# Appendix L
# Green Remediation Evaluation and Implementation Approach

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# ABBREVIATIONS

| | |
|---|---|
| BMP | best management practice |
| BODR | *Basis of Design Report* |
| $CH_4$ | methane |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| $CO_2$-eq | carbon dioxide equivalent |
| CWA | Clean Water Act |
| EmF | emission factor |
| ENR | enhanced natural recovery |
| EPA | U.S. Environmental Protection Agency |
| ESA | Endangered Species Act |
| FS | Feasibility Study |
| g | gram |
| g/hp-hr | grams of pollutant per horsepower-hour |
| GAC | granular activated carbon |
| GHG | greenhouse gas |
| GWP | global warming potential |
| HC | hydrocarbon |
| hp | horsepower |
| LDW | Lower Duwamish Waterway |
| LDWG | Lower Duwamish Waterway Group |
| MOVES3.0.2 | Motor Vehicle Emission Simulator |
| $N_2O$ | nitrous oxide |
| $NO_x$ | nitrogen oxide |
| OSWER | Office of Solid Waste and Emergency Response |
| PM | particulate matter |
| $PM_{2.5}$ | particulate matter less than 2.5 microns in diameter |
| $PM_{10}$ | particulate matter less than 10 microns in diameter |
| RAO | remedial action objective |
| RD | remedial design |
| RDWP | *Remedial Design Work Plan for the Lower Duwamish Waterway Upper Reach* |
| RMC | residuals management cover |
| ROD | *Record of Decision* |

| | |
|---|---|
| $SO_2$ | sulfur dioxide |
| VOC | volatile organic compound |

# 1 Introduction

This appendix presents the *Green Remediation Evaluation and Implementation Approach* for the sediment remedy for the upper reach (river miles [RMs] 3.0 to 5.0) of the Lower Duwamish Waterway (LDW) Superfund Site in King County, Washington. The remedy was selected in the U.S. Environmental Protection Agency's (EPA's) November 2014 *Record of Decision* (ROD; EPA 2014); this evaluation is consistent with the *Remedial Design Work Plan for the Lower Duwamish Waterway Upper Reach* (RDWP; Anchor QEA and Windward 2019), as a component evaluation associated with the remedial design (RD). This evaluation was prepared on behalf of the City of Seattle, King County, the Port of Seattle, and The Boeing Company, collectively referred to as the Lower Duwamish Waterway Group (LDWG).

This Green Remediation Evaluation and Implementation Approach reflects the information in the Intermediate (60%) RD It also builds upon previous green remediation analyses conducted for the LDW Feasibility Study (FS; AECOM 2012). Although the previous LDW FS analyses focused primarily on quantifying air emissions to evaluate the environmental footprint of the proposed remedial alternatives for short-term risk comparison purposes, this Intermediate (60%) RD *Green Remediation Evaluation and Implementation Approach* builds on the previously developed air emissions calculations but also presents an environmental footprint evaluation for all five core elements identified by EPA's Office of Solid Waste and Emergency Response in the *Superfund Green Remediation Strategy* (EPA 2010a).

## 1.1 Purpose

According to EPA's Office of Solid Waste and Emergency Response *Superfund Green Remediation Strategy* (EPA 2010a), "*green remediation is generally recognized as a major step in maximizing the environmental outcome of a contaminated land cleanup*" by incorporating specific strategies into remedial actions that minimize their environmental footprint to achieve greater net environmental benefits.

Therefore, and as described in the RDWP (Anchor QEA and Windward 2019), the purpose of the *Green Remediation Evaluation and Implementation Approach* is as follows:

1. Establish the project's environmental footprint for the sediment remedy presented in the Intermediate (60%) RD *Basis of Design Report* (BODR) through the five core elements identified in the *Superfund Green Remediation Strategy* (EPA 2010a): air, water, materials and waste, energy, and land and ecosystems (see Section 2).
2. Identify potential applicable greener construction activities, technologies, and practices that could be applied to the extent practicable during the sediment remedy implementation (e.g., dredging; sediment transloading, transportation, and disposal; material placement; habitat

restoration; and structural work), in an effort to reduce the project's environmental footprint (consistent with the EPA Region 10's *Clean and Green Policy* [EPA 2009a]) while still achieving the ROD remedial action objectives and protectiveness requirements in a timely manner.

This appendix includes the following information:

- **Section 2** (Green Remediation Framework), which summarizes the available green remediation EPA guidance and policy that were considered in this evaluation
- **Section 3** (Construction Activities Required for the Sediment Remedy), which describes the primary, secondary, and ancillary construction activities that are anticipated to be required for the sediment remedy
- **Sections 4 through 8** (Green Remediation Core Elements 1 through 5), which evaluate key metrics used to assess the project's environmental footprint for each EPA core element (i.e., air emissions, use of water, use of materials and waste generation, use of energy, and protection of land and ecosystems)
- **Section 9** (Implementation Approach: Best Management Practices), which summarizes the potential most applicable best management practices (BMPs) to minimize the impacts of the sediment remedy

The development of this appendix is based on the BODR's Intermediate (60%) RD criteria, available information to date for the upper reach, and other key elements for implementing the sediment remedy, as well as engineering best professional judgment.

# 2 Green Remediation Framework

In August 2009, the Office of Solid Waste and Emergency Response (OSWER)[1] issued the green remediation policy, known as the *Principles for Greener Cleanups*, which focuses on evaluating the environmental footprint of cleanup activities (EPA 2009b). The policy goal is to "evaluate cleanup actions comprehensively to ensure protection of human health and the environment and to reduce the environmental footprint of cleanup activities, to the maximum extent possible" and identifies five core elements of a green cleanup assessment that should be used in selecting and implementing protective cleanup activities.

In hand with the OSWER *Principles for Greener Cleanups*, EPA Region 10 also issued in August 2009 the *Clean and Green Policy* (EPA 2009a) with the goal of promoting sustainable strategies in order to improve the environmental benefits of federal cleanup programs. Specific objectives of the *Clean and Green Policy* are as follows:

- "Protect human health and the environment by achieving RAOs.
- Support sustainable human use and reuse of remediated land.
- Minimize impacts to water quality and water resources.
- Reduce air toxics emissions and greenhouse gas production.
- Minimize material use and waste production.
- Conserve natural resources and energy." (EPA 2009a)

In addition, the Office of Superfund Remediation and Technology Innovation, through the 2010 *Superfund Green Remediation Strategy* (EPA 2010a), established a green remediation program management tool designed to help the Superfund Remedial Program in minimizing and reducing negative environmental effects that might occur during an environmental cleanup. The five core elements described in the *Superfund Green Remediation Strategy* provide a framework for developing BMPs that can lead toward the green remediation objective; these five core elements are as follows:

- "**Air and Atmosphere:** *Many Superfund cleanups involve onsite and offsite emissions of GHGs and air pollutants from activities such as treatment processes, operation of heavy machinery, and transportation of routine vehicles and cargo trucks. These emissions may be reduced by applying the most appropriate advanced technologies and sound field practices.*"
- "**Water:** *Superfund cleanups may also involve consumption of significant amounts of water for treatment processes and typically need management of surface water. Green remediation strategies focus on reducing water consumption, reusing treated water, and using efficient techniques to manage and protect surface water and groundwater.*"

[1] As of December 2015, OSWER is now known as the Office of Land and Emergency Management (OLEM; https://19january2017snapshot.epa.gov/aboutepa/oswer-olem_.html).

- "**Materials and Waste:** *Site remediation may use significant amounts of raw materials and sometimes generates its own hazardous and non-hazardous wastes, including materials and debris that often are shipped offsite. Green remediation strategies offer opportunities to reduce materials consumption and waste generation, use recycled and local materials and spent products, and purchase environmentally preferred products."*
- "**Energy:** *Many Superfund cleanups involve energy intensive technologies. Green remediation strategies focus on opportunities to improve energy efficiency and use renewable energy sources."*
- "**Land and Ecosystems:** *Superfund sites often involve degraded onsite and offsite ecosystems and may have conditions that make the site unsafe for human or other use. Green remediation strategies focus on remedial actions that minimize further harm to the area, protect land resources and ecosystems at or near the site, and foster the return of sites to ecological, economic, social, or other uses."* (EPA 2010a)

Furthermore, in February 2012, the Office of Superfund Remediation and Technology Innovation released the *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012). It provides a framework for evaluating the environmental footprint associated with any remedial action (cleanup activities), understanding the remedy components with the greatest influence, and determining key metrics for each of the green remediation core elements.

## 2.1 LDW ROD Requirements on Green Remediation

The LDW ROD includes requirements for green remediation practices (see Section 13.2.5 of the ROD; EPA 2014) to be considered in the selected remedy, to the extent practicable. These ROD requirements included the following practices, consistent with EPA *Region 10's Clean and Green Policy* (EPA 2009b):

- "*Use renewable energy and energy conservation and efficiency approaches, including Energy Star equipment.*
- *Use cleaner fuels such as low-sulfur fuel or biodiesel, diesel emissions controls and retrofits, and emission reduction strategies.*
- *Use water conservation and efficiency approaches including Water Sense products.*
- *Use reused or recycled materials within regulatory requirements.*
- *Minimize transportation of materials and use rail rather than truck transport to the extent practicable."* (EPA 2014)

This appendix presents strategies that incorporate these LDW ROD requirements on green remediation into the sediment remedy.

## 2.2 Other Related Green Remediation Guidance and Policy Documents

In addition to the key EPA policy documents described previously (2009 *Region 10's Clean and Green Policy* [EPA 2009a], the 2010 *Superfund Green Remediation Strategy* [EPA 2010a], and the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* [EPA 2012]), the following documents were reviewed and considered to assess whether additional elements could be incorporated into the development of the *Green Remediation Evaluation and Implementation Approach*:

- *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA 2008a)
- "Considerations of Greener Cleanup Activities in the Superfund Cleanup Process" (EPA 2016)
- *Standard Guide for Greener Cleanups* (ASTM 2017)
- *Standard Guide for Integrating Sustainable Objectives into Cleanup* (ASTM 2020)
- *Green Remediation Best Management Practices: An Overview* (EPA 542-F-16-001, December 2015; EPA 2015a, and EPA 542-F-22-003, April 2022; EPA 2022)

Specific green remediation practices and BMPs applicable to each of the five green remediation core elements were also reviewed and considered for Section 9 of this appendix. These documents, sourced from the "*Green Remediation Best Management Practices*" fact sheet series produced by EPA are available at EPA's "Contaminated Site Clean-Up Information (CLU-IN)" website and include the following specific fact sheets:

- *Clean Fuel & Emission Technologies for Site Cleanup* (EPA 542-F-10-008, August 2010; EPA 2010b)
- *Integrating Renewable Energy into Site Cleanup* (EPA 542-F-11-006, April 2011; EPA 2011a)
- *Introduction to Green Remediation* (May 2011; EPA 2011b)
- *Materials and Waste Management* (EPA 542-F-13-003, December 2013; EPA 2013)
- *Excavation and Surface Restoration* (EPA 542-F-19-002, August 2019; EPA 2019)
- *Integrating Renewable Energy* (EPA 542-F-22-001, EPA 2022)

This *Green Remediation Evaluation and Implementation Approach* has been developed to be consistent, to the extent practicable, with the above EPA green remediation guidance and policy documents, the outlined evaluation methodology, and the application of sustainable cleanup activities, technologies, and practices.

## 2.3 Methodology

As stated in Section 1.1, the purpose of the *Green Remediation Evaluation and Implementation Approach* is to establish the environmental footprint of the sediment remedy and evaluate potential greener construction activities, technologies, and practices. A cleanup project's environmental footprint is defined by EPA's 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012) as the combined effect that the multiple project components may have on the environment. Doing an environmental footprint analysis brings a number of benefits to a project, including the following: 1) estimating footprint reductions that might be achieved from making project improvements; and 2) identifying aspects of a cleanup project that dominate the footprint, allowing the project design team to more specifically target those aspects during RD and implementation.

The environmental footprint of a project can be conceptually quantified by evaluating the five green remediation core elements through defined metrics, which are designed to not only reflect parameters that a project design team has a relatively direct ability to change but also encourage practices that would result in favorable changes to the metric values. It is important to note that the construction activities and the Intermediate (60%) RD criteria and assumptions serve as the starting point for the development of the environmental footprint of the sediment remedy in this appendix. Results from the quantification of the environmental footprint will help identify potential BMPs that could be prescribed in the specifications (at the Pre-Final [90%] RD deliverable), either as requirements or as additional potential practices and procedures to promote and encourage a green and sustainable remedy.

Section 2 and Table 2.1 of EPA's 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012) present the typical metrics to be considered for a cleanup project; Section 3 of the same document presents the step-by-step process to quantify applicable metrics. The metrics selected for the environmental footprint of the upper reach sediment remedy in this appendix are as follows[2]:

- Total air emissions (Section 4)
- Total water use (Section 5)
- Total use of raw materials and total generated waste (Section 6)
- Total energy use (Section 7)

The methodology adopted from EPA's 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012) for this appendix "*does not constitute an EPA requirement. Use of this methodology is intended to support the remedial process and to help improve the environmental outcome of cleanup efforts but not to disrupt, delay, or otherwise reduce protectiveness of a remedy*" (EPA 2012).

[2] Quantitative metrics are not provided for the green remediation core element 5, "protection of land and ecosystems," because this core element is described using qualitative metrics, consistent with EPA's 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012).

# 3 Construction Activities Required for the Sediment Remedy

As stated in the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012), construction activities associated with the upper reach sediment remedy are the baseline for determining the project's environmental footprint, to comprehensively include the work required to implement, understand the sediment remedy components with the greatest influence, and appropriately represent the environmental impacts and effects the project may potentially generate on the environment. It is important to note that the construction activities included in this appendix are based on past engineering experience with similar projects but are conceptual in nature.

Defining the construction activities is also an opportunity to implement green remediation practices, consistent with the goals of the *Superfund Green Remediation Strategy* (EPA 2010a). The anticipated construction activities needed to implement the sediment remedy can be classified as primary (major construction activities), secondary (minor construction activities), and ancillary (additional activities that are indirectly required or associated with the sediment remedy implementation). For the purposes of this evaluation, all of the equipment used in the primary and secondary construction activities is assumed to be operated using hydrocarbon fuels. The construction activities associated with the upper reach sediment remedy are described in detail in this section.

The following anticipated construction activities and associated assumptions (e.g., equipment types) are considered representative for the purposes of this evaluation; however, the selected contractor will identify actual proposed equipment, materials suppliers, rail service providers, and disposal facilities in the contractor's Remedial Action Work Plan.

