Appendix I

Evaluation of Capping Technology

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Appendix I – Evaluation of Capping Technology

I.1 Introduction

Appendix I presents an evaluation of sand and gravel caps. The capping technology screening is presented in Appendix B. Two capping technology types were retained for further consideration during design:

- Sand or gravel caps; and
- Concrete-filled fabric mattresses (concrete mattresses).

It is assumed that sand and gravel caps would be used in the majority of the capping areas. Concrete mattresses would only be used if necessary in relatively small areas where sand and gravel caps are not suitable because of steep slopes and associated marginal slope stability. Based on experience of this technology being successfully employed in the Thea Foss Waterway, concrete mattresses can generally be designed to meet project-specific needs, such as isolation of certain contaminants, by modifying design components. Thus, concrete mattresses are considered generally feasible. The feasibility of sand caps is dependent on the ability of the cap thickness to physically isolate the contaminants of potential concern (COPCs) in the underlying sediments. The feasibility evaluation for sand caps is presented below.

I.2 Feasibility of Sand and Gravel Caps

Sand and gravel caps are intended to isolate contaminated sediments from the surrounding environment as an alternative to removal. Capping involves placement of a specified thickness of clean material (i.e., sand and gravel) on top of contaminated sediments. A typical cap design is shown on Figure I-1. Placement of a sand cap typically is achieved by controlled dumping from a barge, conveyor, or clamshell. In-situ sand capping of COPC-impacted sediments at open water sites has been performed since the late 1970s. A considerable body of literature has been developed spanning capping feasibility, design, and case histories. However, capping is still considered a state-of-the-art alternative because of continual advances in the field. The key components of a sand cap for providing isolation of the sediment and associated pore water are based on extensive research and modeling by the U.S. Army Corps of Engineers (Palermo et al., 1996).

The feasibility assessment evaluates if the following requirements can be achieved using a sand cap:

- Physical isolation of chemical of potential concern (COPC)-impacted sediments from contact with the water column and the benthic community (i.e., organisms in the surficial sediment and part of the food chain);

- Stabilization of COPC-impacted sediments preventing resuspension and transport of resuspended sediments in the river;

- Reduction of the flux of dissolved COPCs (i.e., arsenic, copper, lead, chrysene, and 4,4'-DDE) with properly selected cap media sorption characteristics.

For the purpose of the EE/CA feasibility assessment, modeling was conducted to evaluate the potential performance of a sand cap in terms of physical and chemical isolation. If sand capping is selected for further evaluation, the stabilization and erosion protection component of the cap design will be considered in greater detail during design.

I.3 Cap Performance Modeling Methods

Cap performance modeling was performed using the web-based model developed by the South and Southwest Region Hazardous Substance Research Center (HSRC, 2005). The model simulates the unsteady transport of a chemical contaminant in porewater following procedures presented in the U.S. Army Corps of Engineers Guidance for Subaqueous Dredged Material Capping (Palermo et al., 1996). This analytic model describes advective, dispersive, and diffusive solute flux through capping materials, and accounts for retardation of solute movement due to sorption/desorption processes. Processes such as biodegradation and reduction in source area mass and concentration due to transport through the cap were not accounted for (i.e., an infinite contaminant source with no degradation was assumed). The model was used to evaluate dissolved phase transport of arsenic, copper, lead, chrysene, and 4,4'-DDE through a hypothetical two-foot thick sand cap and a hypothetical three-foot thick sand cap.

Data required for this model included vertical groundwater seepage velocity, sediment and cap porosity, sediment and cap bulk density (excluding pore space), effective cap thickness, COPC concentrations in sediment, sediment/water and cap/water partitioning coefficients, diffusivity, and dispersivity. Values for these parameters used in the modeling are summarized in Tables I-1 and I-2. Selection of each of these parameters is discussed in the following paragraphs. For input parameters with a potential range of values, the most conservative value was chosen.

A porosity of 0.5, based on consolidation test results, was used for the fine sand sediments. A porosity of 0.4 was assumed for the sand capping medium. Sediment and cap material bulk density were estimated to be 2.65 g/cm3.

A groundwater seepage velocity of 1.05×10^{-9} cm/s was estimated using a vertical hydraulic gradient of 0.001, an estimated hydraulic conductivity of 3.7×10^{-7} cm/s (BBL, 2004), and an estimated aquifer porosity of 0.35 based on aquifer material grain size data (Freeze and Cherry, 1979). The velocity of surface water in Slips 1 and 3 was conservatively set to 0.05 m/sec based on results of ADCP measurements during Spring 2004 (BBL, 2004).

