60% Remedial Design Basis of Design Report

# Appendix J
# Water Quality Effects Evaluation

# TABLE OF CONTENTS

## TABLES



## FIGURE

# ABBREVIATIONS

| | |
|---|---|
| µg/L | microgram per liter |
| ARAR | Applicable or Relevant and Appropriate Requirement |
| BMP | best management practice |
| BODR | *Basis of Design Report* |
| CLARC | Cleanup Levels and Risk Calculation |
| cm | centimeter |
| COC | contaminant of concern |
| CQAP | Construction Quality Assurance Plan |
| CWA | Clean Water Act |
| cy/day | cubic yard per day |
| cy/hour | cubic yard per hour |
| DER | *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach* |
| DRET | Dredge Elutriate Testing |
| Ecology | Washington State Department of Ecology |
| EPA | U.S. Environmental Protection Agency |
| LDW | Lower Duwamish Waterway |
| mg/kg | milligram per kilogram |
| mg/L | milligram per liter |
| NTU | nephelometric turbidity unit |
| OC | organic carbon |
| PCB | polychlorinated biphenyl |
| RAA | remedial action area |
| RAL | remedial action level |
| RD | remedial design |
| TSCA | Toxic Substances Control Act |
| TSS | total suspended solids |
| USACE | U.S. Army Corps of Engineers |
| WAC | Washington Administrative Code |
| WQMP | Water Quality Monitoring Plan |

# 1 Introduction

## 1.1 Background

Dredging of contaminated sediment inherently results in temporary water quality effects during construction. To address these effects, significant efforts have been made to understand, evaluate, and limit such effects during remedial activities (e.g., *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*; USACE 2008).

This appendix evaluates the potential water quality effects from two primary sources associated with mechanical dredging of contaminated sediment in the Lower Duwamish Waterway (LDW) middle reach by predicting the following:

1. Disturbance of sediment during dredging, which leads to sediment resuspension, sediment loss from the dredge bucket, and subsequent release of contaminants into the water column
2. Discharge of dredge return water[1] during barge dewatering, which releases dissolved-phase contaminants into the water column

This analysis is intended to support the development of water management requirements in the Specifications and a Water Quality Monitoring Plan (WQMP) as part of the Construction Quality Assurance Plan (CQAP) that will be developed during Pre-Final (90%) remedial design (RD). The results of this appendix can be considered by the U.S. Environmental Protection Agency (EPA) to inform the detailed water quality monitoring requirements in EPA's Clean Water Act (CWA) Section 404 Applicable or Relevant and Appropriate Requirement (ARAR) memorandum, to be developed and issued by EPA in the future.

## 1.2 Water Quality Criteria

The LDW middle reach RD is required to substantively comply with applicable federal and Washington State water quality criteria, as noted in Section 3.2 of the Intermediate (60%) RD *Basis of Design Report* (BODR). EPA will determine the specific compliance criteria, monitoring and measurement methods, authorized mixing zones, and other conditions in the CWA Section 404 ARAR memorandum. The WQMP will develop specific monitoring requirements to be used during construction, in alignment with EPA's CWA Section 401 Water Quality Certification.

According to EPA's *Record of Decision* (EPA 2014), the LDW is classified as marine water under Washington State water quality standards and regulations. This classification is based on salinity levels that meet the threshold specified in Washington Administrative Code (WAC) 173-201A-260(3)(e),

[1] Dredge return water refers to excess water generated from the captured water and porewater from sediment as the sediments dewater on the barge, and it is typically separated from the dredged material on the barge. The segregated water is typically either filtered to remove suspended solids (by pumping the water) or passively draining the water through a filter media (e.g., geotextile fabric) and then returned back to the receiving water within the dredging work zone.

with tidal conditions extending past the LDW turning basin. WAC 173-201A-610 and 612, Table 612, identifies use designations for marine waters; the LDW is considered a continuation of Elliott Bay for the purpose of applying marine water quality criteria. As a result, this appendix uses the more conservative (i.e., stringent) water quality criteria between the federal standards (40 *Code of Federal Regulations* 131.45) and the state standards (WAC 173-201A) for the protection of aquatic life in marine waters. These acute and chronic water quality criteria, including details regarding contaminant-specific water quality requirements, were obtained from the Washington State Department of Ecology's (Ecology's) Cleanup Levels and Risk Calculation (CLARC; Ecology 2025)[2] database and are presented in Table J1-1.

Turbidity water quality standards for the LDW middle reach construction were established based on WAC 173-201A-210(1)(e) for waters designated as "excellent" marine quality (EPA 2014). The turbidity criterion is to not exceed 5 nephelometric turbidity units (NTU) above background (or 10% above background if background is 50 NTU or higher) at the edge of the designated area of mixing during construction activities.

In addition, for estuarine waters in Washington State, the standard point of compliance for a temporary area of mixing is identified as 150 feet from the activity causing the disturbance. However, sediment remediation projects often request an area of mixing larger than the point of compliance due to safety or access considerations that make it difficult to sample that close to the working equipment or due to working in shallow waters that limit the ability for suspended solids to mix in the water column. Therefore, the proposed area of mixing for the LDW middle reach will be developed in the WQMP based on a variety of considerations. For the purposes of this appendix, a mixing zone of 150 feet is assumed for evaluating compliance with marine acute water quality criteria and 300 feet for compliance with marine chronic water quality criteria—consistent with the mixing zones approved by EPA for the LDW upper reach project (EPA 2024).

## 1.3 Objectives of Water Quality Effects Evaluation

The objectives of this water quality effects evaluation are as follows:

1. Estimate the predicted contaminant of concern (COC) concentrations that may be mobilized into the water column during dredging at the edge of the area of mixing during construction.
2. Estimate the predicted COC concentrations that may be generated from discharging dredge return water during barge dewatering to waters within the construction work zone and may be transported to the edge of the area of mixing.

[2] The CLARC is a database maintained by Ecology that compiles both Washington State and federal cleanup levels for various media and contaminants.

Section 2 summarizes the contaminant input parameters common to both analyses, with additional details and the results from these analyses provided in Sections 3 and 4, respectively.

# 2 Contaminant Input Parameters

## 2.1 Contaminant Concentrations

Contaminant concentrations in dredged sediment are a key input to the water quality effects evaluation. Core samples in the *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach* (DER; Anchor QEA and Windward 2025) design dataset were used to estimate COC concentrations in dredged sediment. The evaluation in this appendix includes all chemicals in the design dataset that are subject to applicable marine water quality compliance criteria in Ecology's CLARC database; a total of 10 COCs were identified: eight metals, total polychlorinated biphenyls (PCBs), and pentachlorophenol (see Table J1-1).