## 3.1 Primary Construction Activities

The following construction activities are identified as primary because they represent the major construction activities conducted within or outside of the project site and directly contribute to the project's environmental footprint:

- Sediment removal (assumed mechanical dredging, using either a barge-mounted precision excavator or barge-mounted derrick crane/bucket) under these scenarios:
  - Open-water dredging
  - Nearshore dredging
  - Restricted access dredging
  - Shoreline/bank excavation
- Identified debris removal, using an excavator, where possible, or potentially conventional derrick with clamshell, grapple, or vibratory hammer for removal of large debris
- Sediment transloading, upland transportation, and off-site disposal:

  - Transportation (via tugboat and barge) of dredged sediments to the transload facility (located within the LDW vicinity)
  - Offloading of the dredge sediments and debris at the transload facility into stockpiles, loading stockpiles into containers, and loading containers onto railcars for off-site upland landfill disposal
  - Transportation (via truck and rail) of dredged sediments for off-site upland landfill disposal (assumed to be in Arlington, Oregon)
  - Water treatment of transloaded materials at the transloading facility
- Material transportation and placement of clean materials (i.e., sand, gravelly sand, and light riprap that meet specified quality criteria) and amendments (assumed to be granular activated carbon [GAC] for RAAs 18, 24, and 26) to the upper reach. Materials are intended for backfill, enhanced natural recovery (ENR), residuals management cover (RMC), amended cover, and 'prospective' shoreline capping. The materials are assumed to be placed via mechanical placement, using barge-mounted precision excavator or barge-mounted derrick crane/bucket:
  - Transportation of clean materials to the LDW, including the following:
    - Transportation (via truck) of clean materials from a local quarry to an onshore staging area (outside of the LDW upper reach)
    - Transportation (via tug and barge) of clean materials from an onshore staging area (outside of the LDW upper reach) to the LDW upper reach
    - Transportation (via truck) of GAC from a vendor in Richland, Washington, to the upper reach
  - Placement of sand for RMC and ENR
  - Placement of sand/GAC blended material for amended cover
  - Placement of gravelly sand and light riprap materials for 'prospective' shoreline capping
- Structural work:
  - Timber and steel pile removal and replacement
  - Relocation/reinstatement of docks/floats
  - Temporary shoring of bulkheads
  - Outfall work (including temporary pipe support, energy dissipator, and apron/bank installation/protection)

## 3.2 Secondary Construction Activities

The following anticipated activities are identified as secondary because they represent the minor construction activities to be conducted within the project site:

- Site preparation:
  - Equipment mobilization

  - Shoreline/bank area site clearing
  - Upland staging area setup and staging of equipment
- Bathymetric and topographic surveying
- Environmental compliance
  - Confirmational sediment sampling and environmental monitoring
- Site closure
  - Equipment decontamination and demobilization

## 3.3 Ancillary Activities (Not Evaluated)

Ancillary activities, or activities indirectly required or associated with the implementation of the sediment remedy, are sourced elsewhere and not dependent on the remedy itself; therefore, they are not considered applicable activities to the project's environmental footprint. Ancillary activities may include the following:

- Import and purchase of electricity, heating/cooling, or steam, and related transmission and distribution
- Mining/quarrying/excavation from borrow pits of raw materials and aggregates required for backfill, RMC, ENR, amended cover, and 'prospective' shoreline capping
- Manufacturing of construction equipment and materials
- Manufacturing of staging equipment and temporary/support facilities
- Extraction, production, refinement, and transportation of fuels, lubricants, etc.
- Transport/commuting of workers to/from the project site
- Landfill emissions, management, and operations

Therefore, ancillary activities are not further considered or evaluated in this *Green Remediation Evaluation and Implementation Approach*.

# 4 Green Remediation Core Element 1: Air Emissions

Conventional sediment remediation involves construction activities that consume a significant amount of gasoline, diesel, and other fuels to power heavy equipment. These fuels release air pollutants that contribute to greenhouse gas (GHG) and pollution accumulation in the atmosphere. For this appendix, the evaluation of the green remediation core element 1 was conducted using air emission metrics. Air emissions were estimated for primary and secondary construction activities (as described in Section 3) for the following air constituents:

- Hydrocarbons (HC)
- Volatile organic compounds (VOCs)
- Carbon monoxide (CO)
- Nitrogen oxides ($NO_X$)
- Particulate matter less than 10 microns in diameter ($PM_{10}$)
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$)
- Sulfur dioxide ($SO_2$)
- Carbon dioxide ($CO_2$), also a key GHG

This section discusses air emission sources and categories (Section 4.1), equipment assumptions for baseline and local average market conditions[3] (Section 4.2), assumed fuel usage inputs for the air emission calculations based on time or mass-distance traveled (Section 4.3), associated air emission factors (EmFs; Section 4.4), and the results of the air emission calculations (Section 4.5).

## 4.1 Air Emissions Sources and Categories

The 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012) and relevant emissions accounting protocols (WRI/WBCSD 2004; EPA 2005) specify establishing "operational boundaries" for the emissions-generating entity under consideration (referred to as the "reporting entity," which can be a country, company, or project). For this appendix, the LDW upper reach project is defined as the "reporting entity."

The air emission calculation process involves the following: 1) identifying air emissions sources associated with its "operations" (in this case the anticipated construction activities associated with the implementation of the sediment remedy); and 2) categorizing the resultant air emissions as direct ("Scope 1"), indirect ("Scope 2"), or optional ("Scope 3," or other indirect), per EPA (2005, 2012) and

[3] Baseline conditions are defined as the conditions presented in the Preliminary (30%) RD, whereas the local market average conditions are updated conditions following a survey of local contractors. These terms are further defined in Section 4.2.

WRI/WBCSD (2004),[4] which are defined for this project in the following subsections. The upper reach is a working waterway, and industrial activities and public use will occur simultaneously with anticipated cleanup construction activities. This air emissions inventory evaluates the incremental increase in air emissions related to the upper reach cleanup construction only and does not consider day-to-day air emissions within or adjacent to the upper reach associated with industrial activities or public uses.

### *4.1.1 Direct Air Emissions (Due to Primary and Secondary Construction Activities)*

Direct air emissions are from sources derived from conducting remedial construction activities and owned or controlled by the "reporting entity" (the LDW upper reach project). In this case, direct air emissions sources include primary and secondary construction activities (as described in Sections 3.1 and 3.2), such as stationary, mobile, and process-related sources from owned or controlled construction equipment and vehicles used to carry out dredging, transload, upland transportation, disposal,[5] material placement, structural work, surveying, and environmental compliance activities.

Direct air emissions were generally estimated for these activities based on assumptions associated with the type and number of equipment and vehicles, the duration of their use based on the specific function, the effective operation time, and the daily fuel consumption. Direct air emissions inventory has been based entirely on calculating fossil fuel consumption (primarily diesel fuel).[6] However, the opportunities for renewable energy source use during the sediment remedy implementation are identified in Sections 7.2 and 9.4 of this appendix and, as discussed therein, could be further evaluated during RD and implemented in specific construction activities, where feasible, to help reduce the air emissions associated with the sediment remedy.

### 4.1.2 *Indirect Air Emissions (Not Evaluated)*

Indirect air emissions are a consequence of conducting remedial construction activities but occur at sources owned or controlled by a separate, different "reporting entity." Examples of indirect air emission sources might include importing/purchasing electricity, heating/cooling, or steam and

[4] "Direct," "indirect," and "optional" emissions categories are designations presented in EPA's 2005 *Climate Leaders Greenhouse Gas Inventory Protocol* (EPA 2005). Scopes 1, 2, and 3 are associated descriptive terms, as well as corresponding designations presented in *The Greenhouse Gas Protocol* (WRI/WBCSD 2004).

[5] Although transload and upland transportation and off-site disposal of dredge sediments may be conducted outside of the project site and may fall under the control of a another "reporting entity" (i.e., subcontractors), the air emissions resulting from these activities are of significant magnitude relative to the indirect air emissions. Therefore, these air emissions are included in this inventory in the direct emissions category because they are key components of the remedial construction activities from the upper reach project.

[6] For the purposes of this Intermediate (60%) RD *Green Remediation Evaluation and Implementation Approach*, sulfur content of diesel fuel is assumed to be 15 parts per million (ultra-low sulfur diesel).

related transmission/distribution, extraction/quarrying/excavation of raw materials; manufacturing of construction equipment and materials; extraction, production, refinement, and transportation of purchased fuels, lubricants, etc.; employee transport and commuting; and landfill air emissions due to operations at the disposal facility. These indirect air emissions are related to the ancillary activities described in Section 3.3.

These types of air emissions have not been quantified for the project and are not evaluated because they are considered beyond the scope of this analysis; it is unknown to what extent they would be accounted for in any inventories conducted by other "reporting entities" (i.e., manufacturers, vendors, contractors). Therefore, indirect air emissions are not further considered or evaluated in this *Green Remediation Evaluation and Implementation Approach*.

### *4.1.3 Other Greenhouse Gas Emission Contributions (Not Evaluated)*

GHGs are gases that are trapped in the atmosphere due to the combustion of fossil fuels (coal, natural gas, and oil), solid waste, trees, and other biological materials and as a result of livestock and other agricultural practices, land use, and the decay of organic waste in municipal solid waste landfills (https://www.epa.gov/ghgemissions/overview-greenhouse-gases[7]; EPA 2022). The largest GHG contributors are $CO_2$, methane ($CH_4$), and nitrous oxide ($N_2O$); other GHGs are emitted in smaller quantities. Total GHG emissions are typically reported as metric tons (tonnes) of carbon dioxide equivalents ($CO_2$-eq), calculated by multiplying the tonnes of each GHG emitted by that GHG's global warming potential[8] (GWP; EPA 2005) and summing the results. Therefore, $CH_4$ and $N_2O$ can be typically included in the $CO_2$-eq total.

For all diesel fuel vehicle types tracked as part of this inventory, the EmFs are 0.26 grams per gallon for $N_2O$ and 0.8 grams per gallon (or less) for $CH_4$, as presented in *Direct Emissions from Mobile Combustion Sources* (EPA 2008b, Table A-6). $CO_2$ has an EmF of 10.21 kilograms per gallon (EPA 2022). Although the GWPs of $N_2O$ and $CH_4$ are 298 and 25, respectively,[9] the contribution of $CO_2$ to $CO_2$-eq is more than 100 times greater than the collective contribution of $N_2O$ and $CH_4$.[10] For this reason, GHG emissions from $N_2O$ and $CH_4$ would not be discernible in a $CO_2$-eq total reported to two significant figures (as is typical engineering practice for this type of evaluation); therefore, they

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[7] Website accessed in May 2022.

[8] The GWP represents the effect a given GHG has on global warming in the atmosphere relative to one unit of $CO_2$. GWPs for all of the GHGs are listed in *Climate Leaders Greenhouse Gas Inventory Protocol - Design Principles*, Table 6-3 (EPA 2005).

[9] For every tonne of GHG emitted, the contributions to global warming associated with $N_2O$ and $CH_4$ are 298 and 25 (Table 5-2; EPA 2015b) times higher, respectively, than for $CO_2$.

[10] For each gallon of diesel fuel burned, the $CO_2$ contribution over the combined $N_2O$ and $CH_4$ contribution is equal to 10,210 g $CO_2$/[(0.26 g $N_2O$ x 298) + (0.8g $CH_4$ x 25)] = 105.

have not been included in this inventory due to this *de minimus* contribution. Therefore, $CO_2$ and $CO_2$-eq should be considered equivalent in the air emissions inventory of this appendix.

## 4.2 Baseline and Local Average Market Conditions and Associated Equipment Assumptions

EPA has developed an engine classification for on-road vehicles (light and heavy duty, locomotives, motorcycles, etc.) and nonroad equipment/engines (marine engines/vessel, construction equipment) called the Tier System, with the purpose of identifying air emission standards corresponding to when a specific engine was manufactured and help reduce engine emissions (https://www.epa.gov/emission-standards-reference-guide[11]; EPA 2022). The EPA emission standards for each tier are specific to the type of equipment (on-road vehicles, nonroad equipment/engines), the year of manufacture, and the engine power. The following is the definition of EPA's Tier System[12]:

- **Pre-Tier Engines:** All equipment manufactured prior to 1996; it is assumed that this equipment was produced without a requirement to meet specific air emission standards.
- **Tier 1 Engines:** All equipment manufactured between 1997 and 2005.
- **Tier 2 Engines:** All equipment manufactured between 2001 and 2010.
- **Tier 3 Engines:** All equipment manufactured between 2006 and 2011.
- **Tier 4 Engines:** All equipment manufactured in 2008 and later.

As part of the air emission analysis, the EPA's Tier System was used to calculate air emissions for the baseline conditions and the local market average conditions using different distributions of engine tiers to evaluate the impact on overall emissions. The baseline condition is a conservative estimate presented in the Preliminary (30%) RD and assumes the use of equipment with Tier 2 and lower tier engines only (i.e., all equipment manufactured before 2010). Prior to developing this Intermediate (60%) RD *Green Remediation Evaluation and Implementation Approach*, a survey among local marine construction contractors was performed to establish the assumptions for the local market average condition. The local market average condition uses the approximate distribution of the age of construction equipment currently in active use (as of 2022) in the Puget Sound area in Washington. The results of the local market survey were used to establish a range of engine types that could be potentially used during sediment remedy implementation through the specifications. Engine tier

[11] Website accessed in December 2022.

[12] Note that the model year range between tiers overlaps in some cases because model year requirements vary based on the horsepower (hp) of the equipment (e.g., a 50-hp engine manufactured in 2003 was required to meet Tier 1 emission standards, while a 160-hp engine manufactured in the same year [2003] was required to meet instead Tier 2 emission standards; EPA 2022). The range in model years provided in this appendix represents the widest possible range for the specific tier.

distribution and equipment assumptions for the baseline condition[13] and the local market average condition[14] are presented in this appendix in Table L-1 for comparative purposes.

For the purposes of this this analysis, air emission calculations for both the baseline conditions and the local average market conditions are presented to showcase potential air emission improvements that could inform and aid, if appropriate, in establishing specification requirements (i.e., minimum tier level required).

## 4.3 Air Emission Calculation Inputs

Direct air emissions for primary and secondary construction activities are calculated based on estimating diesel fuel usage for each construction activity on a time basis (for construction equipment and vehicles) and on a mass-distance basis (for placement material and dredged sediment transport). Emissions were then calculated using available EmFs from various EPA sources (see Section 4.4).

Table L-2 presents the inputs for the direct air emissions calculations by construction activity, including quantities (i.e., dredged sediment and placement material volume), production rates for each construction activity (both obtained from Appendix M of the BODR), anticipated daily fuel usage or distance traveled, and estimated daily equipment operation rates and durations (assumed based on professional judgment and experience from similar projects).

### *4.3.1 Time-Based Fuel Usage Estimates*

For all direct air emissions-generating activities (except for transportation of placement material and dredged sediment), the following input parameters were used to estimate total diesel fuel usage:

- Assumed construction vehicle, or equipment types and numbers
- Estimated daily vehicle operation and uptime (effective operation time)
- Estimated fuel consumption rates
- Total implementation time (defined as total quantity divided by the specific production rate for each construction activity)

Table L-3 presents a list of the assumptions for equipment and vehicles and fuel usage per piece of equipment.

