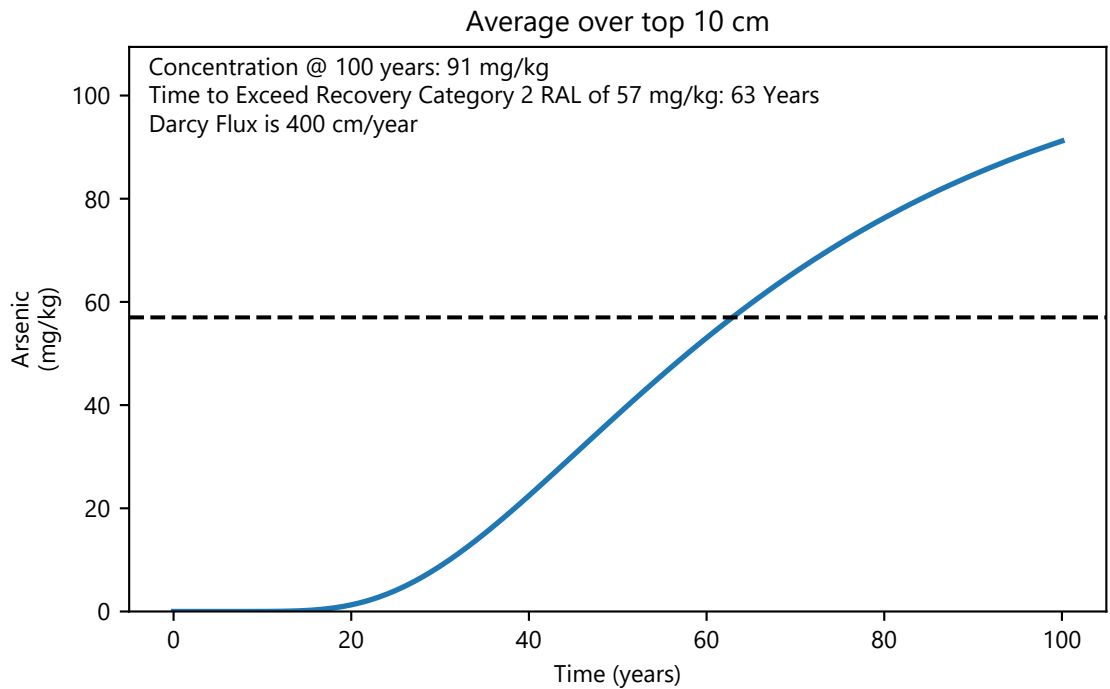
Figure G-22a
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap with 10% ZVI
(400 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 141 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 29 Years
Darcy Flux is 800 cm/year

Arsenic (mg/kg) vs Time (years)

Average over top 45 cm

Concentration @ 100 years: 253 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 13 Years
Darcy Flux is 800 cm/year

Arsenic (mg/kg) vs Time (years)