Sediment cores located within the remedial action areas (RAAs) where either dredging or partial dredge/cap were the identified technologies (see Section 5.5 of the BODR) were included in the evaluation documented in this appendix.[3] For conservativeness, cores within the evaluated RAAs that did not exceed remedial action levels (RALs) were excluded. The following steps were carried out for the selected cores:

1. Determine Depth of Contamination: For each core, the depth of contamination was determined based on the maximum depth at which COC concentrations exceeded the RAL, as specified in Table 28 of EPA's *Record of Decision* (EPA 2014).
2. Calculate Dredge Depth:
    a. Dredging-only scenario. For each core, the dredge depth was set as the maximum depth of contamination plus 1 foot of overdredging (i.e., a 4-foot depth of contamination results in a 5-foot sediment removal).
    b. Partial dredge/cap scenario. For each core, the dredge depth was set as the cap thickness plus 1 foot of overdredging.
3. Estimate Vertically Weighted Average Concentration: Because the dredging process inherently mixes sediment over the depth of removal, the vertically weighted average concentration was calculated for each core by using the core intervals above the calculated dredge depth. This was done by multiplying each core interval's COC concentration by its interval length, summing the products, and dividing the sum by the total length of the core intervals included in the product for each core (see Figure J2-1).
4. Determine LDW Middle Reach-Wide Maximum and Average Concentrations for Each Modeled COC: For cores within each RAA and for each modeled COC, the maximum and average concentrations were calculated to represent worst-case and average-condition scenarios. For purposes of estimating LDW middle reach-wide concentrations without biasing sediment

[3] Sediment cores excluded from the evaluation are either located outside the RAAs or within RAAs where technologies other than dredging or partial dredge/cap have been assigned.

concentrations high or low, RAAs were grouped into "Toxic Substances Control Act (TSCA) Waste Areas"[4] (encompassing RAAs 21A, 31B, 31C and 31D) and "Non-TSCA Waste Areas" (encompassing the remaining RAAs with dredging or partial dredge/cap).[5] The former grouping is representative of four RAAs with significantly higher PCB sediment concentrations than the rest of the LDW middle reach. Although RAAs 24B through 24D were identified with high PCB and metals concentrations, these RAAs are not included in this analysis because sediment removal in RAAs 24B through 24D will be conducted using dry excavation methods, as described in Sections 5.6 and 9.6.5 of the BODR. The maximum concentrations within each grouping were used to evaluate compliance with marine acute water quality criteria for each modeled COC, simulating a worst-case scenario. Similarly, the average concentrations within each grouping were used to evaluate compliance with marine chronic water quality criteria for each modeled COC, reflecting typical (average) conditions. For total PCBs and pentachlorophenol, the organic carbon (OC)-normalized concentrations were calculated using the average OC fraction in sediment cores—1.7% in Non-TSCA Waste Areas and 1.9% in TSCA Waste Areas—and was only applied when estimating dissolved-phase concentrations, as described in Section 4, because the water quality criteria for the two COCs are based on total concentrations.

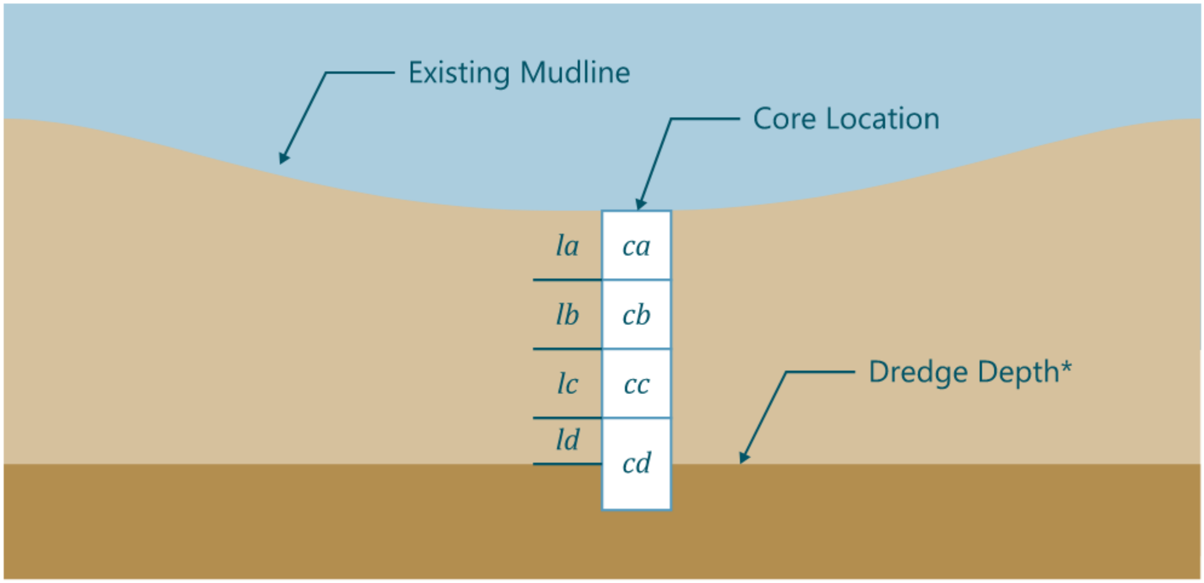
Table J2-1 presents a summary of maximum and average COC concentrations calculated for the TSCA and Non-TSCA Waste Areas of the LDW middle reach. Model input concentrations will be updated at Pre-Final (90%) RD, as additional data are collected as part of the LDW middle reach Phase III pre-design investigation.

---

[4] For the purposes of this BODR, "TSCA Waste Areas" refers to areas containing material with dry weight PCB concentrations greater than 50 milligrams per kilogram (mg/kg). Non-TSCA Waste Areas generally do not include materials that may be designated as Resource Conservation and Recovery Act hazardous waste or Washington State dangerous waste with the exception of RAL exceedance areas 8, 9, 20, 21, and 24B. Waste designations will be finalized during Pre-Final (90%) RD after the results from the Phase III pre-design investigation are received and evaluated.

[5] The exception is sample LDW23-SS1171 (in RAA 19). Sample LDW23-SS1171 showed elevated PCB RAL exceedances only in the surface interval (0 to 10 centimeters [cm]), not in the core interval (0 to 60 cm). This sample is not included as part of the TSCA Waste Areas because for the purposes of this appendix, it is assumed that dredging inherently mixes sediments; therefore, the core data are considered more representative of what would be encountered in a dredge bucket. Additionally, this location was reanalyzed and the PCB concentrations were found to be several orders of magnitude less than 50 mg/kg.

**Figure J2-1**
**Calculation of Vertically Weighted Average Concentration**




$$Cavg = \frac{(la)(ca)+(lb)(cb)+(lc)(cc)+(ld)(cd)}{la+lb+lc+ld}$$

*Where:*

*cx* = concentration in core interval "x"
*lx* = length of core interval "x" included in vertically weighted average
*Cavg* = vertically weighted average

Note:
*Dredge depth was estimated based on the maximum depth of contatmination for each core, plus 1 foot of overdredge (i.e., bottom of interval c represents the maximum depth of contamination, and ld represents the 1 foot of overdredge).

## 2.2 Partitioning Coefficients

The partitioning coefficients for modeled COCs are also a key input for the water quality effects evaluation. Partitioning coefficients can vary widely depending on geochemical conditions, the nature of solids (including potential presence of multiple sorbing phases), and COC characteristics (e.g., mixture of PCBs). For simplicity, the partitioning coefficients were selected from available information in the CLARC database for the 10 COCs (Table J1-1). These values are generally lower than those reported in the literature (Allison and Allison 2005; Hawker and Connell 1988; De Bruijn et al. 1989) and thus provide more conservative estimates (i.e., higher concentrations) of dissolved-phase concentrations.

# 3 Potential Water Quality Effects During Dredging

This section summarizes the application of a mathematical model to evaluate compliance with water quality criteria and includes model description, input parameters and the rationale for model assumptions, and model-predicted COC concentrations.