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[13] For the purposes of the baseline conditions, no construction equipment was assumed to be considered Tier 1 or Tier 3.
[14] Based on local marine construction contractor survey, no construction equipment was identified by the survey to be considered Tier 1 or Tier 3.

### *4.3.2 Mass-Distance-Based Fuel Usage Estimates*

For activities related to transportation of placement material and dredged sediments, a mass-distance-traveled approach was used to estimate total fuel usage. The mass of placement material and dredged sediments, and the distance traveled during transportation via rail, truck, or barge, was accounted for, and available ton-mile[15]-based fuel economy factors (EPA 2022) were used to calculate total fuel usage.

Input parameters to estimate fuel usage due to transportation of placement materials (via truck and tug/barge) and dredged sediment for disposal (via rail) included the mass of materials (in tons) and distances traveled (in miles). Assumptions related to rail, truck (on road and nonroad), and barge diesel fuel consumption and transport capacity are presented in Tables L-4, L-5a, L-5b, and L-6, respectively.

## 4.4 Air Emission Factor Sources

Air EmFs for HC, VOCs, CO, $NO_X$, $PM_{10}$, $PM_{2.5}$, $SO_2$, and $CO_2$ are either provided in or are calculated using assumptions from EPA's *Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES3.0.2* (EPA 2021). Air EmFs (in grams of pollutant per horsepower-hour [g/hp-hr]) vary based on the horsepower of the equipment; the equipment and associated engine power assumed in this appendix are listed in Table L-3.

### *4.4.1 Air Emission Factors for HC, VOCs, CO, $NO_X$, and PM*

Air EmFs for HC, VOCs, CO, $NO_X$, $PM_{10}$, and $PM_{2.5}$ are provided in Table A-4 in Appendix A of Motor Vehicle Emission Simulator (MOVES3.0.2; EPA 2021) on-road vehicles (light- and heavy-duty, locomotives, motorcycles, etc.) and nonroad equipment/engines (marine engines/vessel, construction equipment). Based on an analysis of particle size distribution data of particulate matter (PM) emissions from diesel engines, all PM emissions are assumed to be smaller than 10 microns, and 97% of PM emissions are smaller than 2.5 microns (EPA 2021). Therefore, no adjustment was applied to the PM emission factor to calculate total $PM_{10}$ emissions, and an adjustment of 0.97 was applied to the PM emission factor to calculate total $PM_{2.5}$ emissions.

Air EmFs for HC, VOCs, CO, $NO_X$, $PM_{10}$, and $PM_{2.5}$ for rail, trucks, and vessels (mass-distance-based air emission estimates) and for the various tier engines (baseline conditions and equipment assumptions described in Section 4.2) are presented in Tables L-4, L-5a, L-5b, and L-6, respectively. Air EmFs for HC, VOCs, CO, $NO_X$, $PM_{10}$, and $PM_{2.5}$ for construction equipment and vehicles (time-based air

[15] A unit of freight transportation is equivalent to a ton of freight moved 1 mile.

emission estimates) and for the various tier engines (baseline and local average market conditions and equipment assumptions in Section 4.2) are presented in Table L-7.

### *4.4.2 Air Emission Factors for $SO_2$ and $CO_2$*

Air EmFs for $SO_2$ and $CO_2$ were calculated based on relationships provided in MOVES3.0.2 (EPA 2021). Equations 1 and 2 use a brake-specific fuel consumption factor, which is provided in Table A-4 in Appendix A of MOVES3.0.2 (EPA 2021), to compute $CO_2$ and $SO_2$ air EmFs, respectively.

**Equation 1**

$$SO_2 = \left(BSFC * \frac{lb}{g} * (1 - \mathrm{soxcnv}) - \mathrm{HC}\right) * 0.01 * soxdsl * \frac{Mass\ SO_2}{Mass\ S}$$

where:

| | | |
|---|---|---|
| $SO_2$ | = | Sulfur dioxide emission factor (g/hp-hr) |
| BSCF | = | Horsepower-specific brake-specific fuel consumption (unitless) |
| HC | = | Hydrocarbon emission factor (g/hp-hr) |
| soxcnv | = | Fraction of fuel sulfur converted to direct PM (unitless) |
| $\frac{lb}{g}$ | = | Conversion factor from pounds to grams (unitless; 453.6) |
| soxdsl | = | Percent of sulfur in nonroad diesel fuel by weight (%) |
| Mass S | = | Mass of sulfur (g) |
| Mass $SO_2$ | = | Mass of sulfur dioxide (g) |

**Equation 2**

$$CO_2 = \left(BSFC * \frac{lb}{g} - HC\right) * \frac{Mass\ C}{Mass\ Diesel} * \frac{Mass\ CO_2}{Mass\ C}$$

where:

| | | |
|---|---|---|
| $CO_2$ | = | Carbon dioxide emission factor (g/hp-hr) |
| BSCF | = | Horsepower-specific, brake-specific fuel consumption (unitless) |
| HC | = | Hydrocarbon emission factor (g/hp-hr) |
| $\frac{lb}{g}$ | = | Conversion factor from pounds to grams (unitless; 453.6) |
| Mass C | = | Mass of carbon (g) |
| Mass Diesel | = | Mass of diesel (g) |
| Mass $CO_2$ | = | Mass of carbon dioxide (g) |

Air EmFs for $SO_2$ and $CO_2$ for rail, trucks, and barges (mass-distance-based air emission estimates) and for the various tier engines (baseline conditions and equipment assumptions described in Section 4.2) are presented in Tables L-4, L-5a, L-5b, and L-6, respectively. Air EmFs for $SO_2$ and $CO_2$ for construction equipment and vehicles (time-based air emission estimates) and for the various tier engines (baseline and local average market conditions and equipment assumptions described in Section 4.2) are presented in Table L-7.

## 4.5 Air Emission Results

A detailed summary of total direct air emissions (in metric tonnes) by construction activity and for each of the eight air constituents is presented in Table L-8, for assumed Pre-Tier, Tier 2, and Tier 4 engines (regardless of any equipment distribution). Applying the engine tier distribution and equipment assumptions listed in Table L-1, high-level summaries of the total direct air emissions (in metric tonnes), associated with the baseline and local average market conditions for each of the eight air constituents, are presented in Table L-9 and Figures L-1 and L-2, respectively, broken out by construction activity.

As depicted in Figure L-1, for all air constituents evaluated, the construction activities that represent the vast majority of the total direct air emissions, under the baseline conditions, are sediment transload, upland transportation, and disposal; sediment dredging; and clean material transportation and placement. As depicted in Figure L-2, for all air constituents evaluated, the construction activities that represent the vast majority of the total direct air emissions, under the local market average conditions, are sediment dredging and sediment transload, upland transportation, and disposal,[16] followed by clean material transportation and placement.

As shown in Figure L-1, the four air constituents in the baseline conditions that contribute the most to the direct air emissions due to the sediment transload, upland transportation, and disposal activity are $CO_2$ (56%), $SO_2$ (55%), $NO_X$ (51%), and CO (47%). The remaining four air constituents (HC, VOCs, $PM_{10}$, and $PM_{2.5}$) account for between 35% and 42% of direct air emissions for this same construction activity. For the sediment dredging and clean material transportation and placement activities, all air constituents contribute 14% to 23% and 20% to 24%, respectively, to the direct air emissions. For the structural work activity, all air constituents contribute in a similar proportion (approximately from 9% to 16%) to the direct air emissions.

As shown in Figure L-2, the five air constituents in the local average market conditions that contribute the most to the direct air emissions due to the sediment dredging activity are $PM_{10}$ and $PM_{2.5}$ (32%), $NO_X$ (29%), and HC and VOCs (28%). The remaining three air constituents ($SO_2$, $CO_2$, and

[16] For $PM_{10}$ and $PM_{2.5}$ only, total direct air emissions for the structural work activity are greater than for the sediment transload, upland transportation, and disposal activity.

CO) account for between 16% and 21% of direct air emissions for this same construction activity. For the sediment transload, upland transportation, and disposal, the three air constituents that contribute the most to the direct air emissions are $CO_2$ (48%), $SO_2$ (47%), and CO (45%); the remaining five air constituents (HC, VOCs, $PM_{10}$, $PM_{2.5}$, and $NO_X$) account for between 15% and 26% of direct air emissions for this same construction activity. Total direct emissions from the clean material transportation and placement activity are similar (18% to 26%) for all air constituents.

Applying the engine tier distribution and equipment assumptions listed in Table L-1, high-level summaries of the total direct air emissions (in metric tonnes), associated with the baseline and local average market conditions for each of the eight air constituents, are presented in Table L-10 and Figures L-3 and L-4, respectively, broken out by equipment type. Among all vehicle and equipment types for each of the construction activities, the use of various vessels (including tugboats, push boats, and work boats, used to not only haul dredge sediment to the transload facility but also to haul clean materials for placement to the site and position other marine construction equipment) accounts for the majority of the total direct air emissions consistently for both scenarios (baseline and local average market conditions), as shown in Figures L-3 and L-4; in both cases, four of eight air constituents (HC, VOCs, $PM_{10}$, and $PM_{2.5}$) are the primary contributors with total direct emissions ranging from 43% to 68%. Under the baseline condition, the transportation via rail of dredged sediments (for off-site disposal) accounts for the majority of the total direct air emissions for four of the eight air constituents (CO, $NO_X$, $SO_2$, and $CO_2$) ranging from 30% to 34%; for the same equipment type, three of the eight air constituents (CO, $SO_2$, and $CO_2$) are predominant, with total direct air emissions ranging from 32% to 38%. In addition, under the baseline conditions, truck transportation (to haul dredged sediments to an intermodal facility for off-site upland landfill disposal and to haul clean placement materials from a local quarry to an onshore staging area) represents 11% to 25% of total direct air emissions for all eight air constituents, making it in general the third-largest source of contaminants. However, for the local average market conditions, truck transportation is limited to hauling clean placement materials (with $SO_2$ and $CO_2$ being the only air constituents contributing).

As stated in Section 4.2, the air emission results from local average market conditions were included as part of this analysis to provide a more realistic prediction of direct air emissions generated during sediment remedy implementation, based on current existing construction marine equipment among local remediation contractors. Therefore, Table L-11 provides a comparison of the total direct air emissions (in metric tonnes) between the baseline conditions and the local average market conditions for each of the eight air constituents, expressed as a relative change in total emissions by adopting a larger proportion of high-tier engine types (Tier 4). The largest reduction in total direct air emissions (approximately 26% for CO to 75% for $NO_X$) when comparing the local average market conditions to the baseline conditions is evident for the sediment transload, upland transportation, and disposal activity. This is consistent with the high percentage of Tier 4 engines assumed to be applied to equipment needed for this construction activity under the local average market conditions. However, Table L-11 also shows a slight increase in total direct air emissions for the sediment dredging activity (0.7% for $SO_2$ to 1.6% for $CO_2$) and the material transportation and placement activity (0.8% for $CO_2$ to 0.9% for $SO_2$). As stated in Section 4.4.2 and as shown in Table L-7, air emission factors for $SO_2$ and $CO_2$ are highly dependent on the brake-specific fuel consumption, which is higher for Tier 2 and Tier 4 engines (relative to Pre-Tier engines) for equipment like cranes, resulting in slightly higher emissions as engine tiering increases.

## 4.6 Conclusions

In conclusion, the local average market conditions scenario represents a realistic distribution of tier engines, based on current availability of construction marine equipment in the Puget Sound area for sediment remediation. The engine tier distribution in the local average market conditions scenario will inform, as appropriate, the basis for establishing potential minimum tier level specification requirements (to be developed at Pre-Final [90%] RD) for the contractor to select their equipment. Minimum tier level specification requirements will reduce, to the extent practicable, air emissions during sediment remedy implementation.

As shown in Table L-11, the implementation of a higher tier level as a specification requirement for the contractor should significantly reduce total emissions for all equipment because the greatest reductions are observed for activities, such as sediment transload, upland transportation, and disposal (57% to 75% total emission reduction from baseline to local average market conditions) and clean material transportation and placement (22% to 32% total emission reduction from baseline to local average market conditions). However, from this analysis, it is also shown that total emissions from some activities will have relatively little improvement with a higher tier level, such as the sediment dredging activity (which resulted in only 0% to 7% decrease in total emissions; Table L-11) and structural work (which resulted in only 0% to 8% decrease in total emissions; Table L-11). The incorporation of a sensitivity analysis (to be developed at Pre-Final [90%] RD) would allow for the identification of specific equipment types that would provide the greatest benefit from applying a minimum tier level specification requirement.

Section 9.1 presents the potential BMPs that could be applicable to the various construction activities of the upper reach sediment remedy and help reduce air emissions during remedial construction.

# 5 Green Remediation Core Element 2: Use of Water

As part of the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012), use of water was evaluated as green remediation core element 2. For this analysis, water use is defined as water that is extracted from a potable or nonpotable source for use in sediment remediation or other construction activities (e.g., transload, dust control, or decontamination) and does not include water derived from dewatering dredge materials. Water use within the context of sediment remediation is assumed to be relatively minimal for most remedial technologies. The most common nonpotable water uses (outside of personnel use) identified in the implementation of the sediment remedy are water spraying for dust control purposes, water used in equipment decontamination, and additional water needs at the transload facility.

Water spraying to address dust control is expected to be limited to application at the on-site upland staging area, where equipment and materials may be staged during construction. It is assumed that water would be applied at a rate of 4,000 gallons (equivalent of one water truck) per week to limit dust production during construction in the summer months (July through September). However, the in-water work window for the LDW is from October to February, outside of the summer months, so if the work happens as scheduled, no water use is expected from water spraying.

Water use associated with equipment decontamination is expected to be low. Decontamination is only anticipated to occur during mobilization (prior to the start of construction), prior to transitioning from dredging to material placement activities, and during demobilization (at the end of construction). The decontamination process is limited to only equipment that comes into contact with dredged sediments (i.e., material handling buckets) and is expected to require less than 5,000 gallons of water during the course of each construction season.

Similar to equipment decontamination, water use at the transload facility is expected to also be low; it is assumed that the transload facility would require less than 1,000 gallons of water during the course of each construction season.

Overall, the water use of the LDW upper reach sediment remedy is expected to be minimal, with water primarily being used for equipment decontamination and water use at the transload facility. It is assumed that all of the water use described in this section is nonpotable water (either rain collected water, river water, or a nonpotable public water supply; no potable water usage is considered in this appendix). The total nonpotable water consumption for three construction seasons is expected to be approximately 18,000 gallons. Section 9.2 presents standard BMPs that are typical to help reduce water consumption during remediation activities.