Effective thickness of the cap (i.e., cap thickness for chemical isolation) can be defined as the thickness of the cap available for long-term chemical containment. It is dependent on the initial thickness of the placed cap, consolidation of the cap, consolidation of the underlying sediments, erosion, and the bioturbation depth. An initial cap thickness of three feet was assumed. Sensitivity analyses were run using a cap thickness of two feet. For the purpose of evaluating the thickness of cap compromised due to cap placement, a consolidation magnitude of the underlying sediments was estimated to be one foot. For this initial modeling effort, erosion and consolidation of the sand cap were assumed to be negligible. A bioturbation depth of 10 cm (4 inches) was selected.

An average of COPC concentrations measured in surface, subsurface, and under-pier sediment samples from proposed capping areas were used as the initial sediment concentrations in the capping evaluation.

Concentration data for samples collected from Berth 401 (T4-VC01), Slip 1 (T4-VC03, T4-VC04, T4-VC11, T4-UP03 through T4-UP08), Wheeler Bay (T4-VC18 and T4-VC19), and Slip 3 (T4-UP12 through T4-UP14) were used to develop these average capped sediment concentrations.

Site-specific K_d values for the capping evaluation were developed from DRET results by dividing the sediment sample COPC concentration by the respective DRET COPC eluent concentration. To develop the capping evaluation COPC list, average capped sediment COPC concentrations were multiplied by the DRET K_d values to estimate potential sediment pore water concentrations. These potential sediment pore water concentrations were compared with the minimum applicable criterion for each COPC. Potential sediment pore water COPC concentrations that exceeded the minimum applicable criterion were retained for further evaluation using the capping model. The COPCs retained for further evaluation were arsenic, cadmium, copper, lead, chrysene, and 4,4'-DDE.

Values for K_d for the six COPCs and K_{oc} for chrysene and 4,4'-DDE are provided in Table I-2 along with the TCLT K_d values described in Appendix K. f_{oc} values for the sediment and sand cap are provided in Table K-3. For a conservative evaluation, the minimum K_d value was used in the capping model for the five of the COPCs. Because the estimated site-specific K_d and K_{oc} values for 4,4'-DDE were based on a single J-qualified concentration and non-detect values, and the estimated site-specific K_{oc} values were orders of magnitude lower than published literature values, a K_{oc} value of 155,000 L/kg was used for modeling purposes (Fetter, 1994).

A value of approximately 5×10^{-6} cm^2/sec was chosen for the molecular diffusivity of the COPCs. A dispersivity equal to one half of the average grain size was estimated for the sediment and the cap material (HSRC, 2004).

The model parameters values listed in Tables I-1 and I-2 represent the best conservative estimates based on site-specific field data and literature values. Therefore, additional sensitivity runs were not conducted for this phase of the sediment cap modeling evaluation.

I.4 Results

A preliminary cap performance evaluation was conducted by modeling a 3-foot-thick and a 2-foot-thick cap. The 3-foot cap was assumed initially during the early phase of the EE/CA using engineering judgement. Modeling of the 2-foot cap was performed to check the sensitivity of the model. The results of the cap performance evaluation modeling are provided in Table I-3 for both, the 3-foot and the 2-foot cap. As shown, the results for both scenarios indicate that the minimum applicable criteria will not be exceeded at the base of the bioturbation zone or at the sediment cap/water interface. Therefore, capping of COPC-impacted sediments with a permeable cap is considered a viable remedial option at this time. The caps that were modeled consisted of a bioturbation layer, a consolidation layer, and a chemical isolation layer. Additional layers such as scour protection and layers for other purposes (e.g., operational requirements) may be added during the removal action design.

I.5 Assessment of Potential Impacts on Willamette River Flood Stage and Flood Storage

Terminal 4 is within the mapped 100-year floodplain (Zone AE) of the Flood Insurance Rate Map (FIRM) 4101830060E, revised October, 19, 2004. The potential impact of CDF construction on the water surface elevation of the 100-year flood within the Willamette River and floodplain was assessed to evaluate compliance with the Executive Order for Floodplain Management (Executive Order 11988), USEPA implementing regulations, and the Federal Emergency Management Agency (FEMA) regulations.