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
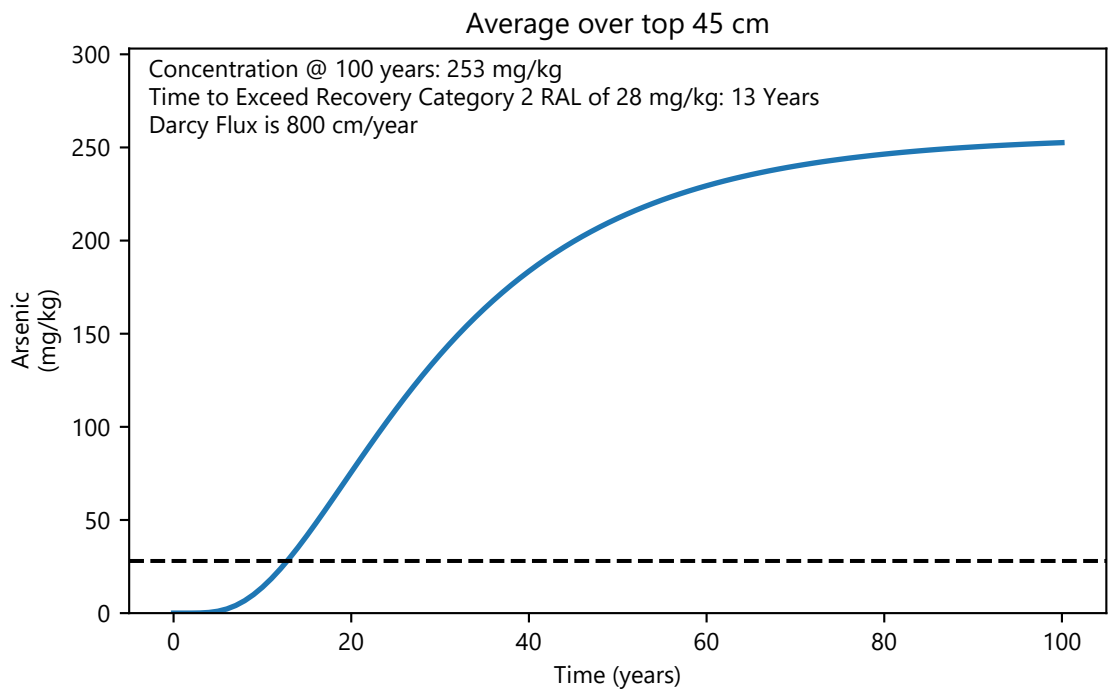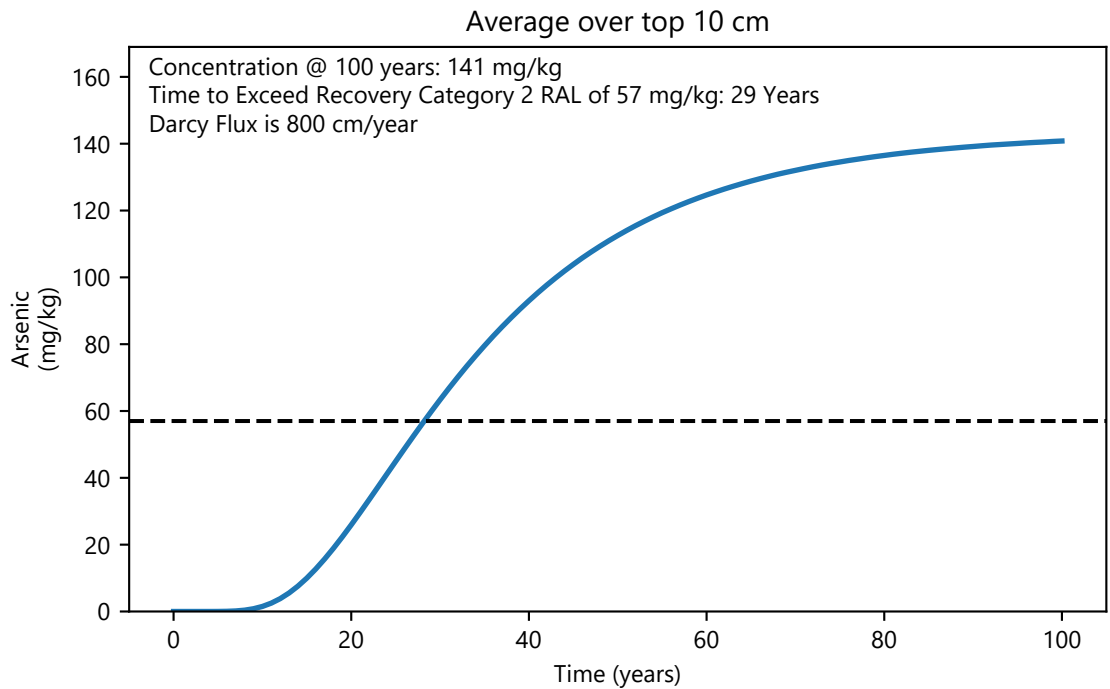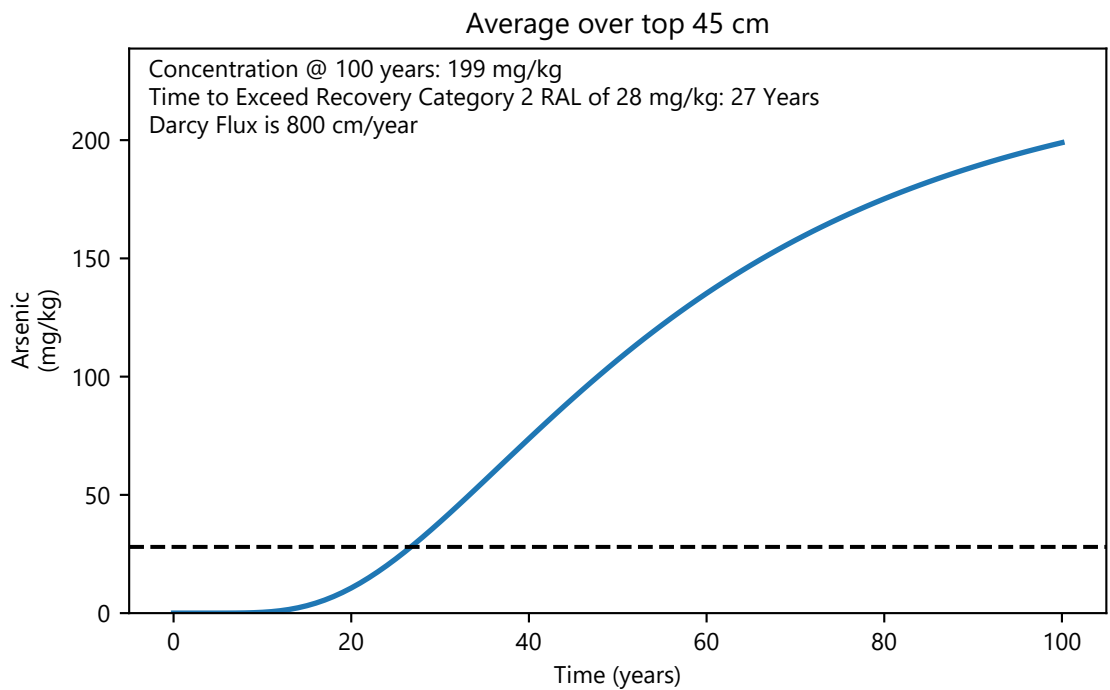57 