# 6 Green Remediation Core Element 3: Use of Materials and Waste Generation

Consistent with the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012), the green remediation core element 3 (use of materials and waste generation) focuses on quantification of raw, recycled, and waste materials associated with the LDW upper reach sediment remedy with the intent of reducing raw material usage and waste generation and increasing material recycling, all to the extent practicable. Overall, the benefits of quantifying this core element may include the following:

- Reducing the depletion of natural resources, such as sand, gravel, and cobble
- Reducing the use of landfills for disposal
- Reducing the environmental impact of production of new materials
- Reducing the overall project cost

Table L-12 presents the quantities of raw and waste materials identified from construction activities required for the sediment remedy.

The largest use of clean raw materials for the sediment remedy is anticipated to be for material placement activities (approximately 73,800 cubic yards, including the need to import clean materials, such as sand, gravelly sand, and light riprap, used for backfill, RMC, ENR, and 'prospective' shoreline capping) and for structural work (including the need to replace approximately six timber and steel piles) (Table L-12).

Consistent with Section 10.6.2 of the BODR, it was assumed in this appendix that all materials for placement activities will be regionally sourced from commercially available suppliers (i.e., sand and gravel quarries) that can supply materials for backfill for RMC/ENR/amended cover (e.g., sand) and for shoreline capping. These materials will need to meet design quantities, delivery schedules, gradations, and chemical quality criteria established in RD for each material type. As stated in the BODR (Section 10.6.2), beneficial use of clean dredged material was evaluated as a potential source of materials, but it entails significant coordination and timing complications, among other issues, and for recent cleanup projects, has been difficult to accomplish. Given the anticipated schedule for cleanup in the upper reach, beneficial use of clean dredged material has been screened from further consideration. If beneficial use opportunities are identified during subsequent design stages, consideration of these sources will be included in an updated *Green Remediation Evaluation and Implementation Approach* at Pre-Final (90%) RD.

The largest source of waste generated is the dredge contaminated sediment, which will be approximately 107,500 cubic yards, equivalent to 163,900 tons, to be disposed in an off-site landfill facility (Table L-12). The beneficial use of dredged contaminated sediments either before or after treatment was also investigated for the LDW project (AECOM 2012). However, contaminated untreated sediment is not suitable for direct beneficial use applications; therefore, beneficial use of contaminated sediments has not been further considered. In addition to dredged sediments, approximately 20 steel and timber piles, and approximately 650 tons of debris will be required to be removed and will generate additional waste (Table L-12). Because of the metals and concrete contained in some of these wastes, they are expected to have the greatest opportunity for reuse or recycling to reduce landfill disposal.

Section 9.3 presents the potential BMPs that could be appliable to the various construction activities of the LDW upper reach sediment remedy and help reduce raw material use and waste generation.

# 7 Green Remediation Core Element 4: Use of Energy

Significant amounts of energy, specifically originating from fossil fuels, are expected to be consumed to power engines and equipment, facilitate transport activities, and run operations associated with the LDW upper reach sediment remedy. As part of the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012), use of energy based on fossil fuel consumption (e.g., gasoline or diesel) to carry out the sediment remedy was evaluated as a metric for green remediation core element 4; potential options to use renewable energy are also discussed.

## 7.1 Total Energy Use

Typical sediment remedies are primarily conducted with diesel-powered engines and equipment. Diesel fuel consumption is assumed to be the key metric that quantifies the total energy that is anticipated to be used for the upper reach remedy implementation. Table L-13 presents the approximate volume of diesel fuel consumed for each construction activity for the overall LDW project. The highest energy consumption is anticipated to occur for the upland transportation and disposal of sediment material (approximately 136,200 gallons), followed by mechanical offloading (approximately 57,700 gallons) at the transload facility and all types of dredging and excavation (approximately 41,300 gallons). Also, all types of material placement, structural work, and transportation of clean placement material to the upper reach account for an energy consumption of approximately 26,500, 25,600, and 19,800 gallons, respectively.

Consistent with Section 10.2.6 of the BODR, it is assumed that the upper reach project has a commercial transload facility in close proximity (Duwamish Reload Facility, operated by WM [formerly Waste Management]) that could readily be used for transloading dredged materials from barges and loading into trucks or railcars for transportation to a disposal facility. Because a project-specific transload facility will not be further considered in RD, the contractor will be responsible for identifying and proposing the actual transload facility in the Remedial Action Work Plan. It is assumed that for both the baseline and local average market conditions scenarios, all transloading activities would occur at a commercial facility that only operates a diesel-powered crane for transloading.

Minor construction activities, such as surveying and environmental monitoring, are expected to use the least amount of diesel-based energy (less than 1,000 gallons each). Based on the Intermediate (60%) RD assumptions, the upper reach sediment remedy is anticipated to use approximately 308,300 gallons of diesel energy over three construction seasons.

## 7.2 Potential Renewable Energy Use

With recent advancements in electric-powered engines, manufacturers are beginning to produce electric-powered construction equipment alongside their legacy diesel equipment. According to Seattle City Light (https://www.seattle.gov/city-light/about-us/what-we-do), 91% of all electric energy generated in 2020 was from renewable sources (86% hydropower and 5% wind power) and another 6% came from low- to no-emission sources (nuclear and biogas); the remaining 3% came from unspecified sources. This means the use of electric-powered equipment can be nearly emission-free.

### *7.2.1 Transload Electrification*

Because one of the highest diesel energy consumption sources is derived from transloading activities, significant energy savings could be realized with an electric-powered crane. Of the approximately 57,700 gallons of diesel anticipated to be consumed in the mechanical transloading process (which includes the use of a tugboat, a 100-ton crane, and a front-end loader), the diesel-powered offloading crane represents approximately 70% of the total fuel consumption (or 40,400 gallons of diesel fuel). Therefore, using an electric-powered crane or excavator to offload dredge material would reduce the total diesel energy consumption to approximately 17,300 gallons. The commercial transload facility located in the LDW, the Duwamish Reload Facility, is currently using electric power for transloading operations off of barges. Selection of this transload facility by the contractor could eliminate fuel consumption and substantially reduce associated air emissions for the offloading portion of the transloading process (but would not affect the tugboat fuel consumption).

### *7.2.2 Marine Vessel Electrification*

In addition to electrifying land-based construction equipment, contractors are also beginning to evaluate electrifying water-based dredge equipment. In 2021, the Port of Long Beach completed a 10-year-long, approximately $1.5 billion, electrification project at the Long Beach Container Terminal at Middle Harbor and is now able to conduct nearly all operations (including maintenance dredging) using electricity (https://polb.com/port-info/news-and-press/port-reaches-milestone-at-long-beach-container-terminal-08-20-2021/).[17] To supply the electrical power required by the Long Beach Container Terminal, the Port of Long Beach installed four electrical substations capable of delivering shore power to nearby vessels. The installation of these substations took more than 4 years and cost approximately $185 million. This has resulted in overall air emissions reductions, cheaper operating/maintenance costs, and downtime optimization (i.e., no need for refueling and less maintenance) during in-water construction activities. Currently there are no substations along the

[17] Website accessed in May 2022.

LDW upper reach capable of delivering sufficient electrical power to perform electric dredging, and it is assumed at least two substations or equivalent temporary power drops would be needed to potentially allow for electric dredging in the entire LDW upper reach area.

As part of the survey among local marine construction contractors discussed in Section 4.2, each contractor was asked about the potential for the conversion of their existing diesel-powered equipment into electric-powered. A summary of challenges and concerns identified follows:

- No current availability of electric-powered dredges in Washington State, so equipment would be required to be either:
  - Retrofitted (with an estimated average cost of $200,000 per piece of equipment)
  - Shipped from southern California (with an estimated mobilization cost of $200,000 per piece of equipment)
  - Purchased new (with an estimated cost of $1,000,000 per piece of equipment)
- Additional capital investment for ancillary equipment required to support electric-powered dredging would be needed:
  - Procurement of electric cable, cable reel, transformers, protective housing for cable (with a total estimated cost between $200,000 and $400,000)
  - Development of infrastructure consisting of multiple electric terminals (with an estimated cost between $100,000 and $300,000, per terminal location); costs estimated in coordination with the local electric utility (Seattle City Light)
- Specific electric equipment technical and logistical requirements and considerations limit the implementability of electric dredging and/or could delay completion of the remedial action in the upper reach:
  - Electric dredges are likely limited to a 1-mile radius around the electric terminal; ideally power sources would be located on both sides of the river to cover all potential dredging areas
  - Battery-powered equipment currently has limited reliability and does not supply enough active time to be feasible (maximum of 4 hours capacity) without multiple redundant equipment dedicated to a single task
  - Management of electric tether (i.e., electric cable connecting shore power to the dredge):
    - May add up to 20% additional downtime on construction activities as reeling of the cable is an intensive activity, when moving from one dredging location to another, and contractors may be unfamiliar with the equipment
    - Additional barge, tugboat, and deckhands required for the additional tether-related activities

        - Electric tether would be ideally placed along the shoreline; floating cable across the LDW is an option, but would necessarily require protective housings, adding additional cost, and complexity/logistics/coordination for LDW navigation
    - Shallow water presents increased risk of damage to electric cable
    - High level of coordination is required for vessel traffic and tribal fishing because all electric dredging equipment (dredge, cable, and additional vessels and equipment for the additional tether-related activities) will block or partially block navigation areas within the LDW. Given the many users navigating the LDW, this level of coordination may not be feasible or fully effective to prevent accidents.
- Timing for implementation:
    - Local contractors and Seattle City Light identified a minimum lead time of approximately 1 year to be able to accommodate and implement electric dredges and required infrastructure in the Seattle area (including time for procurement and retrofitting of dredging equipment, electric terminal design and installation, etc.)
- Unproven technical feasibility with Pacific Northwest contractors; local contractors are unfamiliar and inexperienced with electric dredging operations
- Contracting, safety, and liability issues. Because electric dredging has not been implemented on a congested waterway analogous to the LDW, the ability to successfully bid such a project is unknown. Risks to waterway users may not be acceptable. Equitable sharing of risks and liabilities between the Contractor and Owner would be challenging.

Many of these challenges would require additional capital investment to purchase, develop, or retrofit existing equipment. Additional evaluations will continue to be carried forward during RD to assess the viability of electrification for sediment remediation in the LDW through the various construction activities. The feasibility of implementing electrical dredging also depends upon the timing when remedial action will occur. Because the upper reach design and overall anticipated implementation schedule are further along than those for the middle or lower reaches, electrical dredging may be more feasible for consideration for the latter two reaches.

### *7.2.3 Use of Biodiesel*

Biodiesel represents another potential renewable energy source. Biodiesel is a renewable, biodegradable alternative to standard diesel fuel that is made by mixing modified vegetable oils and diesel fuel. Because of the increasing interest in use of biodiesels in the early 2000s, EPA conducted a "comprehensive analysis of the emission impacts of biodiesel using publicly available data" (EPA 2002). For use in a conventional diesel engine, biodiesel must be mixed with conventional diesel fuel. Using a common biodiesel mixture of 20% biodiesel and 80% conventional diesel, the EPA emissions analysis measured reductions in PM (10.1%), hydrocarbons (21.1%), and CO (11.0%) and no change or an increase in $NO_X$ and $CO_2$ emissions. In addition, fuel efficiency is also expected to be reduced when using biodiesel, increasing operating equipment times. Therefore, no overall net emission reductions or environmental benefits are identified.

In addition to marginal improvements in emissions, biodiesel availability in the region is very limited. According to the U.S. Department of Energy's Alternative Fuels Data Center (https://afdc.energy.gov/), only one commercial fueling station supplies biodiesel within 100 miles of the project area (Dr. Dan's Alternative Fuel Werks, located near the Ballard neighborhood of Seattle). Because of the limited availability of biodiesel suppliers in the vicinity of the LDW and project site, biodiesel was not considered further as an alternative energy source because the emissions generated to supply and deliver biodiesel to the project site would exceed the benefits of using biodiesel itself.

### *7.2.4 Conclusions*

Section 9.4 presents the potential BMPs that could be appliable to the various construction activities of the LDW upper reach sediment remedy and help reduce consumption of diesel-powered energy. In addition to the BMPs listed in Section 9.4, the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012) identifies the following renewable energy sources that can be considered in place of diesel fuel:

- Use of biodiesel in place of diesel for heavy equipment use or transportation only if local supply of biodiesel is made largely available in the near future in the vicinity of the project site
- Voluntary purchase of renewable electricity from an electricity provider in the form of a "green pricing" or "green marketing" product
- Voluntary purchase of renewable electricity through the purchase of renewable energy certificates

# 8 Green Remediation Core Element 5: Protection of Land and Ecosystems

The protection of land and the ecosystem is another important aspect of green remediation. Ecosystems have physical, biological, and chemical elements that facilitate the transfer and storage of materials and energy through the environment. The ROD (EPA 2014) describes the criteria to define the areas that are considered habitat for compliance with Section 404 of the Clean Water Act (CWA) and Section 7 of the Endangered Species Act (ESA).

Per the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012), this green remediation core element 5 involves minimizing degradation and/or enhancing the ecology of the project (the LDW upper reach) and other affected areas, through a qualitative description of the effects of the sediment remedy on land and ecosystems. BMPs provide tools for preserving existing wildlife habitat during remediation and accelerating the beneficial reuse of previously degraded land to enhance biodiversity following remediation actions.

The LDW upper reach sediment remedy will primarily be implemented from water-based vessels, but limited excavation of intertidal areas and banks may require land-based excavation equipment, land access, and specific staging areas to manage the excavated material (see Section 10.2.2); in those cases, clearing and grubbing of existing vegetation will be needed. In addition, an on-site upland staging area may be necessary to stockpile clean placement material or as a location to move equipment from the uplands into the water. For the protection of land, selection of an upland staging area (if required) and transloading facility should be limited to areas already developed for industrial use, to avoid clearing trees and other potential habitat.

As with all in-water projects, work is restricted to specific windows designed to minimize impacts on the aquatic ecosystem. Approved in-water construction activities will occur during fish windows designated for the LDW (generally from October through February) to protect threatened or endangered species under the ESA.

In summary, this element is already addressed by Section 11.6 of the BODR, in which an evaluation of potential impacts to all habitat types, including ROD-defined "habitat areas" (EPA 2014), from implementation of remedial activities will be conducted to comply with the CWA Section 404 and Section 7 of the ESA. The design for the upper reach will seek to maintain or improve habitat to the extent practicable. If it is determined that the existing habitat cannot be maintained or improved after RD for all three reaches of the LDW, a draft and final Compensatory Mitigation Plan will be included in the RD submittals for the lower reach. Section 9.5 of this appendix presents additional potential BMPs that could be applicable to the various construction activities of the upper reach sediment remedy and help in protecting land and ecosystems.

# 9 Implementation Approach: Best Management Practices

This section presents a comprehensive list of potential BMPs that might be applicable to the five green remediation core elements identified the *Superfund Green Remediation Strategy (*EPA 2010) in relation to the upper reach sediment remedy and its anticipated construction activities. Potential applicable BMPs, consistent with the Intermediate (60%) RD, are described in the following sections.