Pursuant to the FEMA regulations, no increase in the base flood elevation can result due to placement of fill or placement of structures within a floodway. Consequently, if the caps are placed within the floodway boundary, this would require an analysis to demonstrate that the encroachment into the floodway will not increase the base flood elevation. An analysis was performed to assure that the caps would not cause a rise in the base flood elevations. The assessment was conducted by using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) to model 100-year floodplain and floodway elevations for the Willamette River near Terminal 4 under existing conditions and with the construction of a full CDF in Slip 1 and the proposed caps associated with Alternative C to ensure a comprehensive analysis of the potential impacts of the preferred alternative. A detailed description of the modeling procedures and results are provided in Attachment K-1 to Appendix K. The preliminary assessments of flood stage rise and flood storage impacts showed negligible effects on these parameters.

I.6 References

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Table I-1
Physical Input Parameter Values for Base Case Scenario -
Sediment Cap Model

SEDIMENT PROPERTIES	Value	Units	Source
Sediment dispersivity	1.25E-04	m	1/2 measured sediment grain size
Seepage velocity	3.30E-02	cm/year	estimated from site-specific K and assumed vertical hydraulic conductivity
Particle density of sediment	2650	kg/m^3	Day, 1999
Sediment consolidation time	6	months	assumed value
Sediment deposotion velocity	0	cm/year	model default
Sediment consolidation distance	0.3	m	estimated from consolidation test results
Sediment thickness	1.5	m	site-specific data
Sediment porosity	0.5	(none)	estimated from consolidation test results
Sediment Foc	0.008	(none)	from sediment sample T4-CM2
CAP LAYER PROPERTIES			
Cap initial thickness	0.914	m	assumed value
Cap consolidation distance	0	cm	assumed value
Cap porosity	0.4		assumed value
Cap Foc	0.001		assumed value
Cap dispersivity	5.00E-04	m	1/2 measured sediment grain size
Cap particle density	2650	kg/m^3	Day, 1999
UPPER CAP PROPERTIES	SI Units		
Height of armor rocks above cap/water interface	0	cm	assumed no armor layer
Height of bioturbation zone	10	cm	Palermo et al., 1998
Biodiffusion coefficient	10	$cm^2/year$	model default
WATER COLUMN PROPERTIES	SI Units		
Initial height of water column	9.14	m	site-specific data
Manning friction factor at water/sediment interface	0.025	(none)	model default
Average linear velocity of stream	0.05	m/s	BBL, 2004

Table I-2
Chemical Input Parameter Values for Base Case Scenario -
Sediment Cap Model

METALS

COPC	Maximum Detected TCLT Eluent Concentration (µg/L)	Maximum Detected DRET Eluent Concentration (µg/L)	Lowest Applicable Criterion (µg/L)	Sediment Concentration (mg/kg)	Binary Diffusivity (cm^2/s)	Equilibrium Solubility in Water (mg/L)	Minimum TCLT Partition Coefficient, K_d (L/kg)	Maximum TCLT Partition Coefficient, K_d (L/kg)	DRET Partition Coefficient, K_d (L/kg)
Arsenic	4.1	0.8	0.0022	3.53	5.00E-06	59,400	610	879	3125
Cadmium	0.21	0.04 U	0.094	0.86	5.00E-06	123,000	1429	2880	5412
Copper	13.3	4.25	11	25.5	5.00E-06	421,000	1,729	8,691	12,473
Lead	5.8	1.86	2.5	129	5.00E-06	9,581	4,021	10,100	7,500

ORGANIC COMPOUNDS

COPC	Maximum Detected TCLT Eluent Concentration (µg/L)	Maximum Detected TCLT Eluent Concentration (µg/L)	Lowest Applicable Criterion (µg/L)	Sediment Concentration (µg/kg)	Binary Diffusivity (cm^2/s)	Equilibrium Solubility in Water (mg/L)	Minimum TCLT Partition Coefficient, K_d (L/kg)	Minimum TCLT Partition Coefficient[1], K_{oc} (L/kg)	Maximum TCLT Partition Coefficient, K_d (L/kg)	Maximum TCLT Partition Coefficient[1], K_{oc} (L/kg)	DRET Partition Coefficient, K_d (L/kg)	DRET Partition Coefficient[1], K_{oc} (L/kg)
Chrysene	0.034 J	0.39 U	0.0028	2032	6.21E-06	0.01	1,927	240,875	20,294	2,536,750	1,769	221,125
4,4'-DDE[2]	0.0054 J	0.097 U	0.00059	3.21	5.87E-06	0.022	23	2,875	389	48,625	21.6	2,700

Notes:
1. K_{oc} based on sediment organic carbon fraction of 0.8%.
2. The K_d value for 4,4'-DDE was based on non-detects and one J-qualified detection. Since the predicted K_{oc} was well below literature -based values, a literature-based K_{oc} value of 155,000 L/kg was used for 4,4'-DDE. [Fetter, 1994. Applied Hydrogeology. Prentice Hall, Englewood Cliffs, NJ.]