mg/kg (top panel) and 28 mg/kg (bottom panel)
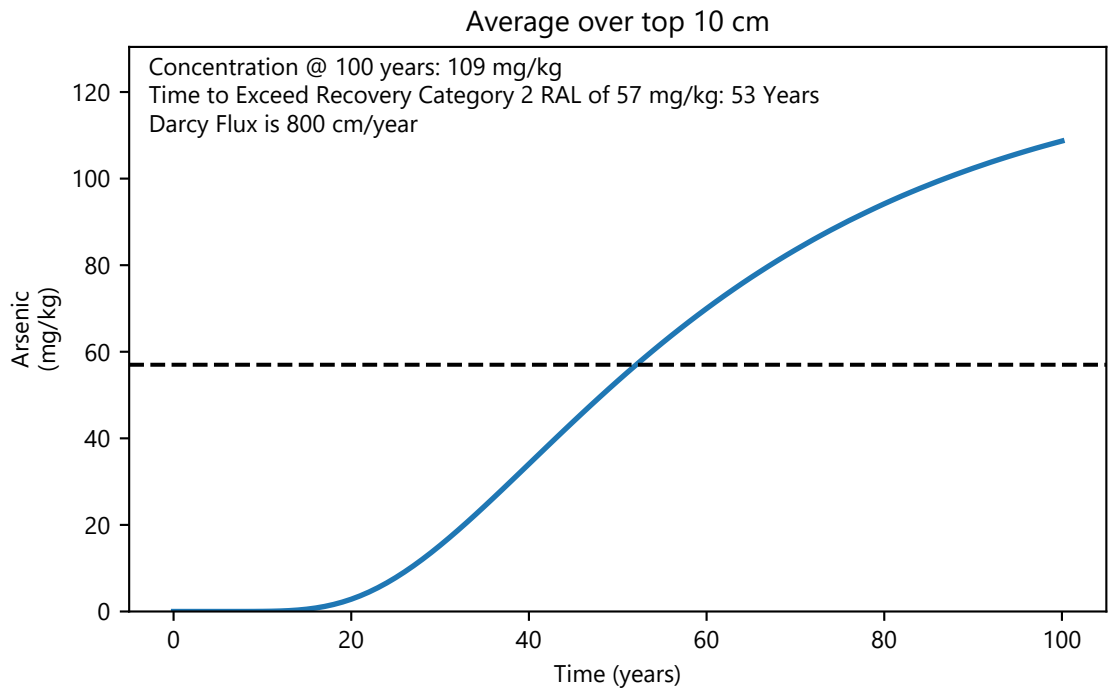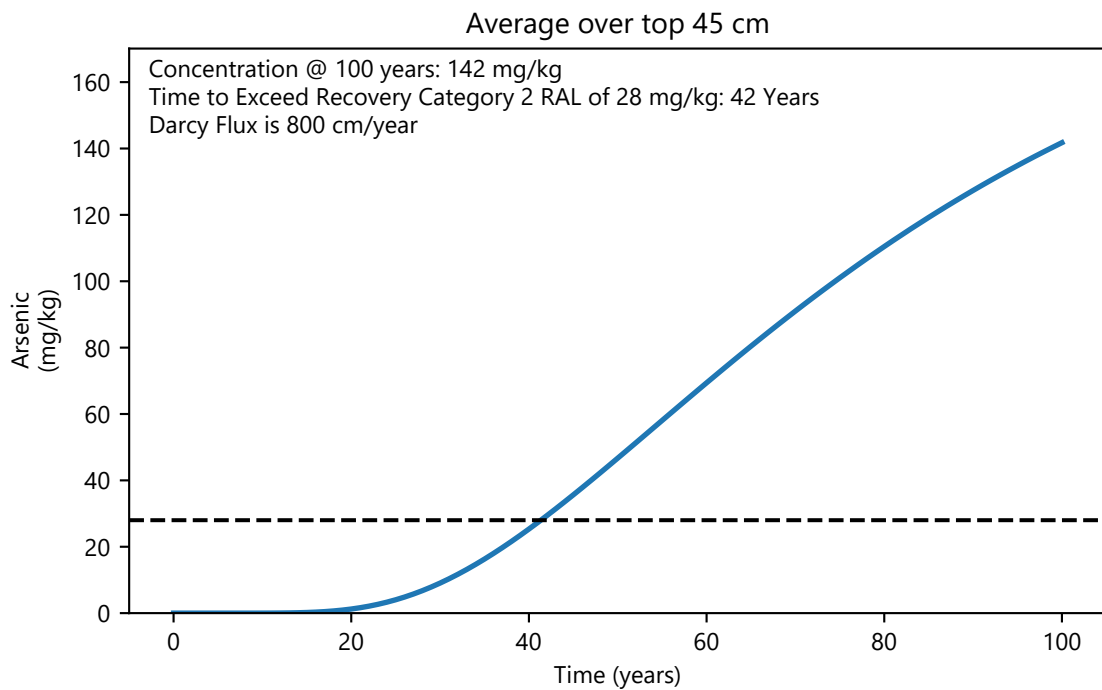
ANCHOR QEA