BMPs will be prescribed in the specifications at the Pre-Final (90%) RD deliverable, either as requirements or as additional potential practices and procedures to promote and encourage a green and sustainable remedy. BMPs will consider the availability of more advanced technologies and materials, for feasibility and implementability of greener practices into the sediment remedy, and in conjunction with procurement restrictions. The contractor will have inherent motivation to select other specific BMPs listed in this section in cases where such BMPs will increase efficiency and reduce cost and therefore have an appropriate return on investment that justifies their use.

## 9.1 BMPs for Air Pollutant Emission Reduction

The *Green Remediation Best Management Practices: Clean Fuel & Emission Technologies for Site Cleanup* (EPA 2010b) establishes the following potential BMPs to reduce emissions of air pollutants during sediment remedy implementation:

- **Selection of Appropriately Sized Vehicles:** Selection of appropriately sized vehicles for the construction activity is key in reducing emissions of air pollutants. Using undersized equipment may result in longer construction durations, which translate into more fuel consumption and therefore increasing air emissions. Similarly, using oversized equipment may result in wasted fuel and associated higher air emissions.
- **Effective Operation and Maintenance:** To increase the efficiency of vehicles and construction equipment, the following BMPs are available:
  - Engine idling restrictions for construction equipment
  - Automatic shut-down devices programmed to cut an engine after a predetermined time limit (such as 3 minutes) unless engine operation is needed for intermittent activities
  - Preventive maintenance to ensure peak operating efficiency (e.g., engine tune-ups according with manufacturer recommendations, checking fuel tank for dirt/insects, keeping tight connections and moving parts well-lubricated, periodic replacement of filters in air and fuel systems, use of manufacturer's recommended grade of motor oil)
  - Changes in daily routines (e.g., selecting high-quality equipment lubricants made of biodegradable ingredients; cleaning up any spilled fuels immediately to avoid damage to vehicles or engine bodies; handling all materials used to absorb fuel spills in accordance with health and safety requirements and storing the material in

noncombustible containers; properly disposing or recycling spent materials or liquid waste such as tires, transmission or brake fluids, used oil and filters, wash-rack waste, coolant, and spent solvent; simple changes in driving techniques [such as avoiding rapid acceleration, braking, and excessive speeds, and removing unneeded items in a vehicle])
  - Effective fleet management (e.g., planning to minimize fuel consumption through efficient transportation routes, transfer of only full loads, selection of appropriately sized vehicles, and low-carbon commuting and travel by workers)
- **Advanced Diesel Technologies:** Clean diesel technologies applied to on-road and nonroad (i.e., off-road) vehicles can significantly reduce diesel pollution created during remediation. As discussed in Section 4.2, the Pre-Final (90%) RD will establish specification requirements (i.e., minimum tier level required) for the contractor to reduce air emissions during sediment remedy implementation. Diesel engines tend to last longer than gasoline engines and are commonly retrofitted with a form of advanced exhaust after treatment to reduce emissions. Forms of advanced technology are diesel oxidation catalysts, diesel particulate filters, partial diesel particulate filters, and selective catalytic reduction.
- **Alternative Fuels:** The use of biofuels and biodiesel blends provides opportunities for reducing PM and sulfur dioxide ($SO_2$) emissions.[18]
- **Fuel Additives:** Additives can enhance fuel performance and often result in improved fuel economy and lower air emissions (e.g., emulsified diesel).
- **Fuel-Efficient or Alternative-Fuel Vehicles:** The following are options for fuel-efficient or alternative-fuel vehicles:
  - Replacement of aging vehicles with newer ones operated by more fuel-efficient engines or relying on alternative fuel can significantly reduce fossil fuel consumption and associated air emissions.
  - Deploying vehicles with higher fuel efficiency for both on-site and off-site activities should also lead to lower fuel costs for site cleanup.
  - Alternative vehicles include those using electric, hybrid gasoline/electric, or compressed natural gas fuel systems.

## 9.2 BMPs for Water Use

The *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA 2008a) and *Green Remediation Best Management Practices: Excavation and*

[18] As of 2010, the use of ultra-low sulfur diesel is a requirement for all nonroad and all new on-road diesel-powered vehicles and equipment with engine ratings of 50 horsepower or more, according to the *Green Remediation Best Management Practices: Clean Fuel & Emission Technologies for Site Cleanup* (EPA 2010b).

*Surface Restoration* (EPA 2019) establish the following potential BMPs for water use during remedy implementation:

- **Minimizing Water Consumption:** Any construction activity should minimize freshwater and potable water consumption (e.g., using native vegetation requiring little or no irrigation or using high-efficiency water fixtures, valves, and piping).
- **Maximize Water Reuse:** Any construction activity should maximize water reuse during daily operations and treatment processes.

As discussed previously in Section 5, water use is minimal during remedy implementation, so no specific BMPs apply.

BMPs aimed to protect water quality during dredging operational activities are described in detail in Section 11.1 of the BODR.

## 9.3 BMPs for Use of Materials and Waste Generation Reduction

BMPs intended to reduce the use of raw materials and waste generation will be established in consideration of procurement restrictions (i.e., the implementing entity could be a public entity). Some of the BMPs may be noncompetitive and therefore not acceptable for project implementation (e.g., selection of a greener supplier or specific greener products).

The *Green Remediation Best Management Practices: Materials and Waste Management* (EPA 2013) establishes the following potential BMPs to reduce waste generation and the use of virgin materials during remedy implementation:

- **Purchase of Greener Products:** The incorporation of greener products should begin during planning stages of the cleanup, to facilitate sustainable materials management[19] during construction. The following BMPs are available:
  - Choose local material suppliers where opportunities are available and appropriate (i.e., a material that is required and meets the specifications) to minimize fuel consumption associated with delivery (if allowed under procurement rules).
  - Choose suppliers that will take back unused materials.
- **Promote Material Reuse and/or Recycling:** The following BMPs are available during remedy implementation to promote material reuse and recycling:
  - Use reconstituted reactive media whenever feasible (e.g., regenerated rather than virgin GAC).
  - Use non-virgin and/or locally sourced backfill, sand, and armor materials (e.g., beneficial use) provided that gradation and chemical quality criteria can be ensured.

[19] The *Green Cleanups Contracting and Administrative Toolkit* (EPA 2015b) is useful EPA guidance, which includes sample procurement and contract language and criteria for sustainable materials management.

- Salvage and sort clean materials with potential value for on-site reuse (such as marina docks or other structural elements that must be moved), recycling (e.g., metal, concrete).

## 9.4 BMPs for Energy Use Reduction and Renewable Energy Promotion

The *Green Remediation Best Management Practices: Integrating Renewable Energy into Site Cleanup* (EPA 2011a) and *Green Remediation Best Management Practices: Integrating Renewable Energy* (EPA 2022) establishes the following potential BMPs to reduce energy use and maximize the use of renewable energy during remedy implementation:

- **Assessing and Optimizing Energy Use:** To the extent possible, replace aging equipment with newer models meeting higher energy conservation standards or utilizing alternative energy sources (e.g., using electric-powered equipment in place of conventional diesel equipment).
- **Maximizing Energy Efficiency and Monitoring Energy Demand:** General BMPs for energy conservation and efficiency include the following:
  - Follow equipment vendor recommendations for routine maintenance, conduct periodic inspections, and quickly repair/upgrade industrial equipment such as fans, pumps, air compressors, and others when needed.
  - Track energy consumption through tools such as plug-in meters and whole-system meter devices.

## 9.5 BMPs for Land Resource/Ecosystem Protection

Section 11.6 of the BODR presents some examples of design measures to offset aquatic habitat modifications (areas defined as above -10 feet mean lower low water) that may be incorporated into the LDW upper reach sediment remedy to the extent practicable, and for compliance with the ROD (EPA 2014), Section 404 of the CWA, and Section 7 of the ESA. Additional BMPs for the protection of land resources and ecosystems will be presented in the forthcoming *Biological Assessment*.

The *Green Remediation Best Management Practices: Excavation and Surface Restoration* (EPA 2019) and the *Ecosystem Services at Contaminated Site Cleanups* (EPA 2017) establish the following additional BMPs for the protection of land resources and ecosystems:

- **Safeguarding Land and Ecosystems**
  - Restrict machinery, vehicle, and worker traffic to well-defined corridors that are minimally obtrusive and to minimize soil compaction and land disturbance during site activities.
  - Include design work zones, traffic plans, and construction phases to minimize or avoid habitat disruption.

   - Avoid removing trees in staging areas/uncontaminated zones, to the extent practicable.
- **Site Preparation and Land Restoration**
   - Restore and/or maintain habitat in ways that mirror existing general conditions.

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# Tables

**Table L-1**
**Baseline and Local Average Market Conditions and Equipment Assumptions for Air Emissions**

| Activity | Equipment type | Production Rate | Assumed Distribution of Equipment Based on EPA's Tier System[1] (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Baseline Conditions[2] | | | Local Average Market Conditions[3] | | |
| | | | Pre-Tier | Tier 2 | Tier 4 | Pre-Tier | Tier 2 | Tier 4 |
| Site Preparation | Tug Boat (800 HP) | N/A | 100% | 0% | 0% | 100% | 0% | 0% |
| Structural Work | Crane (150-ton) | 25 piles per day/77 days of work | 30% | 70% | 0% | 30% | 30% | 40% |
| | Push Boat (800 HP) | 25 piles per day/77 days of work | 100% | 0% | 0% | 100% | 0% | 0% |
| | Work Boat (Two-stroke) | 25 piles per day/77 days of work | 100% | 0% | 0% | 100% | 0% | 0% |
| Sediment Dredging | Crane (150-ton) | Ranging from 700 to 1,100 cy per day | 30% | 70% | 0% | 30% | 30% | 40% |
| | Hydraulic Excavator (180 HP) | Ranging from 500 to 700 cy per day | 0% | 100% | 0% | 0% | 80% | 20% |
| | Push Boat (800 HP) | Linked to crane/excavator | 100% | 0% | 0% | 100% | 0% | 0% |
| | Work Boat (Two-stroke) | Linked to crane/excavator | 100% | 0% | 0% | 100% | 0% | 0% |
| Sediment Transloading, Upland Transportation, and Disposal [4] | Tug Boat (3,000 HP) | N/A | 100% | 0% | 0% | 100% | 0% | 0% |
| | Offloading Crane (100-ton) | 1,100 cy per day | 0% | 100% | 0% | 0% | 70% | 30% |
| | Front-end Loader (Rough Terrain Forklift) | Linked to crane | 0% | 100% | 0% | 0% | 50% | 50% |
| | Truck (20-ton Dump Truck) [5] | N/A | 0% | 100% | 0% | N/A | N/A | N/A |
| | Rail (Locomotive andTrain) | N/A | 0% | 100% | 0% | 0% | 0% | 100% |
| Material Transportation and Placement | Truck (20-ton Dump Truck) [6] | N/A | 0% | 100% | 0% | 0% | 0% | 100% |
| | Truck (20-ton Freight Truck) [7] | N/A | 0% | 100% | 0% | 0% | 0% | 100% |
| | Rail (Locomotive+Train) | N/A | 0% | 100% | 0% | 0% | 0% | 100% |
| | Tug Boat (3,000 HP) | N/A | 100% | 0% | 0% | 100% | 0% | 0% |
| | Crane (150-ton) | Ranging from 1,000 to 1,100 cy per day | 30% | 70% | 0% | 30% | 30% | 40% |
| | Hydraulic Excavator (180 HP) | Ranging from 700 to 800 cy per day | 0% | 100% | 0% | 0% | 80% | 20% |
| | Push Boat (800 HP) | Linked to crane/excavator | 100% | 0% | 0% | 100% | 0% | 0% |
| | Work Boat (Two-stroke) | Linked to crane/excavator | 100% | 0% | 0% | 100% | 0% | 0% |
| Surveys, Confirmational Sediment Sampling, and Environmental Monitoring | Work Boat (Two-stroke) | N/A | 100% | 0% | 0% | 100% | 0% | 0% |

**Table L-1**
**Baseline and Local Average Market Conditions and Equipment Assumptions for Air Emissions**

Notes:
1. The EPA "Tier System" emission standards for each tier are specific to the type of equipment (on-road vehicles and non-road equipment/engines), the year of manufacture, and the engine power. Pre-Tier engines are those manufactured prior to 1996. Tier 1 engines are those manufactured between 1997 and 2005. Tier 2 engines are those manufactured between 2001 and 2010. Tier 3 are those manufactured between 2006 and 2011. Tier 4 engines are those manufactured in 2008 and later.
2. For the purposes of defining the baseline conditions, no construction equipment was assumed to be considered Tier 1 nor Tier 3. Baseline conditions are presented for comparative purposes.
3. For the purposes of defining the local average market conditions for the Intermediate (60%) RD Green Remediation Evaluation and Implementation Approach, engine tier distribution of construction equipment was assumed based on local marine construction contractor survey. In addition, no construction equipment was identified by the survey to be considered Tier 1 nor Tier 3.
4. The assumption of a disposal facility in Oregon is only for the purposes of the Green Remediation Evaluation and Implementation Approach at 60% RD. The contractor will be responsible for identifying and proposing the actual disposal facility in the RAWP.
5. Truck transportation of dredge sediment material from onshore offloading facility to an upland intermodal facility assumed to apply only to the baseline conditions scenario.
6. Truck transportation of clean materials assumed to be from a local quarry to an onshore staging area (outside of the LDW upper reach).
7. The assumption of acquiring GAC from a vendor in Richland, WA is only for the purposes of the Green Remediation Evaluation and Implementation Approach at Intermediate (60%) RD. The contractor will be responsible for identifying and proposing the actual GAC vendor and source in the RAWP.
8. The air emissions inventory for this Green Remediation Evaluation and Implementation Approach was based entirely on tracking fossil fuel consumption (primarily diesel fuel with 15 ppm sulfur content [ultra-low sulfur diesel]).

cy: cubic yard
EPA: U.S. Environmental Protection Agency
HP: Horsepower
LDW: Lower Duwamish Waterway
N/A: not applicable
RAWP: Remedial Action Work Plan
RD: Remedial Design