COPC - Constituent of potential concern

Table I-3
Sediment Cap Model Results

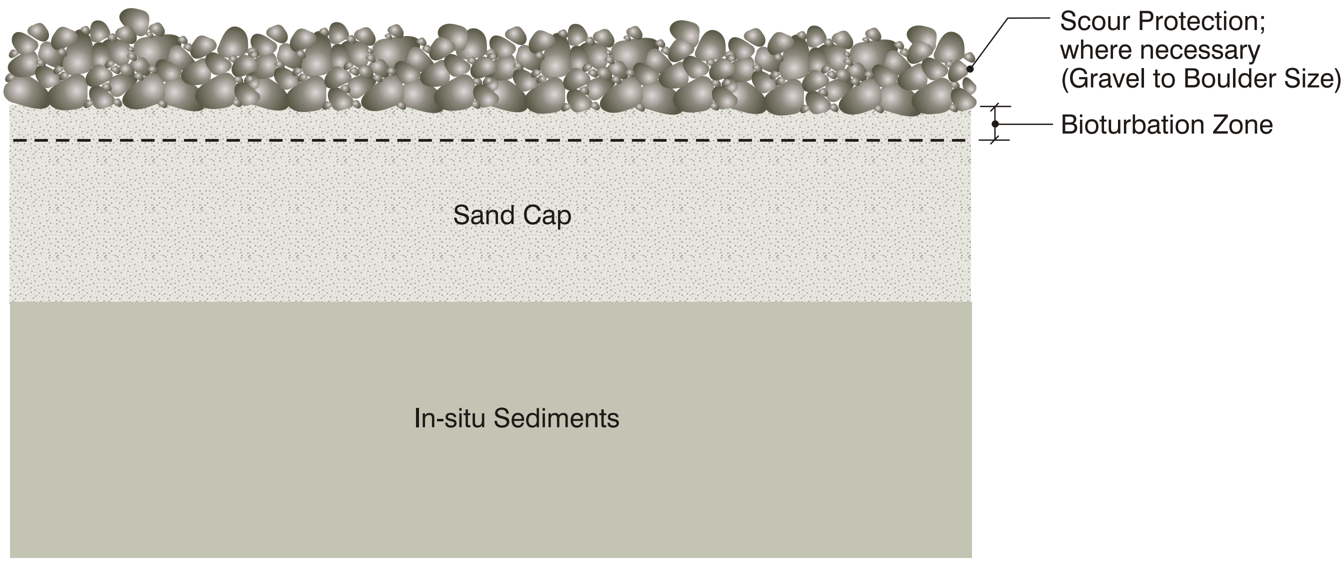
Sediment Cap Thickness 3 feet

COPC	Maximum Detected TCLT Eluent Concentration (μg/L)	Lowest Applicable Criterion (μg/L)	Porewater Concentration Cap/Bioturbation Zone Interface (μg/L)	Porewater Concentration Cap/Surface Water Interface (μg/L)
Arsenic	4.1	0.0022	1.42E-41	2.20E-42
Cadmium	0.21	0.094	3.57E-46	2.10E-46
Copper	13.3	11	4.77E-44	2.18E-44
Lead	5.8	2.5	3.01E-35	5.64E-35
Chrysene	0.034 J	0.0028	3.84E-12	8.68E-14
4,4'-DDE	0.0054 J	0.00059	7.78E-12	8.34E-14

Sediment Cap Thickness 2 feet

COPC	Maximum Detected TCLT Eluent Concentration (μg/L)	Lowest Applicable Criterion (μg/L)	Porewater Concentration Cap/Bioturbation Zone Interface (μg/L)	Porewater Concentration Cap/Surface Water Interface (μg/L)
Arsenic	4.1	2.20E-03	1.80E-23	2.75E-24
Cadmium	0.21	9.40E-02	4.48E-30	2.44E-30
Copper	13.3	11	3.56E-29	1.57E-29
Lead	5.8	2.5	2.36E-19	4.40E-19
Chrysene	0.034 J	2.80E-03	1.80E-05	3.09E-07
4,4'-DDE	0.0054 J	5.90E-04	7.78E-06	1.59E-08

COPC - Constituent of potential concern



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TERMINAL 4 EARLY ACTION
EE/CA REPORT

CROSS SECTION OF TYPICAL
IN-SITU SAND CAP

BBL
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FIGURE
I-1