**Figure G-22b
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap with 10% ZVI
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)**

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 109 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 53 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 199 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 27 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA

Figure G-23
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap with 10% ZVI
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 78 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 79 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 142 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 42 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
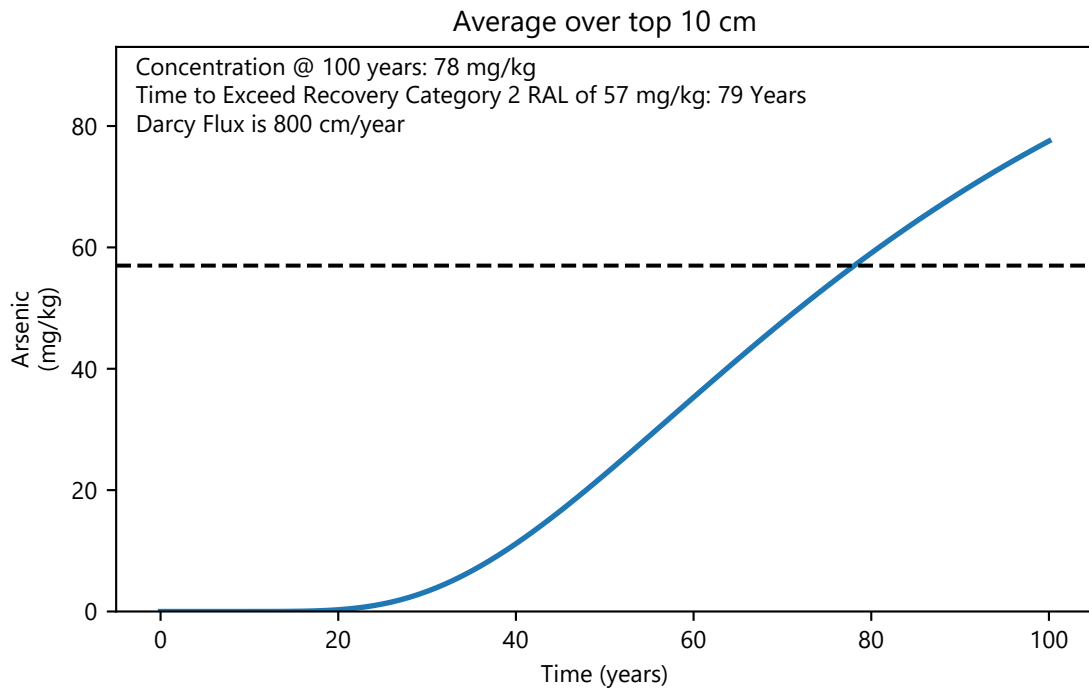
Figure G-24
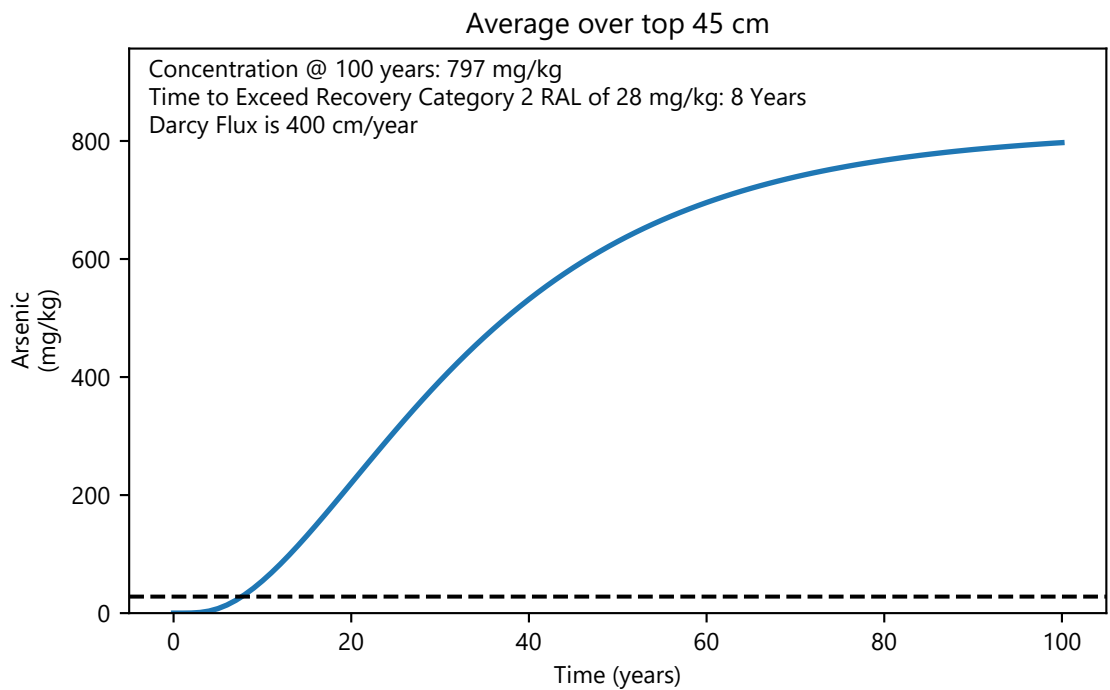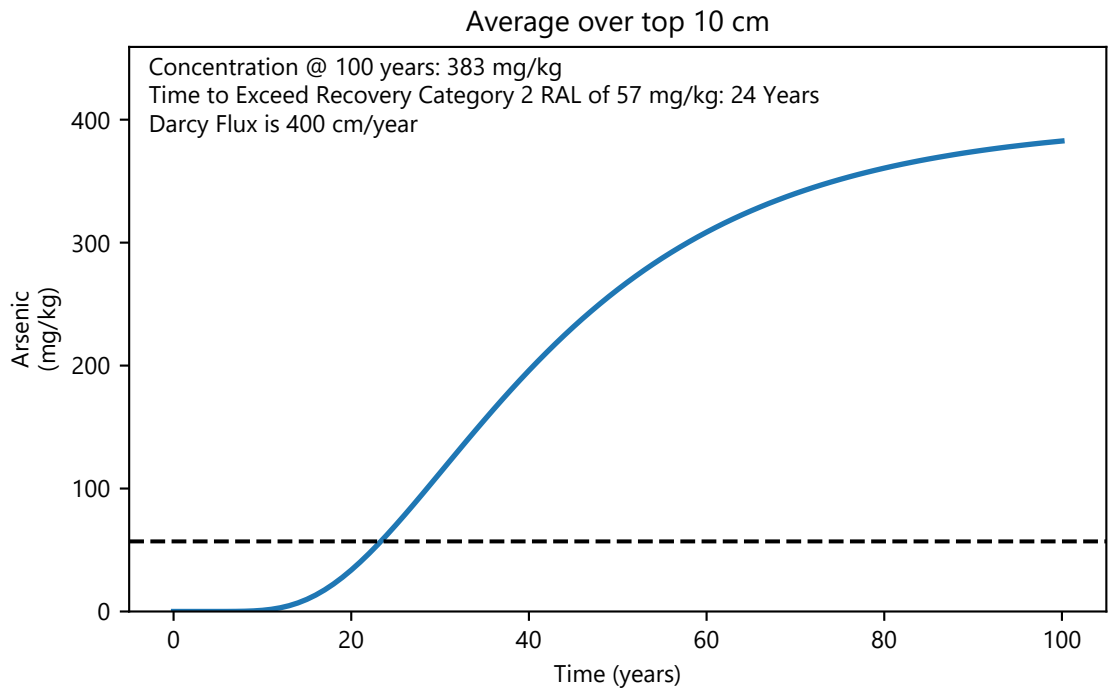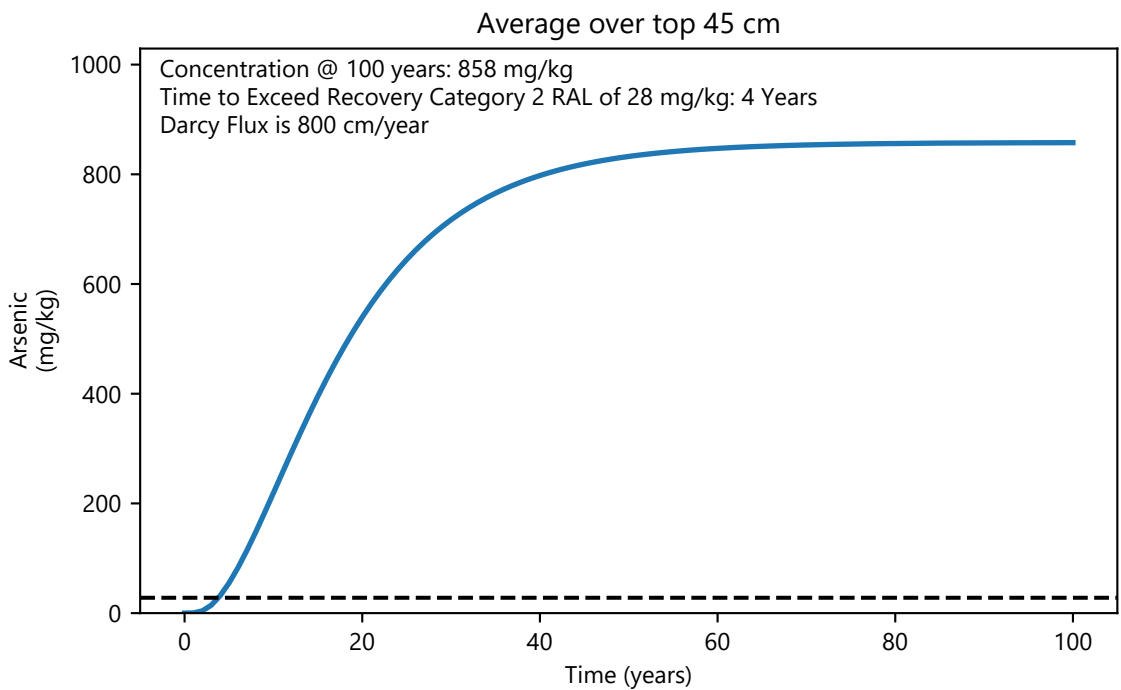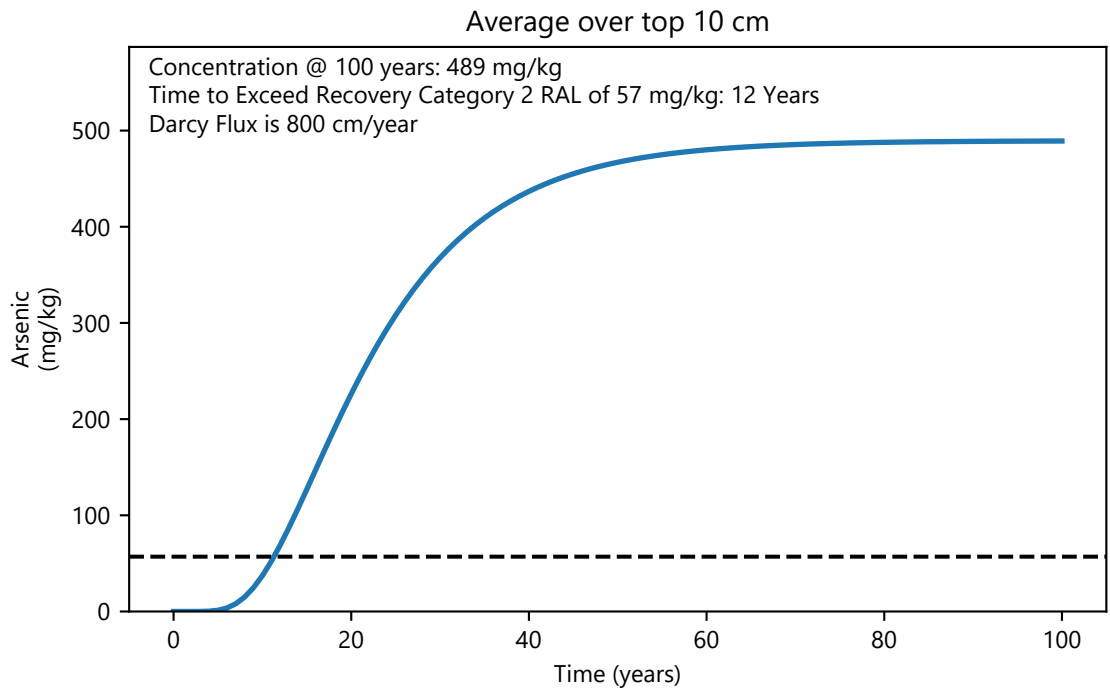**Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap with 10% ZVI**
(800 cm/yr Darcy Flux and 95% UCL Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 383 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 24 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 797 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 8 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