## 3.1 Modeling Evaluation of Predicted Water Quality Effects

### *3.1.1 Model Description*

To evaluate water quality compliance during dredging, the DREDGE model (Hayes and Je 2000) developed by the U.S. Army Corps of Engineers (USACE) was used to predict COC concentrations within the water column at the point of compliance due to suspended solids release during dredging. The model simulates the behavior of suspended sediments and associated COCs through the following key steps:

1. Estimate Sediment Suspension Rate: The model first estimates the mass rate at which sediments become suspended into the water column during mechanical dredging. This is calculated based on the dredging production rate and an assumed percent loss of sediment mass from the dredge bucket.
2. Simulate Suspended Sediment Transport and Dispersion: The model then simulates the movement and transport of the suspended sediment away from the dredging area, accounting for advection, lateral dispersion, and particle settling. These processes collectively predict the total suspended solids (TSS) concentrations at the points of compliance.
3. Calculate COC Concentrations at Points of Compliance: Finally, the model calculates total (i.e., whole water, which includes dissolved and particulate phases) COC concentrations in the water column at the points of compliance using the predicted TSS concentrations and bulk sediment chemistry data for the dredged sediment. The model also calculates dissolved-phase COC concentrations using partitioning theory, assuming instantaneous equilibrium in the water column between solid (particulate) and dissolved phases as a conservative modeling approach (i.e., to the extent desorption of COCs from dredged sediment occurs slowly, dissolved-phase concentrations will be overestimated by the equilibrium assumption).

### *3.1.2 Model Input Parameters*

Table J3-1 presents the DREDGE model input parameters selected for the evaluation and the rationale for each parameter. The DREDGE model inputs consist of dredging and transport characteristics. The general approach was to use reasonable but conservative assumptions (i.e., assumptions that result in higher predicted concentrations at the point of compliance) to account for any uncertainties.

Consistent with the marine water quality criteria specified in WAC 173-201A-240, different averaging periods were applied to COCs based on regulatory guidance. For all COCs (except for total PCBs), the dredging production rate was assumed to be 180 cubic yards per hour (cy/hour) for the acute (1-hour dredge average) evaluation (which is considered to be a very high production rate for the LDW) and 1,000 cubic yards per day (cy/day)[6] for the chronic (4-day dredge average) evaluation. For total PCBs, which are regulated based on a 24-hour average for both acute and chronic water quality criteria, the dredging production rate was assumed to be 1,000 cy/day for both evaluations.

The assumed dredge production rates are considered reasonable average rates because dredging of contaminated sediments is not a continuous operation; contractors typically do not work 24 hours a day (a standard 10-hour workday typically includes 6 to 8 hours of active dredging, with remaining downtime spent on equipment setup, relocation, and maintenance). In comparison, actual production rates observed during the first and second construction season of the LDW upper reach project were generally lower than the production rates assumed here.

For this evaluation, 5% of dredged material was conservatively assumed to be released into the water column from the dredge buckets during dredging, which is higher than the typical loss rate of 1% from environmental buckets, as documented in previous studies (Anchor Environmental 2003; USACE 2008). The 5% loss is a conservative assumption based on actual observations during construction of the LDW upper reach project, where dredge buckets could not always be fully closed during dredging when there was significant debris present. Following sediment release, the DREDGE model assumes that suspended particles are uniformly distributed throughout the water column during the raising of the dredge bucket.

Suspended solids transport lateral dispersion coefficients were established based on discussions with USACE (Schroeder 2019; Table J3-1). The site-specific settling rates in the model were determined based on site-specific sediment grain sizes and densities. The mean settling velocity is a conservative representation of the suspended particles (i.e., fine fraction) and was therefore estimated based on the Stokes's law settling velocity of a particle diameter of 37 micrometers, representative of the median of the fine fraction of dredged material. This is conservative because this approach assigns this settling velocity to the entirety of the sediment mass released even though there are fractions of coarser materials (like sands and gravels) that would settle out much more rapidly, resulting in an overprediction of the resulting TSS (and associated COC concentrations).

The ambient river flow and tidal velocities within the LDW vary; however, a speed of 1 foot per second was used for modeling purposes and is considered representative of moderate flow in the

[6] 1,000 cy/day is the assumed production rate averaged over 24 hours due to the method for assessing compliance with marine chronic water quality criteria.

LDW. Dredging was not assumed to occur during high-flow storm events because dredging contractors may not be able to safely operate during such conditions.

### *3.1.3 Model Results*

Table J3-2 presents model-predicted COC concentrations in the water column and compliance with marine acute water quality criteria for the TSCA Waste and Non-TSCA Waste Areas. At 150 feet from the dredging zone, the DREDGE model predicted a TSS concentration of 26.9 milligrams per liter (mg/L) using a 180 cy/hour production rate (for evaluation of all chemicals other than PCBs) and a TSS concentration of 6.2 mg/L using a 1,000 cy/day production rate (for evaluation of total PCBs). For both TSCA Waste and Non-TSCA Waste Areas, the predicted concentrations of COCs were less than the marine acute water quality criteria for the modeled COCs.

Table J3-3 presents model-predicted COC concentrations in the water column and compliance with marine chronic water quality criteria for the TSCA Waste and Non-TSCA Waste Areas. At 300 feet from the dredging zone, the DREDGE model predicted a TSS concentration of 4.3 mg/L using a 1,000 cy/day production rate. For the Non-TSCA Waste Areas, the predicted concentrations of COCs were less than the marine chronic water quality criteria for the modeled COCs. However, for the TSCA Waste Areas, the concentrations of total PCBs exceeded the marine chronic water quality criterion (by a factor of 4).

In summary, based on LDW middle reach-specific inputs to the DREDGE model (which are conservative as stated in Section 3.1.2) no acute or chronic water quality exceedances were predicted in the Non-TSCA Waste Areas of the LDW middle reach at the 150-foot distance of compliance. In the TSCA Waste Areas, no acute water quality exceedances were predicted, while model-predicted total PCB concentrations indicated that marine chronic water quality criteria may be exceeded.

## 3.2 Turbidity Criteria and Total Suspended Solids Threshold Concentrations

This section summarizes an additional evaluation performed to illustrate how turbidity monitoring can be used to identify potential water quality criteria exceedances in real time during dredging.

Section 3.2.1 discusses the relationship between turbidity and TSS concentrations, and Section 3.2.2 discusses a back-calculation approach to estimate the turbidity levels at the point of compliance that could correspond to marine acute or chronic water quality exceedances for COCs.

### *3.2.1 Relationship Between Turbidity and Total Suspended Solids*

Turbidity is a water quality parameter that indicates the clarity of water by measuring the extent to which light is scattered or absorbed as it passes through the water column. TSS represents the concentration of suspended matter, such as sediment, in the water column. There is no universal relationship between turbidity and TSS in surface water because factors such as colloidal particles, microorganisms (including phytoplankton), and dissolved organic matter can result in elevated turbidity with little impact on TSS. However, higher concentrations of TSS generally lead to higher turbidity measurements, with relationships typically varying by waterbody.

Although TSS is used in the DREDGE model to evaluate compliance with water quality criteria, it cannot be measured in real time during dredging because it requires laboratory analysis. Turbidity, on the other hand, can readily be measured in the field with a sensor and can provide real-time information regarding potential water quality exceedances during dredging operations, with a criterion established relative to ambient background concentrations to assess the contributory effect of dredging on turbidity (e.g., 5 NTU above background, or 10% above background when background turbidity is greater than 50 NTU).

Based on literature (Thackston and Palermo 2000; Anchor Environmental 2003; Blessy et al. 2023; Serajuddin et al. 2019) and Anchor QEA's experience at other remedial dredging sites, the turbidity to TSS relationship ranges from 1 NTU = 0.5 mg/L TSS to 1 NTU = 4 mg/L TSS, with 1 NTU = 2 mg/L TSS being considered as a reasonable relationship. These relationships are used in the following analysis to estimate turbidity thresholds associated with potential water quality exceedances.