**Table L-2**
**General Inputs for Air Emission Calculations**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Equipment Uptime | Equipment Quantity | Total Daily Diesel Usage (gal/day) | Shift Duration (hr) | Production Rate (quantity/day) | One-way Distance (miles) | Quantity Units | Quantity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SITE PREPARATION*** | | | | | | | | | | | |
| **Equipment Mobilization/Demobilization (8 hours/day)** | | | | | | | | | | | |
| | Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | Assume mobilization/demobilization of 2 derrick rigs and 3 material barges. Assume 8 hrs/day for 4 days per construction season. | 0.2 | 5 | 225 | 8 | 1 | na | construction season | 3 |
| ***STRUCTURAL WORK*** | | | | | | | | | | | |
| **Timber and Steel Pile Removal and Replacement (10 hrs/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume pile removal or replacement occurs at 25 piles/day. | 0.7 | 1 | 112 | 10 | 25 | na | # piles | 26 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 25 | na | # piles | 26 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 25 | na | # piles | 26 |
| **Temporary Float Dismantle/Relocation/ Reinstallation, Temporary Shoring of Bulkheads, Outfall Work, and Debris Removal** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume a total of 81 days including 24 days for upland excavation, 5 days for ground restoration, 16 days to install temporary tieback of bulkheads, 15 days for temporary relocation of floats, 4 days for pipe protection, and 12 days for apron/ bank protection. Assume 5 days for identified debris removal. | 0.7 | 1 | 112 | 10 | 1.00 | na | # of days | 81 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1.00 | na | # of days | 81 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 1.00 | na | # of days | 81 |
| ***SEDIMENT DREDGING*** | | | | | | | | | | | |
| **Open-water Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 1,100 | na | cy sediment | 64,374 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1,100 | na | cy sediment | 64,374 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 1,100 | na | cy sediment | 64,374 |
| **Nearshore Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 700 | na | cy sediment | 11,458 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 700 | na | cy sediment | 11,458 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 700 | na | cy sediment | 11,458 |
| **Restricted Access Dredging (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 140 | 10 | 500 | na | cy sediment | 1,670 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 500 | na | cy sediment | 1,670 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 500 | na | cy sediment | 1,670 |
| **Contingency Redredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 700 | na | cy sediment | 10,071 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 700 | na | cy sediment | 10,071 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 700 | na | cy sediment | 10,071 |
| **Shoreline/ Bank Excavation (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 140 | 10 | 600 | na | cy sediment | 19,892 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 600 | na | cy sediment | 19,892 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 600 | na | cy sediment | 19,892 |

**Table L-2**
**General Inputs for Air Emission Calculations**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Equipment Uptime | Equipment Quantity | Total Daily Diesel Usage (gal/day) | Shift Duration (hr) | Production Rate (quantity/day) | One-way Distance (miles) | Quantity Units | Quantity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | | | | | | | | | | | |
| **Mechanical Offloading (10 hours/day)** | | | | | | | | | | | |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | Assume each work day contains one 10 hr-shift. Assume bulking factor of 5% for mechanical offloading. Assume tug boat transports dredge sediment to an offloading area 5 mi away (one-way). | 0.2 | 1 | na | 10 | na | 5 | ton | 172,052 |
| | 100-ton Crane | Diesel Cranes | | 0.7 | 1 | 112 | 10 | 1,100 | na | cy sediment | 113,198 |
| | Front-end Loader | Diesel Rough Terrain Forklifts | | 0.8 | 1 | 48 | 10 | 1,100 | na | cy sediment | 113,198 |
| **Upland Transportation and Disposal (10 hours/day)** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume dredged sediments trucked from LDW upper reach to intermodal facility in South Seattle or Tukwila. Assume 10 miles each way (20 miles round trip). Applicable only to the baseline conditions. | na | 1 | na | 10 | na | 20 | ton | 172,052 |
| | Rail | na | Assume sediment disposal by rail to landfill in Arlington, OR for 300 mi (one-way). | na | 1 | na | 10 | na | 300 | ton | 172,052 |
| | | | | | | | | | | | |
| ***MATERIAL TRANSPORTATION AND PLACEMENT*** | | | | | | | | | | | |
| **Transportation of Clean Materials to LDW Upper Reach** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume sand, gravelly sand, light riprap and cement are transported 20 miles from quarry to onshore staging area by truck and 20 miles to LDW upper reach by barge. Includes material placement quantity for Upper Reach and cPAH-only RAA remediation activities. | na | 1 | na | 10 | na | 20 | ton | 112,262 |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | | 0.2 | 1 | na | 10 | na | 20 | ton | 112,262 |
| | Truck (20-ton Freight Truck) | Diesel Onroad Trucks | Assume granular activated carbon (GAC) is transported 150 miles by truck from Ridgefield, WA vendor to LDW upper reach (one-way). | na | 1 | na | 10 | na | 150 | ton | 5.1 |
| **Open-water Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 1,100 | na | cy sand | 17,971 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1,100 | na | cy sand | 17,971 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 1,100 | na | cy sand | 17,971 |
| **Open-water Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 1,100 | na | cy gravelly sand | 17,662 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1,100 | na | cy gravelly sand | 17,662 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 1,100 | na | cy gravelly sand | 17,662 |
| **Nearshore Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/ day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 1,000 | na | cy sand | 3,342 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1,000 | na | cy sand | 3,342 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 6 | 10 | 1,000 | na | cy sand | 3,342 |
| **Nearshore Placement of Gravelly Sand for Backfill and Habitat Layer (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 1,000 | na | cy gravelly sand | 10,460 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 1,000 | na | cy gravelly sand | 10,460 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 1,000 | na | cy gravelly sand | 10,460 |
| **Capping (Gravelly Sand for Chemical Isolation Layer) (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 600 | na | cy gravelly sand | 1,176 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 600 | na | cy gravelly sand | 1,176 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 600 | na | cy gravelly sand | 1,176 |

**Table L-2**
**General Inputs for Air Emission Calculations**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Equipment Uptime | Equipment Quantity | Total Daily Diesel Usage (gal/day) | Shift Duration (hr) | Production Rate (quantity/day) | One-way Distance (miles) | Quantity Units | Quantity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Capping (Light Riprap for Erosion Protection Layer) (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 112 | 10 | 500 | na | cy light riprap | 1,176 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 500 | na | cy light riprap | 1,176 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 500 | na | cy light riprap | 1,176 |
| **Restricted Access Placement of Sand for Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. Includes material placement quantity for Upper Reach site and cPAH-only RAA remediation activities. | 0.7 | 1 | 140 | 10 | 700 | na | cy sand | 1,234 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 700 | na | cy sand | 1,234 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 700 | na | cy sand | 1,234 |
| **Restricted Access Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 140 | 10 | 700 | na | cy gravelly sand | 35 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 700 | na | cy gravelly sand | 35 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 700 | na | cy gravelly sand | 35 |
| **Upland Placement of Sand for Residuals Management Cover, and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 140 | 10 | 800 | na | cy sand | 2,896 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 800 | na | cy sand | 2,896 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 800 | na | cy sand | 2,896 |
| **Upland Placement of Gravelly Sand for Backfill, and Amended Cover (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.7 | 1 | 140 | 10 | 800 | na | cy gravelly sand | 17,830 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.7 | 1 | 197 | 10 | 800 | na | cy gravelly sand | 17,830 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.2 | 1 | 3 | 10 | 800 | na | cy gravelly sand | 17,830 |
| ***SURVEYS*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one survey per day and each work day contains one 10 hr-shift. Assume a total of 252 survey events based on pre-construction (bathy and topo), post- dredge, post- placement, post-construction (bathy and topo), contractor progress surveys for the construction duration, and as-built survey. | 0.2 | 1 | 3 | 10 | 1.00 | na | surveys | 252 |
| ***CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONMENTAL MONITORING*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one water quality monitoring event per dredge day and each work day contains one 10 hr-shift. Assume 210 water quality monitoring events. Assume 23 confirmational sediment sampling events. | 0.2 | 1 | 3 | 10 | 1.00 | na | monitoring events | 233 |

Notes:
1. Quantities and production rates obtained from Appendix M (Opinion of Probable Cost).
2. Equipment and daily equipment operation rates assumed based on engineering best professional judgment and experience in similar sediment projects.
cy: cubic yard
LDW: Lower Duwamish Waterway
gal: gallon
HP: horsepower
hr: hour
na: not applicable
PB: push boat
SCC: Standard Classification Code
WB: work boat
ZVI zero valent iron

**Table L-3**
**Equipment Type and Fuel Usage Assumptions per Equipment Type**

| Equipment Type | Equipment Uptime (%) | Equipment Daily Use – Work Day (hours/day) | Fuel Consumption Rate (gal/hour) | Daily Diesel Fuel Usage (gal/day) |
|---|---|---|---|---|
| Hydraulic Excavator | 70% | 10 | 20 | 140 |
| Front-end Loader | 80% | 10 | 6 | 48 |
| 150-ton Crane | 70% | 10 | 16 | 112 |
| 100-ton Crane | 70% | 10 | 16 | 112 |
| Tug Boat (3,000 HP) | 20% | 10 | 40 | 80 |
| Tug Boat (800 HP) | 20% | 8 | 28 | 45 |
| Push Boat | 70% | 10 | 28 | 197 |
| Work Boat | 20% | 10 | 1.5 | 3 |

Notes:
1. Equipment uptimes (effective operation time) and fuel consumption rates were from local contractors in Washington State and estimated for each equipment based on engineering best professional judgment and experience on other similar sediment projects.
2. Daily use of equipment is based on assumptions provided in Appendix M (Opinion of Probable Cost).
3. Daily diesel fuel usage is calculated as fuel consumption rate (gal/hour) x equipment uptime (%) x work day (hours/day).
4. Daily diesel fuel usage is calculated for a single piece of equipment. Assumed number pieces of equipment is presented in Table L-2.
gal/day: gallon/day
gal/hour: gallon/hour
HP: horsepower

**Table L-4**
**Rail Transportation Assumptions**

| Parameter | Pre-Tier | Tier 2 | Tier 4 | Unit | Comments/Reference |
|---|---|---|---|---|---|
| Diesel fuel economy for train/locomotive | 470 | | | ton-mi/gal | National average fuel consumption rate of 470 ton-miles/gallon based from data collected by the Association of American Railroads (Pg. 2 of 'Freight Railroads and Climate Change"). |
| Emission Factors | | | | | Source for Emission Factors (HC, CO, $NO_x$ and $PM_{10}$): "Locomotives Exhaust Emissions Standards" (March 2016; Office of Transportation and Air Quality [OTAQ]; EPA- 420-B-16-024)<br>Emission factors for rail transportation correspond to Tier 4 locomotives, manufactured after 2015. Equipment is upgraded every 15 years and this is a reasonable assumption by the time the Lower Duwamish Waterway project is implemented. Source: "Control of Emissions from Idling Locomotives" (December 2013; Office of Transportation and Air Quality [OTAQ]; EPA- 420-F-13-050)<br>Source for Conversion Factors: EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025)<br>In order to use emission factors in g/gal, as conversion factor of 20.8 bhp-hr/gal (for Large Line Haul and Passenger Locomotives) is available in Table 3. VOC emissions are 1.053 times HC emissions and $PM_{2.5}$ emissions are 0.97 times $PM_{10}$ emissions (pg.4).<br>$SO_2$ emissions are dependent upon fuel properties and not engine properties (pg.5):<br>$SO_2$ (g/gal) = (fuel density) x (conversion factor) x (64 g $SO_2$/32 g S) x (S content of fuel)<br>The current density of diesel fuel is 6.76 lbs/gal (3,066 g/gal) (https://www.atlasoil.com/media/documents/safety-data-sheets/Marathon/Marathon_No-2_Ultra-Low-Sulfur-Diesel-Dyed-15-PPM-Sulfur-Max.pdf).<br>The current sulfur content of diesel fuel is 15 ppm (ultra-low-sulfur diesel fuel; https://www.epa.gov/diesel-fuel-standards/diesel-fuel-standards-and-rulemakings).<br>The fraction of fuel sulfur converted to $SO_2$ is 97.8% (pg.5). Therefore, $SO_2$ (g/gal) = (3,066 g/gal) x (0.978) x (64 g $SO_2$ / 32 g S) x (15e-6) = 0.089 g/gal<br>The $CO_2$ emission factor is 10.21 kg $CO_2$/gal, as in Table 8 - "Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution" from Emission Factors for Greenhouse Gas Inventories April 2022). |
| Hydrocarbons (HC) | 1.0 | 0.3 | 0.14 | g/bhp-hr | |
| | 20.8 | 6.2 | 2.91 | g/gal | |
| Volatile Organic Compounds (VOCs) | 1.1 | 0.3 | 0.15 | g/bhp-hr | |
| | 21.9 | 6.6 | 3.07 | g/gal | |
| Carbon Monoxide (CO) | 5.0 | 1.5 | 1.5 | g/bhp-hr | |
| | 104.0 | 31.2 | 31.20 | g/gal | |
| Nitrous Oxides ($NO_X$) | 9.5 | 5.5 | 1.3 | g/bhp-hr | |
| | 197.6 | 114.4 | 27.04 | g/gal | |
| Particulate Matter 10 µm ($PM_{10}$) | 0.2 | 0.1 | 0.03 | g/bhp-hr | |
| | 4.6 | 2.1 | 0.62 | g/gal | |
| Particulate Matter 2.5 µm ($PM_{2.5}$) | 0.2 | 0.1 | 0.0291 | g/bhp-hr | |
| | 4.4 | 2.0 | 0.61 | g/gal | |
| Sulfur Dioxide ($SO_2$) | 0.09 | | | g/gal | |
| Carbon Dioxide ($CO_2$) | 10,210 | | | g/gal | |
| Distance from intermodal facility to Subtitle D disposal landfill facility (transport of dredged sediment) | 300 | | | miles | Dredged sediment is assumed to be transferred from an intermodal facility to an off-site disposal landfill facility, assumed to be located in Arlington, Oregon. |

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
µm: micron
bph: usable power
EPA: U.S. Environmental Protection Agency
g: gram
gal: gallon
hr: hour
kg: kilogram
L: liter
lb: pound
mi: mile
ppm: parts per million