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Figure G-25a
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap with 10% ZVI
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 489 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 12 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 858 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 4 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
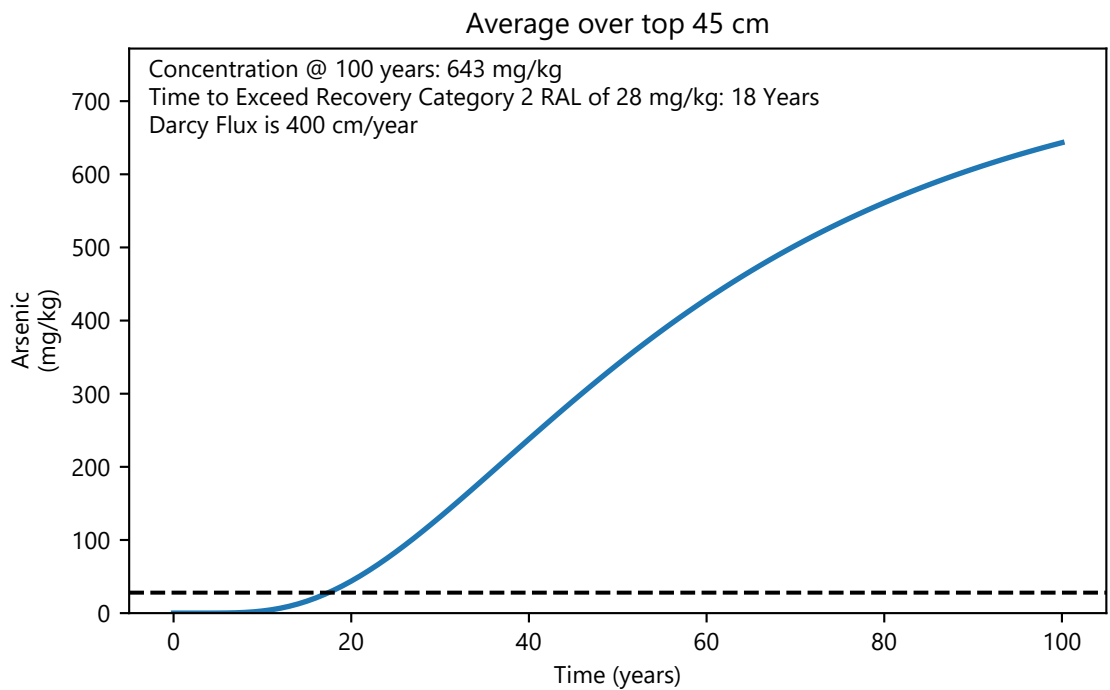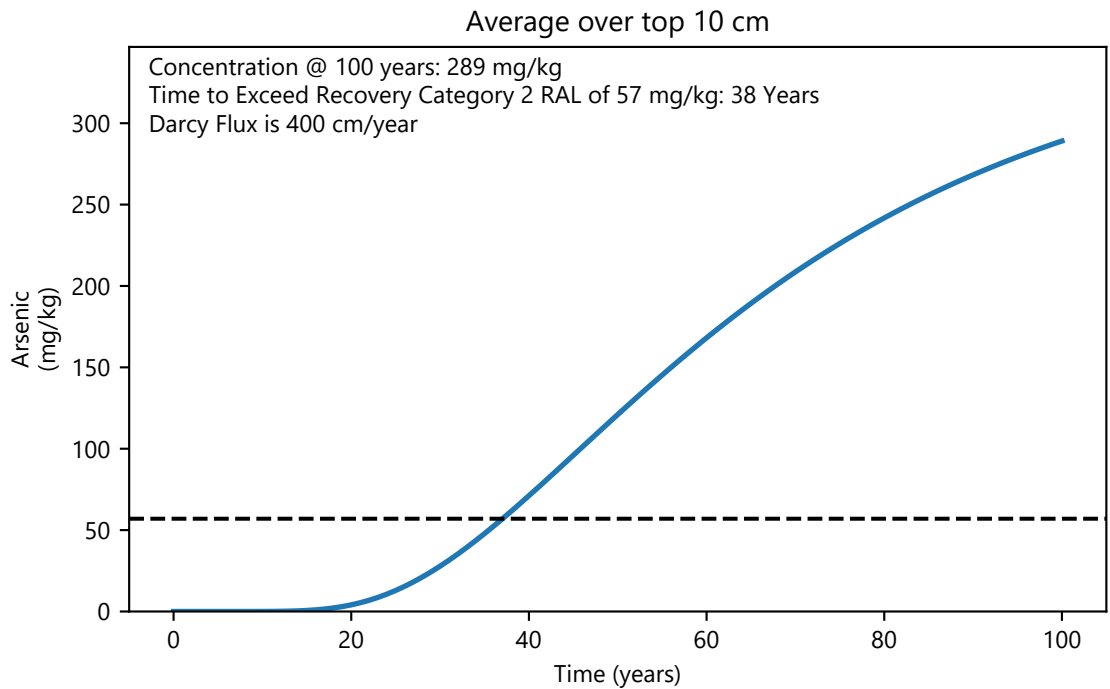
Figure G-25b
Temporal Profile of Arsenic Within the Surface of the Scenario 1 Cap with 10% ZVI
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 289 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 38 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 643 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 18 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA

Figure G-26a
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap with 10% ZVI
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