### *3.2.2 Turbidity and Total Suspended Solids Thresholds*

To estimate the turbidity and TSS concentrations that could result in exceedances of marine water quality criteria, back calculations were performed using the applicable water quality criteria as input surface water COC concentration, and the TSS calculations from the DREDGE model. The results are presented in Table J3-4 and summarized as follows:

- In the Non-TSCA Waste Areas, the lowest TSS concentration that could result in a water quality exceedance at the 300-foot point of compliance is 45 mg/L.
- In the TSCA Waste Areas, the lowest TSS concentration that could result in a water quality exceedance at the 300-foot point of compliance is 1 mg/L.

Using the assumed turbidity to TSS conversion ratio (1 NTU = 0.5 to 4 mg/L TSS), these TSS thresholds correspond to the following turbidity increases associated with dredge releases:

- A turbidity of 11 to 180 NTU in the Non-TSCA Waste Areas
- A turbidity of 0.5 to 4 NTU in the TSCA Waste Areas

Based on the LDW's beneficial use classification of "excellent quality" to support salmonid migration and rearing (EPA 2014), the applicable turbidity compliance standard—defined under WAC 173-201A-210—requires that turbidity not exceed 5 NTU above background, or 10% above background when background levels are 50 NTU or higher, measured at the edge of the designated mixing zone during construction activities.

These findings suggest that in the Non-TSCA Waste Areas, turbidity exceedances would likely occur prior to water quality exceedances, regardless of turbidity to TSS conversion ratio, making it a useful metric for triggering surface water sampling. In contrast, in the TSCA Waste Areas, exceedances of water quality could occur when turbidity is within compliance (i.e., less than 5 NTU). This suggests that, for conservativeness, additional measures discussed in Section 10 of the BODR—such as the implementation of best management practices (BMPs), operational controls during dredging, increased monitoring frequency, or engineering controls (such as silt curtains or physical containment barriers)—could be considered in the RD to help reduce the risk of potential water quality impacts. The specific measures will be discussed in the WQMP as part of the Pre-Final (90%) RD. However, it is important to note that the evaluation conducted in this appendix incorporates conservative assumptions (i.e., high production rates, high sediment loss rate, and low settling velocity); therefore, these additional measures may not ultimately be necessary to meet the water quality criteria.

# 4 Potential Effects During Dredge Return Water Discharge

During dredging operations, dredge return water accumulates in the barge as free water or porewater mixed with the dredged sediment. This water is typically discharged back into the dredging work zone during barge dewatering, following filtration to remove solids. The dredge return water is one of the many processes during dredging that has the potential to contribute to overall effects on the surface water. This section provides a screening-level assessment of potential water quality effects during barge dewatering.

As discussed in Section 10.2.3.3 in the BODR, sediments removed from RAAs 21A, 31B, 31C, and 31D will be containerized (containing non-dewatered sediment) and loaded on railcars for transportation to an acceptable landfill. As a result, dredge return water will not be discharged from TSCA Waste Areas, and this evaluation is limited to Non-TSCA Waste Areas.

## 4.1 Model Description

To evaluate water quality compliance during barge dewatering, a Barge Effluent Model was developed based on procedures described in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C* (EPA and USACE 1998). The model estimates the length of the mixing zone required to meet applicable marine water quality criteria. The modeling approach includes the following components:

- Estimate Effluent Concentration: The model first estimates dissolved-phase chemical concentrations in the barge water prior to discharge, assuming instantaneous equilibrium partitioning between in situ sediment and water retained in the bucket during dredging.
- Predict Mixing Zone Length: Following methods described in EPA and USACE (1998) and summarized as follows, the model then estimates the length of the mixing zone required to meet applicable marine water quality criteria through dispersion processes.

**Mixing Zone Calculation Equations**

$$w = \frac{Q_{eff}\left(\frac{C_{\text{diss}} - C_{\text{WQ}}}{C_{WQ} - C_{BG}}\right)}{v * d}, \qquad t = \frac{1}{\lambda} * 0.094 * w^{\frac{2}{3}}, \qquad l = v * t$$

where:

| | | |
|---|---|---|
| $C_{\text{diss}}$ | = | dissolved-phase chemical concentration prior to discharge (µg/L) |
| $C_{\text{WQ}}$ | = | marine water quality criteria (µg/L) |
| $C_{BG}$ | = | background chemical concentration (µg/L) |
| $Q_{eff}$ | = | effluent discharge rate from barge (cubic foot per second) |
| $v$ | = | ambient river current velocity (foot per second) |
| $d$ | = | depth of mixing (foot) |
| $w$ | = | width of the mixing zone at time t (foot) |
| $t$ | = | time required for lateral spreading (second) |
| $\lambda$ | = | turbulent dissipation parameter |
| $l$ | = | length of the mixing zone at time t (foot) |

## 4.2 Model Input Parameters

Table J4-1 presents the Barge Effluent Model input parameters selected for the evaluation and the rationale for each parameter. The model assumptions are similar to those used in the DREDGE model evaluation and consist of dredging and transport characteristics. The production rate was assumed to be 1,000 cy/day of in situ dredged sediment, representing an average daily condition. The proportion of dredge return water compared to the in situ volume of sediment was conservatively assumed to be 43%, calculated by assuming a bucket fill factor of 70%, and a conservatively high assumption of free water at 30% of the bucket volume placed on the barge (i.e., 30% / 70% = 43%). This assumption results in a discharge rate of dredge return water ($Q_{eff}$) of 430 cy/day.

The turbulent dissipation parameter was assumed to be 0.005, based on the recommendations in EPA and USACE (1998). The depth of mixing was conservatively assumed to be 3 meters, which is less than the typical water depth required for barge access, based on the assumption that mixing does not occur throughout the entire water column. The ambient river current velocity was assumed to be 1 foot per second.

Dissolved-phase COC concentrations were calculated using the same method as described in Section 3.1.1. This approach incorporates dry bulk density, average sediment core concentrations, partitioning coefficients, and the ratio of dredge return water to in situ sediment volume to account for dilution, assuming instantaneous equilibrium between dredged sediments and the dredge return water.

## 4.3 Model Results

The model-predicted COC concentrations in the water column from the dredge return water discharge evaluation are presented in Tables J4-2 and J4-3. The mixing zone distance required to achieve compliance with marine acute water quality criteria in the Non-TSCA Waste Areas was predicted to be 50 feet or less (depending on the specific COC), which is well within the standard 150-foot acute mixing zone. Similarly, the mixing zone distance required to achieve compliance with marine chronic water quality criteria was predicted to be 66 feet or less (depending on the COC), which is also within the standard 300-foot chronic mixing zone.

Based on the results, in the Non-TSCA Waste Areas, no BMPs or additional monitoring measures are needed during barge dewatering to ensure compliance with marine chronic water quality criteria.

# 5 Conclusions and Recommendations

This water quality modeling effort was conducted to evaluate the potential for water quality effects during dredging and barge dewatering within the LDW middle reach. These model outcomes will be updated at Pre-Final (90%) RD, as additional data are collected as part of the LDW middle reach Phase III pre-design investigation.