**Table L-5a**
**Nonroad Truck Transportation Assumptions**

| Parameter | Pre-Tier | Tier 2 | Tier 4 | Unit | Comments/Reference |
|---|---|---|---|---|---|
| Dump Truck | | | | | Assumed truck capacity and fuel consumption based on engineering best professional judgement and experience on other similar sediment projects. |
| Average power | 600 | | | hp | |
| Capacity | 20 | | | tons | |
| Fuel consumption | 13 | | | gal/hr | |
| $CO_2$ emission factor for trucks | 0.21 | | | kg $CO_2$/ton-mile | Source: Table 8- "Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution" from Emission Factors for Greenhouse Gas Inventories April 2022. |
| Diesel fuel economy for trucks | 130 | | | ton-mile/gallon | Calculated as 27.46 kg/gal / 0.211 kg/ton-mi ≈ 130 ton-mile/gal |
| Emission Factors | | | | | Source: "Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES3.0.2" (EPA-420-R-21-021, September 2021)<br>$PM_{2.5}$ emissions are 0.97 times $PM_{10}$ emissions (Pg. 35)<br>$CO_2$ = [BSFC (lb/hp-hr) * 453.6(g/lb) -HC (g/hp-hr)] * 0.87 * (44/12) (Pg.34)<br>$SO_2$ (g/hp-hr) = [BSFC(lb/hp-hr) * 453.6(g/lb)* (1 -soxcnv) -HC(g/hp-hr)] * 0.01 * soxdsl(%) * 2 (Pg.34)<br>BSFC = 0.408 (lb/hp-hr; 0-100 HP) and 0.367 (lb/hp-hr; >100 HP); 0.87 = carbon mass fraction of diesel; 44/12 = ratio of CO2 mass to carbon mass; soxcnv = 0.02247 which is the fraction of fuel sulfur converted to direct PM; 0.01 = conversion factor from weight percent to weight fraction and, 2 = g $SO_2$ /g sulfur<br>VOC emissions are 1.053 times HC emissions<br>Reference: EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025). |
| Hydrocarbons (HC) | 35.3 | 8.7 | 0.571 | g/gal | |
| Volatile Organic Compounds (VOCs) | 37.2 | 9.1 | 0.601 | g/gal | |
| Carbon Monoxide (CO) | 140.2 | 68.9 | 11.112 | g/gal | |
| Nitrous Oxides ($NO_X$) | 435.1 | 212.9 | 59.867 | g/gal | |
| Particulate Matter 10 µm ($PM_{10}$) | 20.9 | 6.9 | 0.467 | g/gal | |
| Particulate Matter 2.5 µm ($PM_{2.5}$) | 20.2 | 6.6 | 0.453 | g/gal | |
| Sulfur Dioxide ($SO_2$) | 0.3 | 0.3 | 0.253 | g/gal | |
| Carbon Dioxide ($CO_2$) | 27,500 | 27,500 | 27,500 | g/gal | |
| Distance from LDW upper reach to intermodal facility (transport of dredged sediment for off-site disposal) | 20 | | | miles | Upland transport of dredged sediment for off-site disposal, by truck, from offloading facility to a nearby intermodal facility is a conservative assumption for the distance required for truck transportation from the LDW upper reach to the intermodal facility. |
| Distance from local quarry to onshore staging area (transport of clean materials for placement) | 20 | | | miles | Upland transport of clean material, by truck, is a conservative assumption for the distance required for truck transportation from the quarry to an onshore staging area in the LDW. |

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
2. In order to use emission factors in g/gal, the steady state factors are converted using the average horsepower of the specific equipment and the fuel consumption rate (gal/hr).
Emission factors (g/gal) = Emission Factors (g/hp-hr)*Equipment horsepower (HP)/ Fuel Consumption (gal/ hr)
µm: micron
BSFC: brake specific fuel consumption (lb/hp-hr)
EPA: U.S. Environmental Protection Agency
g: gram
gal: gallon
hp: horsepower
hr: hour
kg: kilogram
lb: pound
LDW: Lower Duwamish Waterway
mi: mile

**Table L-5b**
**Onroad Truck Transportation Assumptions**

| Parameter | Tier 2 | Tier 4 | Unit | Comments/Reference |
|---|---|---|---|---|
| Dump Truck | | | | |
| Average power | 600 | | hp | Assumed truck capacity and fuel consumption based on engineering best professional judgement and experience on other similar sediment projects. Source: "A Survey of Fuel Economy and Fuel Usage by Heavy-Duty Truck Fleets [(SWT-2016-12, October 2016)" |
| Capacity | 20 | | tons | |
| Fuel consumption | 7.3 | | miles/gallon | |
| $CO_2$ emission factor for trucks | 0.21 | | kg $CO_2$/ton-mile | Source: Table 8- "Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution" from Emission Factors for Greenhouse Gas Inventories April 2022. |
| Diesel fuel economy for trucks | 147 | | ton-mile/gallon | Calculated as 10.21 kg/gal / 0.211 kg/ton-mi ≈ 48 ton-mile/gal |
| Emission Factors | | | | Source: "Bureau of Transportation Statistics, National Transportation Statistics for 2021" Emission factors for HC, CO, NOx and PM 2.5 are from Table 4-43 (Pg. 282). Source: "Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES3.0.2" (EPA-420-R-21-021, September 2021) $PM_{2.5}$ emissions are 0.97 times $PM_{10}$ emissions (Pg. 35) $SO_2$ (g/hp-hr) = [BSFC(lb/hp-hr) * 453.6(g/lb)* (1 -soxcnv) -HC(g/hp-hr)] * 0.01 * soxdsl(%) * 2 (Pg.34) BSFC = 0.408 (lb/hp-hr; 0-100 HP) and 0.367 (lb/hp-hr; >100 HP); soxcnv = 0.02247, which is the fraction of fuel sulfur converted to direct PM; 0.01= conversion factor from weight percent to weight fraction and, 2 = g $SO_2$ /g sulfur VOC emissions are 1.053 times HC emissions Reference: EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025). |
| Hydrocarbons (HC) | 6.61 | 3.64 | g/gal | |
| Volatile Organic Compounds (VOCs) | 6.96 | 3.84 | g/gal | |
| Carbon Monoxide (CO) | 31.48 | 19.77 | g/gal | |
| Nitrous Oxides ($NO_X$) | 136.36 | 55.43 | g/gal | |
| Particulate Matter 10 µm ($PM_{10}$) | 6.16 | 2.18 | g/gal | |
| Particulate Matter 2.5 µm ($PM_{2.5}$) | 5.98 | 2.12 | g/gal | |
| Sulfur Dioxide ($SO_2$) | 0.40 | 0.40 | g/gal | |
| Carbon Dioxide ($CO_2$) | 10,210.00 | 10,210.00 | g/gal | |
| Distance from GAC vendor (Ridgefield, Washington) to LDW upper reach | 150 | | miles | For Intermediate (60%) RD, GAC is assumed to be transported from a vendor located in Ridgefield, WA to the LDW upper reach. |

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
2. In order to use emission factors in g/gal, the steady state factors are converted using the average horsepower of the specific equipment and the fuel consumption rate (gal/hr).
Emission factors (g/gal) = Emission Factors (g/hp-hr)*Equipment horsepower (HP)/ Fuel Consumption (gal/ hr)
µm: micron
BSFC: brake specific fuel consumption (lb/hp-hr)
EPA: U.S. Environmental Protection Agency
g: gram
GAC: granular activated carbon
gal: gallon
hp: horsepower
hr: hour
kg: kilogram
lb: pound
LDW: Lower Duwamish Waterway
mi: mile
RD: remedial design

**Table L-6**
**Barge Transportation Assumptions**

| Parameter | Pre-Tier | Tier 2 | Tier 4 | Unit | Comments/Reference |
|---|---|---|---|---|---|
| Tug/barge - Diesel Inboard/Sterndrive (3,000 HP) | | | | | Average fuel consumption of empty and fully loaded tug/barge: (15+85)/2 = 50, rounded down to 40 gal/hour in order to use NONROAD EPA emission factors.<br>Empty tug/barges typically consume 15 gal/hour.<br>Fully loaded tug/barges consume 85 gal/hour in Seattle area, derived from 1999 Puget Sound Clean Air Agency (www.pscleanair.org) document entitled "1999 TUGBOAT FUEL CONSUMPTION IN SEATTLE AREA"<br>http://www.epa.gov/ttn/chief/conference/ei11/poster/agyei.pdf |
| Average power | 3,000 | | | hp | |
| Fuel consumption | 40 | | | gal/hr | |
| $CO_2$ emission factor for diesel fuel | 10.21 | | | kg $CO_2$/gal | Source: Table 2 - "Mobile Combustion CO2" from Emission Factors for Greenhouse Gas Inventories April 2022) |
| $CO_2$ emission factor for boats | 0.041 | | | kg $CO_2$/ton-mile | Source: Table 8- "Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution" from Emission Factors for Greenhouse Gas Inventories April 2022. |
| Diesel fuel economy for boats | 968 | | | ton-mile / gallon | Calculated as 33.055 kg/gal / 0.041 kg/ton-mi ≈ 806 ton-mile/gal. |
| Emission Factors | | | | | Source: "Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES3.0.2" (EPA-420-R-21-021, September 2021)<br>PM2.5 emissions are 0.97 times PM10 emissions (Pg.35)<br>CO2 = [BSFC (lb/hp-hr) * 453.6(g/lb) -HC (g/hp-hr)] * 0.87 * (44/12) (Pg.34)<br>SO2 (g/hp-hr) = [BSFC(lb/hp-hr) * 453.6(g/lb)* (1 -soxcnv) -HC(g/hp-hr)] * 0.01 * soxdsl(%) * 2 (Pg.34)<br>BSFC = 0.408 (lb/hp-hr; 0-100 HP) and 0.367 (lb/hp-hr; >100 HP); 0.87 = carbon mass fraction of diesel; 44/12 = ratio of CO2 mass to carbon mass; soxcnv = 0.02247 which is the fraction of fuel sulfur converted to direct PM. Soxcnv is equal to 0.02247 for the Base- T4B technology types and 0.3 if PM< 0.1 g/hp-hr for Tier 4F; 0.01= conversion factor from weight percent to weight fraction and, 2 = g SO2 /g sulfur<br>VOC emissions are 1.053 times HC emissions (Pg.4) (EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025)) |
| Hydrocarbons (HC) | 51.0 | 12.5 | 2.63 | g/gal | |
| Volatile Organic Compounds (VOCs) | 53.7 | 13.2 | 2.76 | g/gal | |
| Carbon Monoxide (CO) | 202.5 | 57.3 | 9.83 | g/gal | |
| Nitrous Oxides ($NO_X$) | 628.5 | 307.5 | 170.85 | g/gal | |
| Particulate Matter 10 µm ($PM_{10}$) | 30.2 | 9.9 | 1.58 | g/gal | |
| Particulate Matter 2.5 µm ($PM_{2.5}$) | 29.2 | 0.4 | 0.39 | g/gal | |
| Sulfur Dioxide ($SO_2$) | 0.4 | 0.4 | 0.37 | g/gal | |
| Carbon Dioxide ($CO_2$) | 39,700 | 39,800 | 39,800 | g/gal | |
| Distance from LDW upper reach to offloading area (transport of dredge sediment) | 5 | | | miles | Dredged sediment is assumed to be transported by barge to an offloading area, which is assumed to be 5 miles from middle point of the LDW upper reach. |
| Distance from onshore staging area to LDW upper reach (transport of clean materials for placement) | 5 | | | miles | Sand, gravelly sand, gravel, and cobble are assumed to be transported by barge from onshore staging area to the LDW upper reach. |

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
2. In order to use emission factors in g/gal, the steady state factors are converted using the average horsepower of the specific equipment and the fuel consumption rate (gal/hr).
Emission factors (g/gal) = Emission Factors (g/hp-hr)*Equipment horsepower (HP)/ Fuel Consumption (gal/ hr)
µm: micron
BSFC: brake specific fuel consumption (lb/hp-hr)
EPA: U.S. Environmental Protection Agency
g: gram
gal: gallon
hp: horsepower
hr: hour
kg: kilogram
lb: pound
LDW: Lower Duwamish Waterway
mi: mile

**Table L-7**
**Air Emission Factors for Construction Equipment and Vehicles**

| Type of Vehicle/ Equipment Used | SCC Description | HP | Fuel Consumption Rate (gal/hour) | Pre-Tier Emission Factors (g/gal) | | | | | | | | Tier 2 Emission Factors (g/gal) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HC | VOCs | CO | $NO_X$ | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | $CO_2$ | HC | VOCs | CO | NOX | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | $CO_2$ |
| Work Boat | Two-stroke Outboard (WB) | 45 | 1.5 | 54.00 | 56.86 | 150.00 | 207.00 | 24.00 | 23.28 | 0.161 | 17,539 | 8.37 | 8.81 | 45.97 | 141.84 | 10.17 | 9.86 | 0.163 | 17,684 |
| Push Boat | Two-stroke Outboard (PB) | 875 | 28 | 21.17 | 22.30 | 84.07 | 260.94 | 12.52 | 12.14 | 0.151 | 16,438 | 5.20 | 5.48 | 23.79 | 127.67 | 4.11 | 3.99 | 0.152 | 16,519 |
| 100-ton and 150-ton Cranes | Diesel Cranes | 675 | 16 | 28.69 | 30.21 | 113.91 | 353.53 | 16.96 | 16.45 | 0.2051 | 22,312 | 7.05 | 7.42 | 55.98 | 172.97 | 5.57 | 5.40 | 0.2057 | 22,381 |
| Hydraulic Excavator | Diesel Excavators | 450 | 20 | 15.30 | 16.11 | 60.75 | 188.55 | 9.05 | 8.77 | 0.109 | 11,900 | 3.76 | 3.96 | 18.97 | 97.54 | 2.97 | 2.88 | 0.110 | 11,936 |
| Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | 875 | 28 | 21.17 | 22.30 | 84.07 | 260.94 | 12.52 | 12.14 | 0.151 | 16,468 | 5.20 | 5.48 | 23.79 | 127.67 | 4.11 | 3.99 | 0.152 | 16,519 |
| Telebelt | Diesel Other Material Handling Equipment | | 4 | 76.50 | 80.55 | 303.75 | 942.75 | 45.23 | 43.87 | 0.547 | 59,498 | 18.79 | 19.78 | 94.84 | 487.69 | 14.85 | 14.40 | 0.549 | 59,682 |
| Front-end Loader | Diesel Rough Terrain Forklifts | 238 | 6 | 26.92 | 28.34 | 106.88 | 331.71 | 15.91 | 15.44 | 0.192 | 20,935 | 12.23 | 12.88 | 29.61 | 158.33 | 5.23 | 5.07 | 0.193 | 20,981 |

**Table L-7**
**Air Emission Factors for Construction Equipment and Vehicles**

| Type of Vehicle/ Equipment Used | SCC Description | HP | Fuel Consumption Rate (gal/hour) | Tier 4 Emission Factors (g/gal) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | HC | VOCs | CO | NOX | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | $CO_2$ |
| Work Boat | Two-stroke Outboard (WB) | 45 | 1.5 | 4.08 | 4.30 | 12.24 | 82.86 | 0.81 | 0.79 | 0.105 | 17,698 |
| Push Boat | Two-stroke Outboard (PB) | 875 | 28 | 1.09 | 1.15 | 4.08 | 70.93 | 0.65 | 0.63 | 0.109 | 16,533 |
| 100-ton and 150-ton Cranes | Diesel Cranes | 675 | 16 | 0.46 | 0.49 | 9.03 | 48.64 | 0.38 | 0.37 | 0.2059 | 22,402 |
| Hydraulic Excavator | Diesel Excavators | 450 | 20 | 0.25 | 0.26 | 4.82 | 25.94 | 0.20 | 0.20 | 0.079 | 11,948 |
| Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | 875 | 28 | 1.09 | 1.15 | 4.08 | 70.93 | 0.65 | 0.63 | 0.109 | 16,533 |
| Telebelt | Diesel Other Material Handling Equipment | | 4 | 1.24 | 1.30 | 24.08 | 129.71 | 1.01 | 0.98 | 0.393 | 59,738 |
| Front-end Loader | Diesel Rough Terrain Forklifts | 238 | 6 | 0.44 | 0.46 | 8.47 | 45.64 | 0.36 | 0.35 | 0.138 | 21,019 |