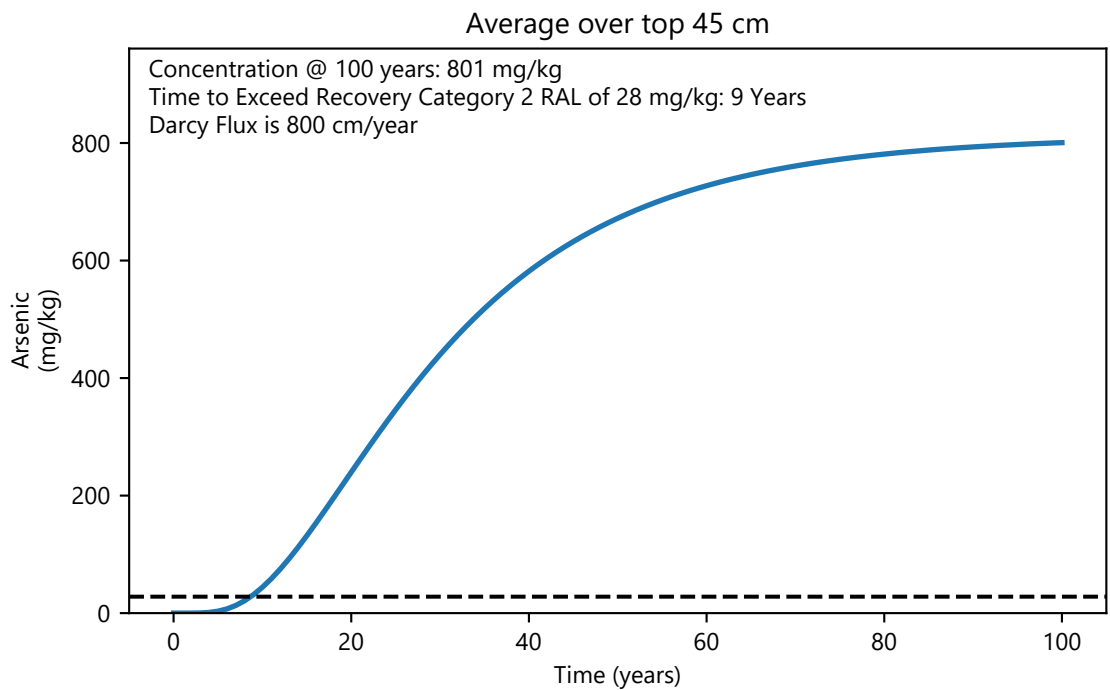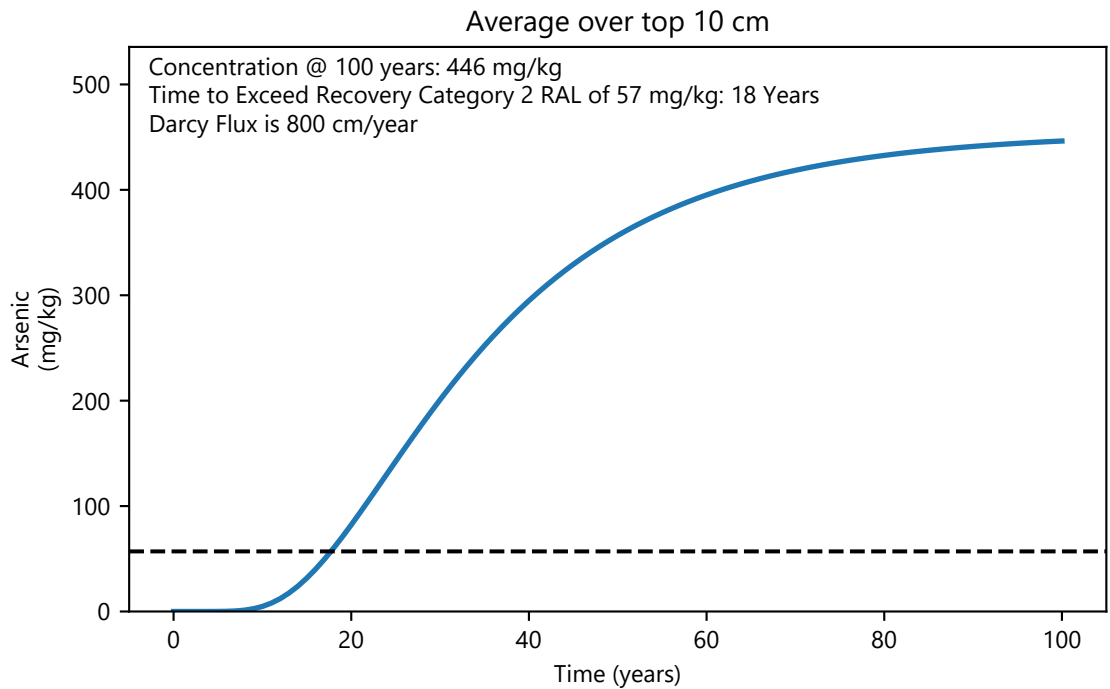Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 446 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 18 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 801 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 9 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
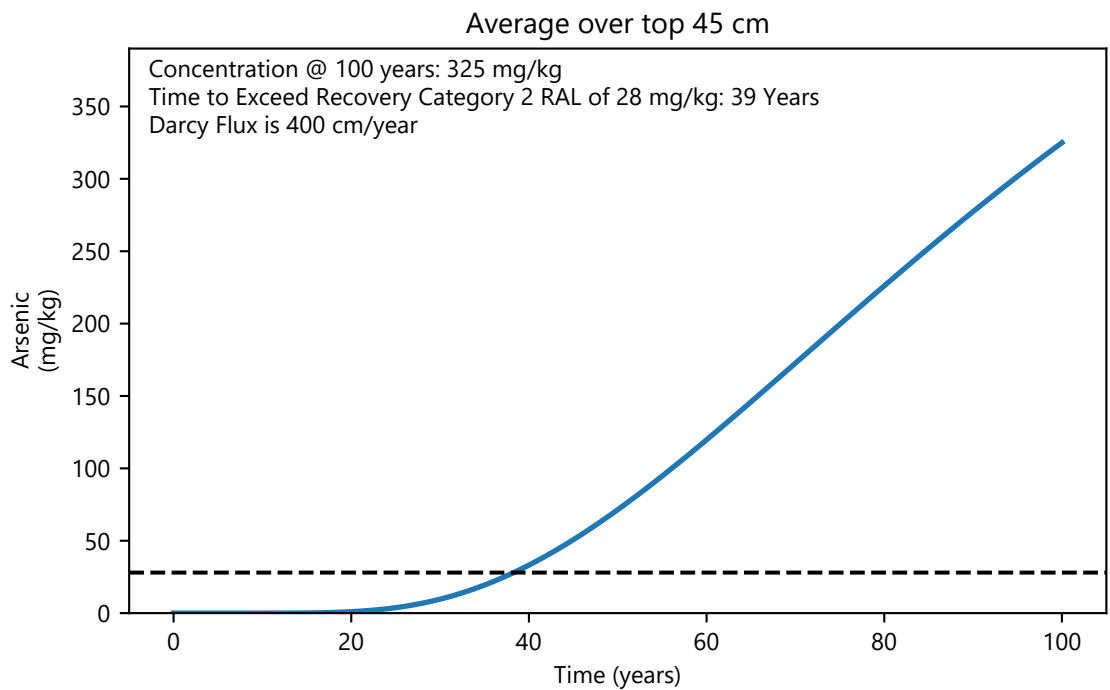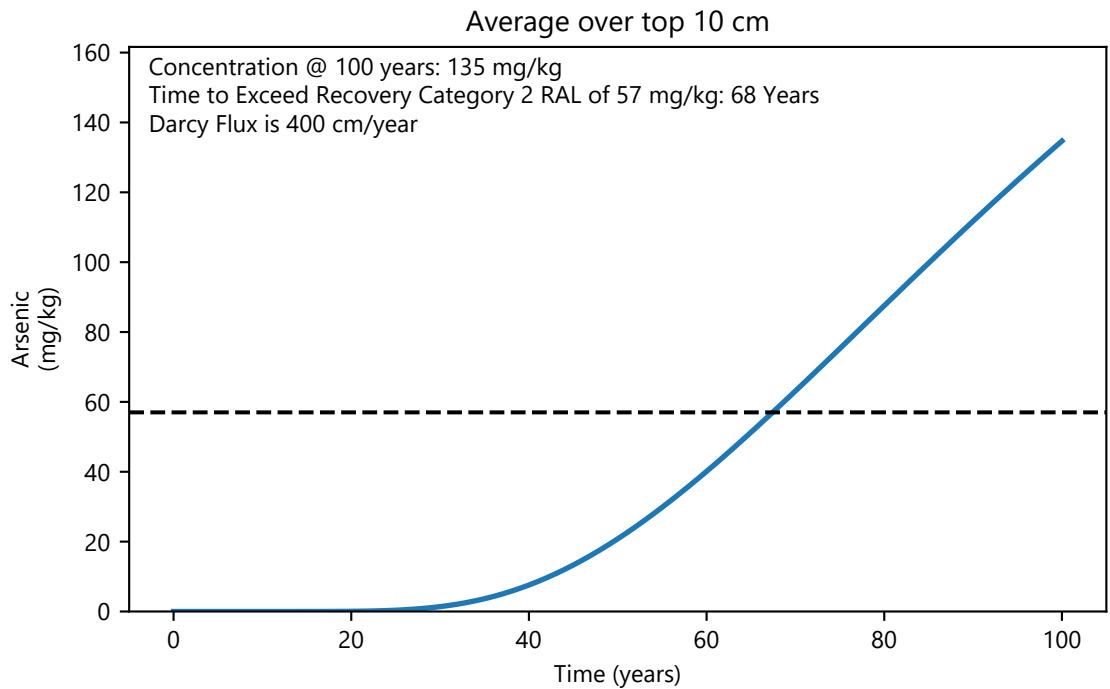57 mg/kg (top panel) and 28 mg/kg (bottom panel)