During dredging in the Non-TSCA Waste Areas, the model predicted that concentrations of COCs at the points of compliance will be less than both acute and chronic water quality criteria. These outcomes are consistent with water quality monitoring results from the LDW upper reach, where water quality sampling during the first and second construction seasons showed no exceedances of marine acute or chronic criteria at the respective points of compliance. In contrast, in the TSCA Waste Areas, the model predicted that total PCB concentrations may exceed marine chronic criteria at the points of compliance in RAAs 21A, 31B, 31C, and 31D. The remedial technology selected for RAAs 24B, 24C, and 24D includes construction of a temporary cofferdam to isolate that area from the main waterway and facilitate sediment removal "in the dry" (see BODR Section 5.5); therefore, it was not included in this analysis. To further assess water quality effects and confirm and validate model-predicted results based on site-specific partitioning, Dredge Elutriate Testing (DRET) will be conducted during the LDW middle reach Phase III pre-design investigation for RAA 31B through D to provide empirical data to confirm the risk of water quality exceedances during dredging. The predictive modeling conducted in this appendix is considered conservative, and DRET testing can be another line of evidence to assess the need for additional BMPs when working within RAA 31B through D.

Turbidity was also evaluated as a potential indicator of water quality compliance during dredging. In the Non-TSCA Waste Areas, the model suggested that turbidity exceedances are likely to occur before water quality chemical concentration exceedances, indicating that turbidity monitoring can be a conservative and effective real-time indicator of water quality effects. Therefore, turbidity can be used to indicate whether there may be a need to conduct surface water sampling. In the TSCA Waste Areas, turbidity exceedances may not be as reliable an indicator of potential water quality chemical concentration exceedances. Therefore, BMPs, operational controls, and more frequent water quality monitoring could be considered as part of the RD when dredging within the TSCA Waste Areas.

For barge dewatering, model results indicate that the mixing zone distances required to achieve compliance with marine acute and chronic water quality criteria in Non-TSCA Waste Areas are within the standard 150-foot and 300-foot mixing zones, respectively. Therefore, no additional tests or BMPs are recommended under the current assumptions. In TSCA Waste Areas, as discussed above, dredged sediments from RAAs21A, 31B, 31C, and 31D will be containerized and loaded on railcars for transportation to an acceptable landfill, and no dredge return water will be discharged.

The proposed water quality criteria; area of mixing (and point of compliance); and procedures for water quality monitoring, reporting, and potential contingency response actions (i.e., procedures to follow in the case of a water quality exceedance) will be described in the WQMP as an appendix to the CQAP during the Pre-Final (90%) RD.

The results of this appendix can be considered by EPA to inform the detailed water quality monitoring requirements in EPA's ARAR memorandum (to be developed and issued by EPA in the future). Actual water quality monitoring, as defined in the forthcoming WQMP, will be conducted during remedial actions, and the contractor will be required to modify operations to remain in compliance with the requirements to be outlined in EPA's ARAR memorandum.

# 6 References

Allison, J.D., and T.L. Allison, 2005. *Partition Coefficients for Metals in Surface Water, Soil, and Waste.* EPA/600/R-05. July 2005.

Anchor Environmental (Anchor Environmental, L.L.C.), 2003. *Literature Review of Effects of Resuspended Sediments Due to Dredging Operations*. Prepared for Los Angeles Contaminated Sediments Task Force Los Angeles, California.

Anchor QEA and Windward (Windward Environmental, LLC), 2025. *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach.* Lower Duwamish Waterway Middle Reach. Final. Submitted to U.S. Environmental Protection Agency. September 30, 2025.

Blessy, V., M. Kumar, C. Saxena, and A. Gupta, 2023. "Predicting Total Suspended Solids from Turbidity for Different Types of Soil Particles." *Acta Scientific Agriculture* 7(12).

De Bruijn, J., F. Busser, W. Seinen, and J. Hermens, 1989. "Determination of Octanol/Water Partition Coefficients for Hydrophobic Organic Chemicals with the 'Slow-Stirring' Method." *Environmental Toxicology and Chemistry* 8(6):499–512.

Ecology (Washington State Department of Ecology), 2025. CLARC Database March 2025 Update. Available at: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables.

EPA (U.S. Environmental Protection Agency), 2014. *Record of Decision.* Lower Duwamish Waterway Superfund Site. United States Environmental Protection Agency Region 10. November 2014.

EPA, 2024. *Clean Water Act §404 ARAR Memo: Substantive Water Quality Requirements For The Lower Duwamish Waterway-Upper Reach Superfund Remedial Action – FINAL*. October 2024.

EPA and USACE (U.S. Army Corps of Engineers), 1998. *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C*.

Hawker, D.W., and D.W. Connell, 1988. "Octanol-Water Partition Coefficients of Polychlorinated Biphenyl Congeners." *Environmental Science & Technology* 22(4):382–387.

Hayes, D.F., and C.H. Je, 2000. *DREDGE Model User's Guide*. University of Utah, Department of Civil and Environmental Engineering. July 2000.

Schroeder, Paul (USACE), 2019. Personal communication with Greg Brunkhorst (Anchor QEA). December 3, 2019.

Serajuddin, M.D., M.A. Chowdhury, M.M. Haque, and M.E. Haque, 2019. "Using Turbidity to Determine Total Suspended Solids in an Urban Stream: A Case Study." In *Proceedings of the 2nd International Conference on Water and Environmental Engineering*, Dhaka (pp. 19–22). September 2019.

Thackston, E. L., and M.R. Palermo, 2000. "Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring." DOER Technical Notes Collection (ERDC TN-DOER-E8), U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. Available at: www.wes.army.mil/el/dots/doer.

USACE (U.S. Army Corps of Engineers), 2008. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*. Technical Report ERDC/EL TR-08-4. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center. February 2008.

# Tables

**Table J1-1**
**Water Quality Criteria and Partitioning Coefficients from Ecology's CLARC Database**

| COC[1] | Water Quality Criteria[2] | | Partitioning Coefficient, Kd (L/kg)[3] | Organic Carbon-Water Partitioning Coefficient, Koc (L/kg) |
|---|---|---|---|---|
| | Marine Acute (µg/L) | Marine Chronic (µg/L) | | |
| Arsenic[4] | 69 | 36 | 29 | -- |
| Cadmium[4] | 33 | 7.9 | 6.7 | -- |
| Chromium VI[4] | 1100 | 50 | 19 | -- |
| Copper[4] | 4.8 | 3.1 | 22 | -- |
| Lead[4] | 210 | 8.1 | 10,000 | -- |
| Mercury[5] | 1.8 | 0.025 | 52 | -- |
| Total PCBs[6] | 10 | 0.030 | -- | 78,100 |
| Pentachlorophenol[6] | 13 | 6.7 | -- | 592 |
| Silver[4] | 1.9 | 0.91 | 8.3 | -- |
| Zinc[4] | 90 | 81 | 62 | -- |

Notes:
1. COCs selected based on COCs in the LDW middle reach design dataset with marine acute and chronic water quality criteria.
2. Water quality criteria are the lowest of the federal standards (40 CFR 131.45) and the state standards (WAC 173-201A) for protection of aquatic life in marine waters.
3. $K_d$ values derived from Ecology's CLARC database (website accessed in June 2025 at https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/contamination-cleanup-tools/clarc/data-tables).
4. Acute and chronic water quality criteria for metals (except mercury) are based on the dissolved fraction.
5. The chronic water quality criterion for mercury is based on total recoverable fraction; the acute water quality criterion for mercury is based on the dissolved fraction (WAC 173-201A-240).
6. Water quality criteria for total PCBs and pentachlorophenol are based on total recoverable fractions (WAC 173-201A-240).
--: not applicable
µg/L: microgram per liter
CFR: *Code of Federal Regulations*
CLARC: Cleanup Levels and Risk Calculation
COC: contaminant of concern
Ecology: Washington State Department of Ecology
L/kg: liter per kilogram
LDW: Lower Duwamish Waterway
PCB: polychlorinated biphenyl
WAC: Washington Administrative Code