Figure G-26b
Temporal Profile of Arsenic Within the Surface of the Scenario 2 Cap with 10% ZVI
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 135 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 68 Years
Darcy Flux is 400 cm/year

Average over top 45 cm

Concentration @ 100 years: 325 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 39 Years
Darcy Flux is 400 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA
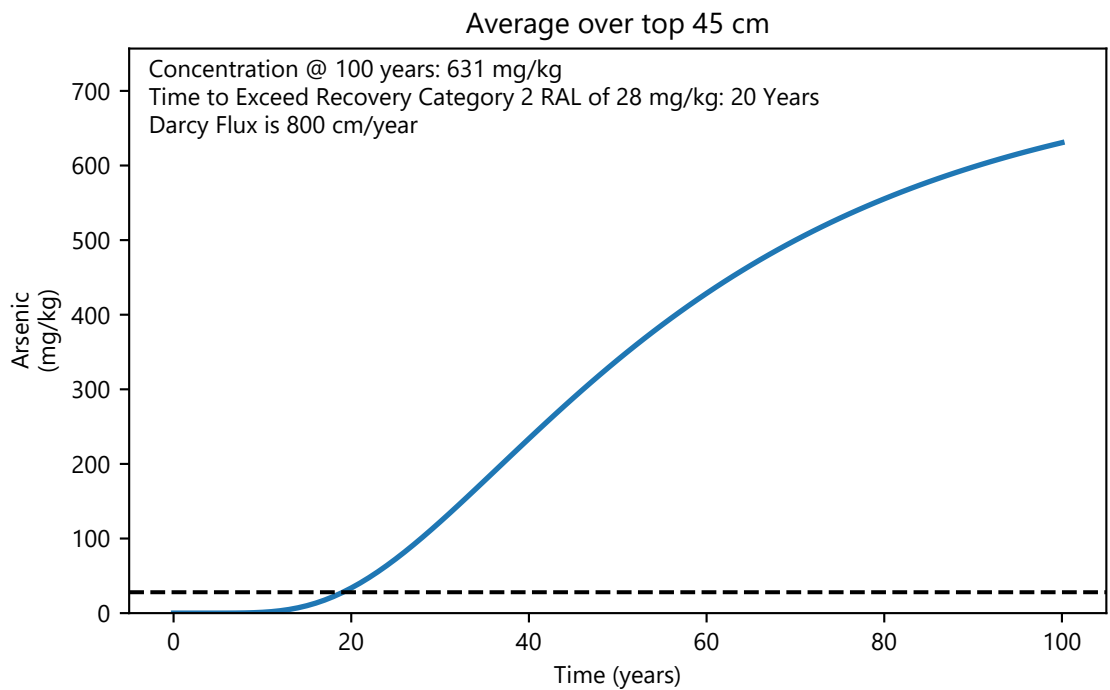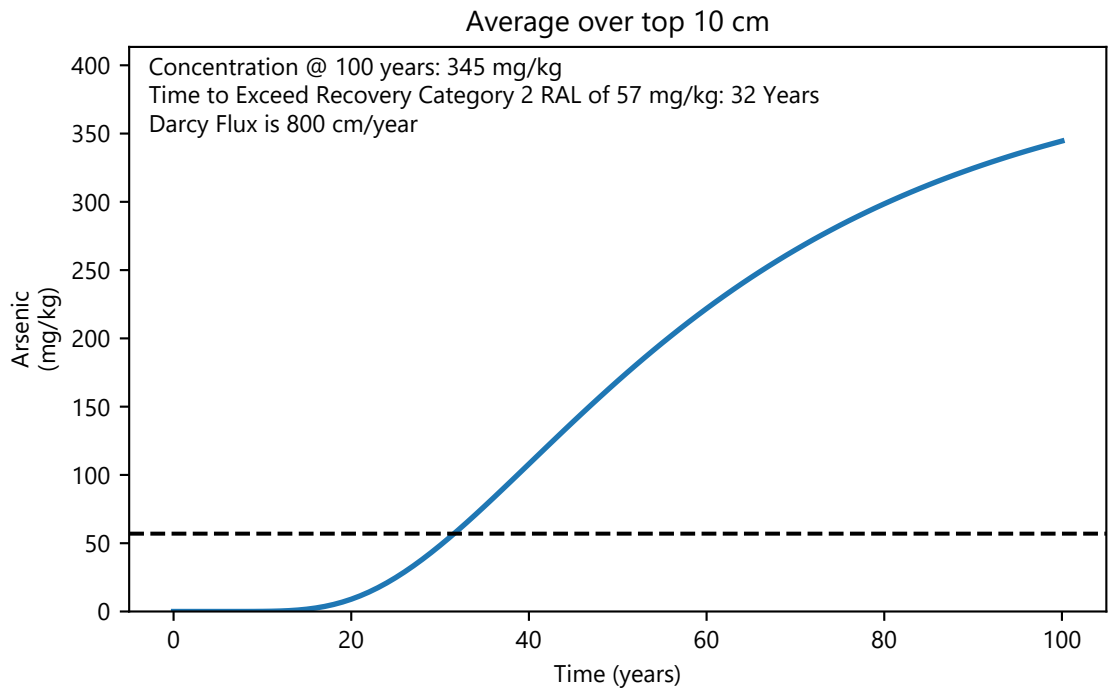
Figure G-27a
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap with 10% ZVI
(400 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 345 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 32 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 631 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 20 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
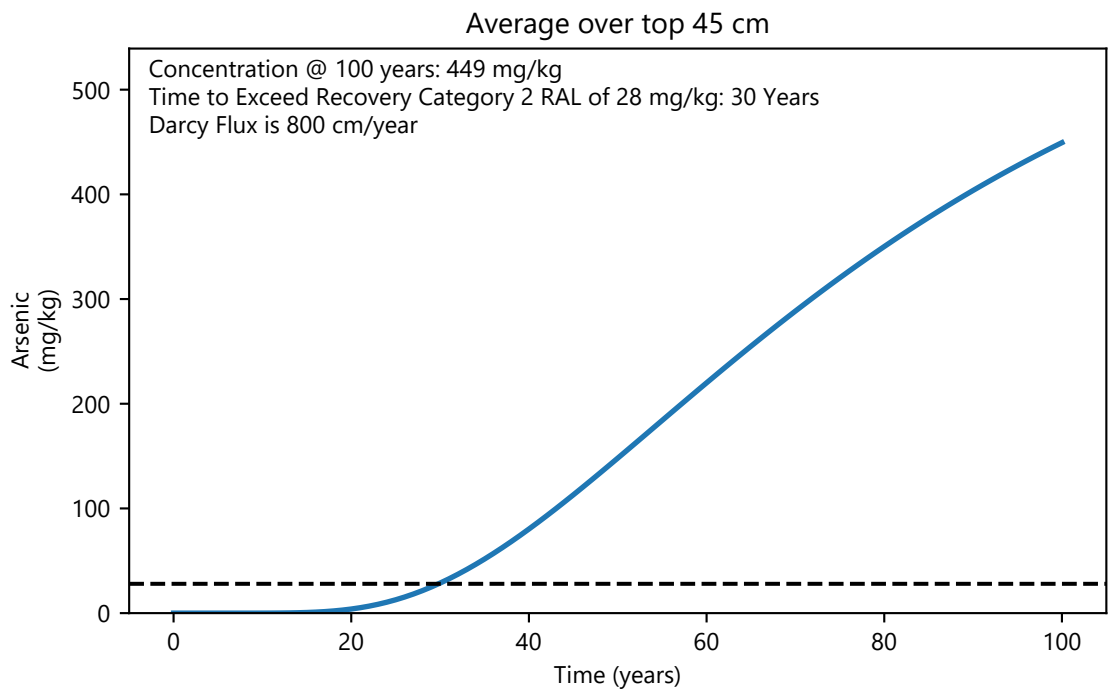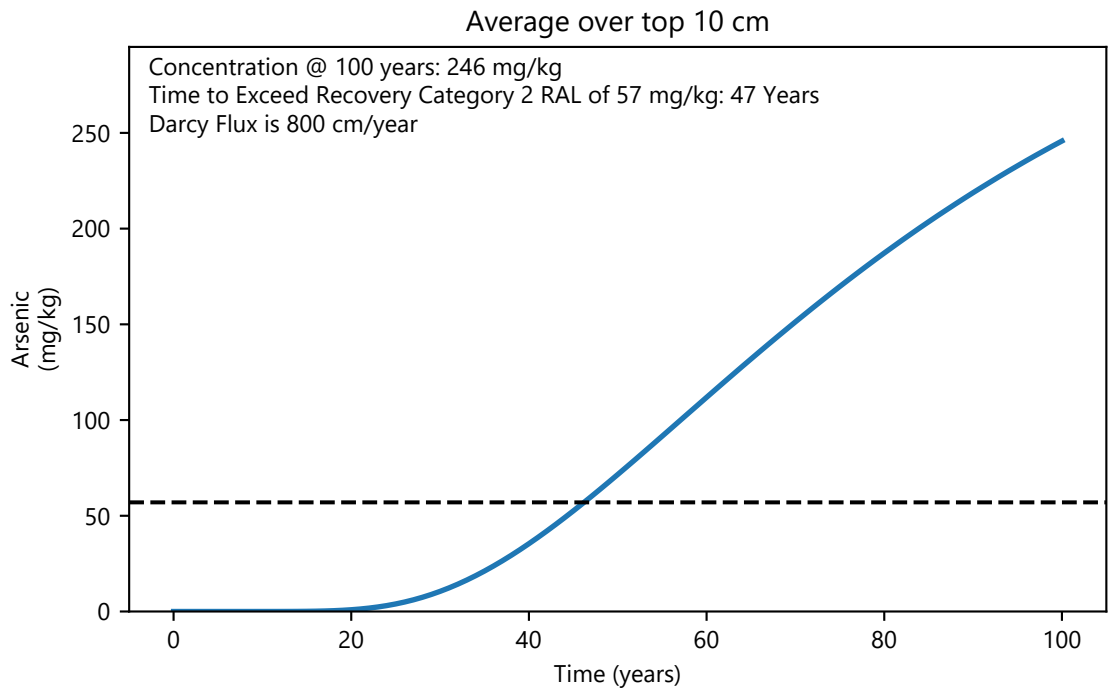57 mg/kg (top panel) and 28 mg/kg (bottom panel)

**Figure G-27b
Temporal Profile of Arsenic Within the Surface of the Scenario 3 Cap with 10% ZVI
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)**

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach

Average over top 10 cm

Concentration @ 100 years: 246 mg/kg
Time to Exceed Recovery Category 2 RAL of 57 mg/kg: 47 Years
Darcy Flux is 800 cm/year

Average over top 45 cm

Concentration @ 100 years: 449 mg/kg
Time to Exceed Recovery Category 2 RAL of 28 mg/kg: 30 Years
Darcy Flux is 800 cm/year

Notes:
The Category 2 Recovery Area RAL is shown as the horizontal dotted line at
57 mg/kg (top panel) and 28 mg/kg (bottom panel)

ANCHOR QEA

Figure G-28
Temporal Profile of Arsenic Within the Surface of the Scenario 4 Cap with 10% ZVI
(800 cm/yr Darcy Flux and Maximum Arsenic Concentration)

Engineered Cap Chemical Isolation Design Analysis
Lower Duwamish Waterway Upper Reach