**Table J2-1**
**Maximum and Average Sediment Concentrations Used in Water Quality Effects Evaluation**

| COC | Unit | Maximum Sediment Core Concentration | | Average Sediment Core Concentration | |
|---|---|---|---|---|---|
| | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | mg/kg | 721 | 24 | 36 | 10 |
| Cadmium | mg/kg | 2.2 | 0.34 | 0.56 | 0.34 |
| Chromium | mg/kg | 50 | 20 | 29 | 20 |
| Copper | mg/kg | 171 | 28 | 58 | 28 |
| Lead | mg/kg | 81 | 62 | 37 | 62 |
| Mercury | mg/kg | 3.4 | 0.076 | 0.23 | 0.076 |
| Pentachlorophenol | µg/kg | 98 | 69 | 24 | 69 |
| Silver | mg/kg | 1.0 | 0.44 | 0.47 | 0.44 |
| Zinc | mg/kg | 373 | 58 | 122 | 58 |
| Total PCBs | mg/kg | 4.64 | 178 | 0.67 | 26.6 |

Notes:

Maximum and average sediment core concentrations are calculated based on method described in Section 2.1 of Appendix J.

For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste encompass the remaining RAAs of the LDW middle reach, where dredging is or partial dredge/cap were the identified technologies for the LDW middle reach. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.

µg/kg: microgram per kilogram

COC: contaminant of concern

LDW: Lower Duwamish Waterway

mg/kg: milligram per kilogram

PCB: polychlorinated biphenyl

RAA: remedial action area

TSCA: Toxic Substances Control Act

**Table J3-1**
**DREDGE Model Input Parameters**

| Parameter | Value | Unit | Rationale |
|---|---|---|---|
| **Dredging Characteristics** | | | |
| Production Rate | 180 cy/hour (acute); 1,000 cy/day (chronic); 1,000 cy/day (acute and chronic for PCBs) | varies | Production rates based on dredging project experience within the LDW and for all chemicals except PCBs. 180 cy/hour represents a maximum 1-hour dredge rate acceptable for comparison to marine acute water quality criteria, and 1,000 cy/day represents an average 4-day dredge rate acceptable for comparison to marine chronic water quality criteria. For PCBs, 1000 cy/day represents an average 24-hour dredge rate acceptable for comparison to both marine acute and chronic water quality criteria. |
| In Situ Dry Density | 951 | $kg/m^3$ | Calculated based on an average total solids of 60% assuming a particle density of 2.60 (specific gravity). |
| Source Strength (Percent Loss from Dredge Bucket) | 5 | percent | 1% is typical loss from an environmental bucket. 5% is assumed as a conservative estimate. |
| **Transport Characteristics** | | | |
| Lateral Dispersion Coefficient | 10,000 | $cm^2/s$ | Reasonable based on personal communication with Paul Schroeder, USACE (December 3, 2019) for LDW and laterally bounded waterways. |
| Settling Velocity | 0.00077 | m/s | Calculated based on Stokes's Law, assuming 37-µm particle size (half of the 74-µm upper threshold of fine-grained material). |
| Water Depth | 5 | m | Within the range of LDW middle reach water depths during construction. |
| Ambient River Current Velocity | 1 | ft/s | Flow changes with river stage and tidal conditions. 1 ft/sec was selected as a reasonable minimum average flow velocity over time. Higher flow velocities reduce predicted TSS due to dilution effects. |
| Particle Size (Diameter) | 37 | µm | Particle size is used to calculate the settling velocity (median of fines fraction). |
| Specific Gravity of Sediment Particles | 2.6 | unitless | The average specific gravity from design dataset samples is 2.6, with a range between 2.53 and 2.70. |

Notes:
µm: micrometer
$cm^2/s$: square centimeter per second
cy: cubic yard
ft/s: foot per second
$kg/m^3$: kilogram per cubic meter
LDW: Lower Duwamish Waterway
m: meter
m/s: meter per second
PCB: polychlorinated biphenyl
TSS: total suspended solids
USACE: U.S. Army Corps of Engineers

**Table J3-2**
**DREDGE Model Output Compared to Marine Acute Water Quality Criteria**

| COC | Marine Acute Water Quality Criteria (µg/L) | Maximum Sediment Core Concentration (mg/kg) | | Model-Predicted COC Concentration at Point of Compliance (µg/L) | | Potential to Exceed Marine Acute Water Quality Criteria | |
|---|---|---|---|---|---|---|---|
| | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | 69 | 721 | 24 | 19 | 0.65 | No | No |
| Cadmium | 33 | 2.2 | 0.34 | 0.058 | 0.0091 | No | No |
| Chromium VI | 1,100 | 50 | 20 | 1.3 | 0.52 | No | No |
| Copper | 4.8 | 171 | 28 | 4.6 | 0.75 | No | No |
| Lead | 210 | 81 | 62 | 1.7 | 1.3 | No | No |
| Mercury | 1.8 | 3.4 | 0.076 | 0.091 | 0.0020 | No | No |
| Total PCBs | 10 | 4.6 | 178 | 0.029 | 1.1 | No | No |
| Pentachlorophenol | 13 | 0.098 | 0.069 | 0.0026 | 0.0018 | No | No |
| Silver | 1.9 | 1.0 | 0.44 | 0.027 | 0.012 | No | No |
| Zinc | 90 | 373 | 58 | 10 | 1.5 | No | No |

Notes:
The point of compliance for marine acute water quality criteria is 150 feet, consistent with the LDW upper reach project (EPA 2024).
For all chemicals except PCBs, the DREDGE model-predicted an average TSS concentration of 26.9 mg/L at the 150-foot point of compliance. This prediction assumes a production rate of 180 cubic yards per hour and represents a 1-hour average consistent with marine acute water quality criteria (WAC 173-201A-240).
For PCBs, the DREDGE model-predicted an average TSS concentration of 6.2 mg/L at the 150-foot point of compliance. This prediction assumes a production rate of 1,000 cubic yards per day and represents a 24-hour average for evaluating both acute and chronic marine criteria (WAC 173-201A-240).
Predicted chemical concentrations at the 150-foot point of compliance reflect modeled TSS concentrations under representative dredging scenarios, and are used to evaluate potential exceedances of marine acute criteria.
Marine acute criteria are the lowest of federal standards (40 CFR 131.45) and state standards (WAC 173-201A) for protection of aquatic life.
Total chromium concentrations are compared to chromium VI marine acute criteria.
Marine acute criteria for metals are based on the dissolved fraction (WAC 173-201A-240).
Marine acute criteria for total PCBs and pentachlorophenol are based on total recoverable fraction (WAC 173-201A-240).
Maximum core concentration refers to the maximum vertically weighted average concentration among cores within each area.
For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste Areas encompass the remaining RAAs of the LDW middle reach, where dredging or partial dredge/cap were the identified technologies for the middle reach remedy. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.
µg/L: microgram per liter
CFR: *Code of Federal Regulations*
COC: contaminant of concern
LDW: Lower Duwamish Waterway
mg/kg: milligram per kilogram
mg/L: milligram per liter
PCB: polychlorinated biphenyl
RAA: remedial action area
TSCA: Toxic Substances Control Act
TSS: total suspended solids
WAC: Washington Administrative Code

Reference:
EPA (U.S. Environmental Protection Agency), 2024. *Clean Water Act §404 ARAR Memo: Substantive Water Quality Requirements For The Lower Duwamish Waterway-Upper Reach Superfund Remedial Action – FINAL* . October 2024.

**Table J3-3**
**DREDGE Model Output Compared to Marine Chronic Water Quality Criteria**

| COC | Marine Chronic Water Quality Criteria (µg/L) | Average Sediment Core Concentration (mg/kg) | | Concentration at Point of Compliance (µg/L) | | Potential to Exceed Marine Chronic Water Quality Criteria | |
|---|---|---|---|---|---|---|---|
| | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | 36 | 36 | 10 | 0.16 | 0.043 | No | No |
| Cadmium | 7.9 | 0.56 | 0.34 | 0.0024 | 0.0015 | No | No |
| Chromium VI | 50 | 29 | 20 | 0.12 | 0.084 | No | No |
| Copper | 3.1 | 58 | 28 | 0.25 | 0.12 | No | No |
| Lead | 8.1 | 37 | 62 | 0.15 | 0.26 | No | No |
| Mercury | 0.025 | 0.23 | 0.076 | 0.0010 | 0.00033 | No | No |
| Total PCBs | 0.030 | 0.67 | 27 | 0.0029 | 0.12 | No | Yes |
| Pentachlorophenol | 6.7 | 0.024 | 0.069 | 0.00010 | 0.00029 | No | No |
| Silver | 0.91 | 0.47 | 0.44 | 0.0020 | 0.0019 | No | No |
| Zinc | 81 | 122 | 58 | 0.52 | 0.25 | No | No |

Notes:
The point of compliance for marine chronic water quality criteria is 300 feet, consistent with the LDW upper reach project (EPA 2024).
For all chemicals, except PCBs, the DREDGE model predicted an average TSS concentration of 4.3 mg/L at the 300-foot point of compliance. This prediction assumes a production rate of 1,000 cubic yards per day and represents a 4-day average consistent with marine chronic water quality criteria (WAC 173-201A-240).
For PCBs, the DREDGE model predicted an average TSS concentration of 4.3 mg/L at the 300-foot point of compliance. This prediction assumes a production rate of 1,000 cubic yards per day and represents a 24-hour average consistent with marine chronic water quality criteria (WAC 173-201A-240).
Predicted chemical concentrations at the 300-foot point of compliance reflect modeled TSS concentrations under representative dredging scenarios, and are used to evaluate potential exceedances of marine chronic criteria.
Marine chronic criteria are the lowest of federal standards (40 CFR 131.45) and state standards (WAC 173-201A) for protection of aquatic life.
Total chromium concentrations are compared to chromium VI marine chronic criteria.
Marine chronic criteria for metals (except mercury) are based on the dissolved fraction (WAC 173-201A-240).
Marine chronic criteria for mercury, total PCBs, and pentachlorophenol are based on total recoverable fraction (WAC 173-201A-240).
Average core concentration refers to the average of the vertically weighted average concentration among cores within each area.
For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste Areas encompass the remaining RAAs of the LDW middle reach, where dredging or partial dredge/cap were the identified technologies for the middle reach remedy. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.

µg/L: microgram per liter
CFR: *Code of Federal Regulations*
COC: contaminant of concern
LDW: Lower Duwamish Waterway
mg/kg: milligram per kilogram
mg/L: milligram per liter
PCB: polychlorinated biphenyl
RAA: remedial action area
TSCA: Toxic Substances Control Act
TSS: total suspended solids
WAC: Washington Administrative Code

Reference:

EPA (U.S. Environmental Protection Agency), 2024. *Clean Water Act §404 ARAR Memo: Substantive Water Quality Requirements For The Lower Duwamish Waterway-Upper Reach Superfund Remedial Action – FINAL* . October 2024.

**Table J3-4**
**Total Suspended Solids Threshold for Compliance with Water Quality Criteria**

| COC | Marine Acute Criteria (µg/L) | Marine Chronic Criteria (µg/L) | Maximum Sediment Core Concentration (mg/kg) | | Average Sediment Core Concentration (mg/kg) | | Model-Predicted TSS Limit for Marine Acute Criteria Compliance (Based on Maximum Sediment Core Concentration) (mg/L) | | Model-Predicted TSS Limit for Marine Chronic Criteria Compliance (Based on Average Sediment Core Concentration) (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | 69 | 36 | 721 | 24 | 36 | 10 | 96 | >1,000 | >1,000 | >1,000 |
| Cadmium | 33 | 7.9 | 2.2 | 0.34 | 0.56 | 0.34 | >1,000 | >1,000 | >1,000 | >1,000 |
| Chromium VI | 1,100 | 50 | 50 | 20 | 29 | 20 | >1,000 | >1,000 | >1,000 | >1,000 |
| Copper | 4.8 | 3.1 | 171 | 28 | 58 | 28 | 28 | 173 | 53 | 111 |
| Lead | 210 | 8.1 | 81 | 62 | 37 | 62 | >1,000 | >1,000 | >1,000 | >1,000 |
| Mercury | 1.8 | 0.025 | 3.4 | 0.076 | 0.23 | 0.076 | 545 | >1,000 | 107 | 329 |
| Total PCBs | 10 | 0.030 | 4.6 | 178 | 0.67 | 27 | >1,000 | 56 | 45 | 1 |
| Pentachlorophenol | 13 | 6.7 | 0.098 | 0.069 | 0.024 | 0.069 | >1,000 | >1,000 | >1,000 | >1,000 |
| Silver | 1.9 | 0.91 | 1.0 | 0.44 | 0.47 | 0.44 | >1,000 | >1,000 | >1,000 | >1,000 |
| Zinc | 90 | 81 | 373 | 58 | 122 | 58 | 245 | >1,000 | 695 | >1,000 |

Notes:
Marine acute water quality criteria are applicable at the 150-foot point of compliance. Marine chronic water quality criteria are applicable at the 300-foot point of compliance.
Maximum core concentration refers to the maximum vertically weighted average concentration among cores within each area and is used to calculate TSS limit for marine acute criteria compliance.
Average core concentration refers to the average of the vertically weighted average concentration among cores within each area, and is used to calculate TSS limit for marine chronic criteria compliance.
For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste Areas encompass the remaining RAAs of the LDW middle reach, where dredging or partial dredge/cap were the identified technologies for the middle reach remedy. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.
Marine acute criteria for all metals are based on the dissolved fraction (WAC 173-201A-240).
Marine acute criteria for total PCBs and pentachlorophenol are based on total recoverable fraction (WAC 173-201A-240).
Marine chronic criteria for metals (except mercury) are based on the dissolved fraction (WAC 173-201A-240).
Marine chronic criteria for mercury, total PCBs, and pentachlorophenol are based on total recoverable fraction (WAC 173-201A-240).
µg/L: microgram per liter
COC: contaminant of concern
LDW: Lower Duwamish Waterway
mg/kg: milligram per kilogram
mg/L: milligram per liter
PCB: polychlorinated biphenyl
RAA: remedial action area
TSCA: Toxic Substances Control Act
TSS: total suspended solids
WAC: Washington Administrative Code

**Table J4-1**
**Dredge Return Water Discharge Model Input Parameters**

| Parameter | Value | Unit | Rationale |
|---|---|---|---|
| **Dredge Characteristics** | | | |
| Production Rate | 1,000 | cy/day | Production rate based on dredging project experience within the LDW. 1,000 cy/day represents an average 24-hour or 4-day dredge rate acceptable for comparison to chronic water quality criteria. |
| In Situ Dry Density | 951 | kg/m$^3$ | Calculated based on an average total solids of 60% assuming a particle density of 2.60 (specific gravity). |
| Proportion of Dredge Return Water to In Situ Volume of Sediment | 43% | percent | Assuming a 70% bucket fill factor and the other 30% of the bucket is made up of water. (30% / 70% = 43%) |
| Dredge Return Water Discharge Rate | 228 | L/min | Equivalent to 430 cy/day of water discharged continuously. |
| **Transport Characteristics** | | | |
| Assumed Turbulent Dissipation Parameter | 0.005 | unitless | Recommended in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C* (USACE 1998) for estuary systems. |
| Depth of Mixing | 3 | m | Discharge is assumed to mix to a depth of 3 meters. |
| Ambient River Current Velocity | 1 | ft/s | Flow changes with river stage and tidal conditions. 1 ft/s was selected as a reasonable minimum average flow velocity over a tidal cycle. Higher flow velocities reduce predicted TSS due to dilution effects. |

Notes:
cy: cubic yard
ft/s: foot per second
kg/m$^3$: kilogram per cubic meter
LDW: Lower Duwamish Waterway
L/min: liter per minute
m: meter
TSS: total suspended solids
USACE: U.S. Army Corps of Engineers

Reference:
USACE (U.S. Army Corps of Engineers), 1998. *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C.*

**Table J4-2**
**Dredge Return Water Discharge Area of Mixing Calculation – Marine Acute Criteria**

| COC | Marine Acute Criteria (µg/L) | Average Sediment Core Concentration (mg/kg) | | Predicted Concentration in Barge Effluent (µg/L) | | Minimum Mixing Zone Required (feet) | | Potential to Exceed Marine Acute Water Quality Criteria | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | 69 | 36 | 10 | 719 | -- | 4.8 | -- | No | -- |
| Cadmium | 33 | 0.56 | 0.34 | 43 | -- | 0.49 | -- | No | -- |
| Chromium VI | 1,100 | 29 | 20 | 854 | -- | -- | -- | No | -- |
| Copper | 4.8 | 58 | 28 | 1,514 | -- | 50 | -- | No | -- |
| Lead | 210 | 37 | 62 | 2.2 | -- | -- | -- | No | -- |
| Mercury | 1.8 | 0.23 | 0.076 | 2.6 | -- | 0.64 | -- | No | -- |
| Total PCBs | 10 | 0.67 | 27 | 0.30 | -- | -- | -- | No | -- |
| Pentachlorophenol | 13 | 0.024 | 0.069 | 1.3 | -- | -- | -- | No | -- |
| Silver | 1.9 | 0.47 | 0.44 | 30 | -- | 6.4 | -- | No | -- |
| Zinc | 90 | 122 | 58 | 1,156 | -- | 5.6 | -- | No | -- |

Notes:
Average core concentration refers to the average of the vertically weighted average concentration among cores within each area.
For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste Areas encompass the remaining RAAs of the LDW middle reach, where dredging or partial dredge/cap were the identified technologies for the middle reach remedy. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.
No evaluation was conducted for the TSCA Waste Areas because dredged sediments in those areas will be containerized and loaded on railcars for transportation to landfill for disposal. No dredge return water will be discharged.
Predicted chemical concentrations in barge effluent are calculated based on in situ dry density, sediment concentration, portion of dredge return water to in situ volume of sediment, and partition coefficients, and represent dissolved-phase concentration only.
Required mixing zone is calculated based on the Dilution Volume Method for CDF Effluent Discharges in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C* (USACE 1998).
The dredge return water discharge rate is 228 L/min.
Compliance with marine acute water quality criteria is achieved if the minimum required mixing zone is less than 150 feet.
--: not applicable
µg/L: microgram per liter
CDF: Confined Disposal Facility
COC: contaminant of concern
LDW: Lower Duwamish Waterway
L/min: liter per minute
mg/kg: milligram per kilogram
PCB: polychlorinated biphenyl
RAA: remedial action area
TSCA: Toxic Substances Control Act
USACE: U.S. Army Corps of Engineers

Reference:
USACE (U.S. Army Corps of Engineers), 1998. *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C.*

**Table J4-3**
**Dredge Return Water Discharge Area of Mixing Calculation – Marine Chronic Criteria**

| COC | Marine Chronic Criteria (µg/L) | Average Sediment Core Concentration (mg/kg) | | Predicted Concentration in Barge Effluent (µg/L) | | Minimum Mixing Zone Required (feet) | | Potential to Exceed Marine Chronic Water Quality Criteria | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas | Non-TSCA Waste Areas | TSCA Waste Areas |
| Arsenic | 36 | 36 | 10 | 719 | -- | 7.6 | -- | No | -- |
| Cadmium | 7.9 | 0.56 | 0.34 | 43 | -- | 2.9 | -- | No | -- |
| Chromium VI | 50 | 29 | 20 | 854 | -- | 6.8 | -- | No | -- |
| Copper | 3.1 | 58 | 28 | 1,514 | -- | 66 | -- | No | -- |
| Lead | 5.6 | 37 | 62 | 2.2 | -- | -- | -- | No | -- |
| Mercury | 0.025 | 0.23 | 0.076 | 2.6 | -- | 24 | -- | No | -- |
| Total PCBs | 0.030 | 0.67 | 27 | 0.30 | -- | 4.6 | -- | No | -- |
| Pentachlorophenol | 6.7 | 0.024 | 0.069 | 1.3 | -- | -- | -- | No | -- |
| Silver | 0.91 | 0.47 | 0.44 | 30 | -- | 11 | -- | No | -- |
| Zinc | 81 | 122 | 58 | 1,156 | -- | 6.0 | -- | No | -- |

Notes:
Average core concentration refers to the average of the vertically weighted average concentration among cores within each area.
For this evaluation, TSCA Waste Areas encompass RAAs 21A, 31B, 31C, and 31D. Non-TSCA Waste Areas encompass the remaining RAAs of the LDW middle reach, where dredging or partial dredge/cap were the identified technologies for the middle reach remedy. The rationale and additional clarifications are provided in Section 2.1 of Appendix J.
No evaluation was conducted for the TSCA Waste Areas because dredged sediments in those areas will be containerized and loaded on railcars for transportation to landfill for disposal. No dredge return water will be discharged.
Predicted chemical concentrations in barge effluent are calculated based on in situ dry density, sediment concentration, portion of dredge return water to in situ volume of sediment, and partition coefficients, and represent dissolved-phase concentration only.

Required mixing zone is calculated based on the Dilution Volume Method for CDF Effluent Discharges in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C* (USACE 1998).
The dredge return water discharge rate is 228 L/min.
Compliance with marine chronic water quality criteria is achieved if the minimum required mixing zone is less than 300 feet.
--: not applicable
µg/L: microgram per liter
CDF: Confined Disposal Facility
COC: contaminant of concern
LDW: Lower Duwamish Waterway
L/min: liter per minute
mg/kg: milligram per kilogram
PCB: polychlorinated biphenyl
RAA: remedial action area
TSCA: Toxic Substances Control Act
USACE: U.S. Army Corps of Engineers

Reference:
USACE (U.S. Army Corps of Engineers), 1998. *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C.*