**Table L-7**
**Air Emission Factors for Construction Equipment and Vehicles**

Notes:
1. Emission factors derived from "Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES3.0.2"(EPA-420-R-21-021, September 2021). Steady state factors derived from Table A-4 (Appendix A). Emissions factors are based on the equipment horsepower and Tier category.
2. Pre- Tier emission factors were assumed to be Tier 0. Emissions Factors for Tier 4 were the most conservative of the final emissions factors from Table A4. $PM_{2.5}$ emissions are assumed to 0.97 times $PM_{10}$ emissions (see Pg. 35).
CO2 (g/hp-hr) = [BSFC (lb/hp-hr) * 453.6(g/lb) -HC (g/hp-hr)] * 0.87 * (44/12); SO2 (g/hp-hr) = [BSFC(lb/hp-hr) * 453.6(g/lb)* (1 -soxcnv) -HC(g/hp-hr)] * 0.01 * soxdsl(%) * 2 (Pg. 34). BSFC = 0.408 (lb/hp-hr; 0-100 HP) and 0.367 (lb/hp-hr; >100 HP); 0.87 = carbon mass fraction of diesel; 44/12 = ratio of CO2 mass to carbon mass; soxcnv = 0.02247 which is the fraction of fuel sulfur converted to direct PM; 0.01= conversion factor from weight percent to weight fraction and, 2 = g SO2 /g sulfur.
VOC emissions are 1.053 times HC emissions (see Pg.4)
Reference: EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025).
3. Emission factors (g/gal) = Emission Factors (g/hp-hr)*Equipment horsepower (HP)/Fuel Consumption (gal/hr)

BSFC: brake-specific fuel consumption
CO: carbon monoxide
$CO_2$: carbon dioxide
gal: gallon
g: gram
HC: hydrocarbon
HP: horsepower
hr: hour
lb: pound
NOX: nitrogen oxides (NO and $NO_2$)
PB: push boat
PM: particulate matter
PM2.5: particulate matter less that 2.5 microns in diameter
PM10: particulate matter less than 10 microns in diameter
ppm: parts per million
SCC: Standard Classification Code
$SO_2$: sulfur dioxide
soxcnv: 0.2447 or 0.3 (fraction of fuel sulfur converted to direct PM)
soxdsl: 0.0015% (episodic weight percent of sulfur in nonroad ultra low sulfur [15 ppm] diesel fuel)
VOC: volatile organic compound
WB: work boat

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Pre-Tier - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***SITE PREPARATION*** | | | | | | | | | | | |
| **Equipment Mobilization/Demobilization (8 hours/day)** | | | | | | | | | | | |
| | Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | Assume mobilization/demobilization of 2 derrick rigs and 3 material barges. Assume 8 hrs/day for 4 days per construction season. | 0.0190 | 0.0200 | 0.0756 | 0.2346 | 0.0113 | 0.0109 | 0.0001 | 14.8 |
| | | | ***SUBTOTAL EMISSIONS - SITE PREPARATION*** | **0.019** | **0.020** | **0.076** | **0.235** | **0.011** | **0.011** | **0.00014** | **14.8** |
| ***STRUCTURAL WORK*** | | | | | | | | | | | |
| **Timber and Steel Pile Removal and Replacement (10 hrs/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume pile removal or replacement occurs at 25 piles/day. | 0.0033 | 0.0035 | 0.0133 | 0.0412 | 0.0020 | 0.0019 | 0.0000 | 2.6 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0043 | 0.0046 | 0.0172 | 0.0534 | 0.0026 | 0.0025 | 0.0000 | 3.4 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0002 | 0.0002 | 0.0005 | 0.0006 | 0.0001 | 0.0001 | 0.0000 | 0.1 |
| **Temporary Float Dismantle/Relocation/ Reinstallation, Temporary Shoring of Bulkheads, Outfall Work, and Debris Removal** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume a total of 81 days including 24 days for upland excavation, 5 days for ground restoration, 16 days to install temporary tieback of bulkheads, 15 days for temporary relocation of floats, 4 days for pipe protection, and 12 days for apron/ bank protection. Assume 5 days for identified debris removal. | 0.26 | 0.27 | 1.03 | 3.21 | 0.15 | 0.15 | 0.0019 | 202.4 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.34 | 0.36 | 1.34 | 4.16 | 0.20 | 0.19 | 0.0024 | 261.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0131 | 0.0138 | 0.0365 | 0.05 | 0.0058 | 0.0057 | 0.00004 | 4.3 |
| | | | ***SUBTOTAL EMISSIONS - STRUCTURAL WORK*** | **0.014** | **0.015** | **0.055** | **0.171** | **0.008** | **0.008** | **0.0001** | **10.8** |
| ***SEDIMENT DREDGING*** | | | | | | | | | | | |
| **Open-water Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.1880 | 0.1980 | 0.7466 | 2.3172 | 0.1112 | 0.1078 | 0.0013 | 146.2 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.2437 | 0.2567 | 0.9678 | 3.0038 | 0.1441 | 0.1398 | 0.0017 | 189.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0095 | 0.0100 | 0.0263 | 0.0363 | 0.0042 | 0.0041 | 0.0000 | 3.1 |
| **Nearshore Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0526 | 0.0554 | 0.2088 | 0.6481 | 0.0311 | 0.0302 | 0.0004 | 40.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0682 | 0.0718 | 0.2707 | 0.8402 | 0.0403 | 0.0391 | 0.0005 | 52.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0027 | 0.0028 | 0.0074 | 0.0102 | 0.0012 | 0.0011 | 0.00001 | 0.9 |
| **Restricted Access Dredging (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0072 | 0.0075 | 0.0284 | 0.0882 | 0.0042 | 0.0041 | 0.0001 | 5.6 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0139 | 0.0147 | 0.0552 | 0.1715 | 0.0082 | 0.0080 | 0.0001 | 10.8 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0005 | 0.0006 | 0.0015 | 0.0021 | 0.0002 | 0.0002 | 0.000002 | 0.2 |
| **Contingency Redredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0462 | 0.0487 | 0.1835 | 0.5696 | 0.0273 | 0.0265 | 0.0003 | 36.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0599 | 0.0631 | 0.2379 | 0.7384 | 0.0354 | 0.0344 | 0.0004 | 46.5 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0023 | 0.0025 | 0.0065 | 0.0089 | 0.0010 | 0.0010 | 0.00001 | 0.8 |
| **Shoreline/ Bank Excavation (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0710 | 0.0748 | 0.2820 | 0.8752 | 0.0420 | 0.0407 | 0.0005 | 55.2 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.1381 | 0.1454 | 0.5483 | 1.7017 | 0.0816 | 0.0792 | 0.0010 | 107.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0054 | 0.0057 | 0.0149 | 0.0206 | 0.0024 | 0.0023 | 0.00002 | 1.7 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT DREDGING*** | **0.91** | **0.96** | **3.59** | **11.03** | **0.53** | **0.52** | **0.00641** | **697.2** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Pre-Tier - Total Emissions (Metric Tonnes) Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | | | | | | | | | | | |
| **Mechanical Offloading (10 hours/day)** | | | | | | | | | | | |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | Assume each work day contains one 10 hr-shift. Assume bulking factor of 5% for mechanical offloading. Assume tug boat transports dredge sediment to an offloading area 5 mi away (one-way). | 0.0453 | 0.0477 | 0.1799 | 0.5584 | 0.0268 | 0.0260 | 0.0003 | 35.3 |
| | 100-ton Crane | Diesel Cranes | | 0.3306 | 0.3482 | 1.3128 | 4.0747 | 0.1955 | 0.1896 | 0.0024 | 257.2 |
| | Front-end Loader | Diesel Rough Terrain Forklifts | | 0.1330 | 0.1400 | 0.5279 | 1.6385 | 0.0786 | 0.0762 | 0.0010 | 103.4 |
| **Upland Transportation and Disposal (10 hours/day)** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume dredged sediments trucked from LDW upper reach to intermodal facility in South Seattle or Tukwila. Assume 10 miles each way (20 miles round trip). Applicable only to the baseline conditions. | 0.9322 | 0.9816 | 3.7014 | 11.4880 | 0.5511 | 0.5346 | 0.0067 | 726.1 |
| | Rail | na | Assume dredged sediments railed from intermodal facility to an off-site landfill disposal facility in Arlington, OR for 300 miles (one-way). | 2.2843 | 3.6080 | 17.1320 | 32.5508 | 0.7538 | 0.7312 | 0.0147 | 1681.9 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | **3.73** | **5.13** | **23** | **50** | **1.61** | **1.56** | **0.02** | **2803.8** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Pre-Tier - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***MATERIAL TRANSPORTATION AND PLACEMENT*** | | | | | | | | | | | |
| **Transportation of Clean Materials to LDW Upper Reach** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume sand, gravelly sand, light riprap and cement are transported 20 miles from quarry to onshore staging area by truck and 20 miles to LDW upper reach by barge. Includes material placement quantity for Upper Reach and cPAH-only RAA remediation activities. | 0.6082 | 0.6405 | 2.4151 | 7.4958 | 0.3596 | 0.3488 | 0.0043 | 473.7 |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | | 0.1183 | 0.1245 | 0.4695 | 1.4573 | 0.0699 | 0.0678 | 0.0008 | 92.1 |
| | Truck (20-ton Freight Truck) | Diesel Onroad Trucks | Assume granular activated carbon (GAC) is transported 150 miles by truck from Ridgefield, WA vendor to LDW upper reach (one-way). | -- | -- | -- | -- | -- | -- | -- | -- |
| **Open-water Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | | 0.0525 | 0.0553 | 0.2084 | 0.6469 | 0.0310 | 0.0301 | 0.0004 | 40.8 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0680 | 0.0717 | 0.2702 | 0.8386 | 0.0402 | 0.0390 | 0.0005 | 52.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0026 | 0.0028 | 0.0074 | 0.0101 | 0.0012 | 0.0011 | 0.00001 | 0.9 |
| **Open-water Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | | 0.0516 | 0.0543 | 0.2048 | 0.6357 | 0.0305 | 0.0296 | 0.0004 | 40.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0669 | 0.0704 | 0.2655 | 0.8241 | 0.0395 | 0.0383 | 0.0005 | 52.0 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0026 | 0.0027 | 0.0072 | 0.0100 | 0.0012 | 0.0011 | 0.00001 | 0.8 |
| **Nearshore Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/ day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | | 0.0107 | 0.0113 | 0.0426 | 0.1323 | 0.0063 | 0.0062 | 0.00008 | 8.4 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0139 | 0.0147 | 0.0553 | 0.1715 | 0.0082 | 0.0080 | 0.00010 | 10.8 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0011 | 0.0011 | 0.0030 | 0.0042 | 0.0005 | 0.0005 | 0.0000032 | 0.4 |
| **Nearshore Placement of Gravelly Sand for Backfill and Habitat Layer (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | | 0.0336 | 0.0354 | 0.1334 | 0.4142 | 0.0199 | 0.0193 | 0.0002 | 26.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0436 | 0.0459 | 0.1730 | 0.5369 | 0.0258 | 0.0250 | 0.0003 | 33.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0017 | 0.0018 | 0.0047 | 0.0065 | 0.0008 | 0.0007 | 0.00001 | 0.6 |
| **Capping (Gravelly Sand for Chemical Isolation Layer) (10 hours/day)** | | | . | | | | | | | | |
| | 150-ton Crane | Diesel Excavators | | 0.0063 | 0.0066 | 0.0250 | 0.0776 | 0.0037 | 0.0036 | 0.00005 | 4.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0082 | 0.0086 | 0.0324 | 0.1006 | 0.0048 | 0.0047 | 0.00006 | 6.3 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0003 | 0.0003 | 0.0009 | 0.0012 | 0.0001 | 0.0001 | 0.0000009 | 0.1 |
| **Capping (Light Riprap for Erosion Protection Layer) (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | | 0.0076 | 0.0080 | 0.0300 | 0.0931 | 0.0045 | 0.0043 | 0.00005 | 5.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0098 | 0.0103 | 0.0389 | 0.1207 | 0.0058 | 0.0056 | 0.00007 | 7.6 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0011 | 0.0015 | 0.0002 | 0.0002 | 0.0000011 | 0.1 |
| **Restricted Access Placement of Sand for Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. Includes material placement quantity for Upper Reach site and cPAH-only RAA remediation activities. | 0.0038 | 0.0040 | 0.0150 | 0.0465 | 0.0022 | 0.0022 | 0.00003 | 2.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0073 | 0.0077 | 0.0292 | 0.0905 | 0.0043 | 0.0042 | 0.00005 | 5.7 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0003 | 0.0003 | 0.0008 | 0.0011 | 0.0001 | 0.0001 | 0.000001 | 0.1 |
| **Restricted Access Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | | 0.0001 | 0.0001 | 0.0004 | 0.0013 | 0.00006 | 0.00006 | 0.0000008 | 0.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0002 | 0.0002 | 0.0008 | 0.0026 | 0.0001 | 0.0001 | 0.000002 | 0.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.00001 | 0.00001 | 0.00002 | 0.00003 | 0.000004 | 0.000004 | 0.00000002 | 0.0 |
| **Upland Placement of Sand for Residuals Management Cover, and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | | 0.0078 | 0.0082 | 0.0308 | 0.0956 | 0.0046 | 0.0044 | 0.00006 | 6.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0151 | 0.0159 | 0.0599 | 0.1858 | 0.0089 | 0.0086 | 0.00011 | 11.7 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0006 | 0.0006 | 0.0016 | 0.0022 | 0.00026 | 0.00025 | 0.0000018 | 0.2 |
| **Upland Placement of Gravelly Sand for Backfill, and Amended Cover (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | | 0.0477 | 0.0503 | 0.1896 | 0.5883 | 0.0282 | 0.0274 | 0.0003 | 37.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | Assume each work day contains one 10-hr shift. | 0.0928 | 0.0977 | 0.3686 | 1.1439 | 0.0549 | 0.0532 | 0.0007 | 72.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0036 | 0.0038 | 0.0100 | 0.0138 | 0.0016 | 0.0016 | 0.00001 | 1.2 |
| | | | ***SUBTOTAL EMISSIONS - MATERIAL TRANSPORTATION AND PLACEMENT*** | **1.29** | **1.36** | **5** | **16** | **0.76** | **0.74** | **0.01** | **995.9** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Pre-Tier - Total Emissions (Metric Tonnes) Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SURVEYS*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one survey per day and each work day contains one 10 hr-shift. Assume a total of 252 survey events based on pre-construction (bathy and topo), post- dredge, post- placement, post-construction (bathy and topo), contractor progress surveys for the construction duration, and as-built survey. | 0.04 | 0.04 | 0.11 | 0.156 | 0.0181 | 0.0176 | 0.0001 | 13.3 |
| | | | ***SUBTOTAL EMISSIONS - SURVEYS*** | **0.04** | **0.04** | **0.11** | **0.156** | **0.0181** | **0.0176** | **0.0001** | **13.3** |
| ***CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONMENTAL MONITORING*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one water quality monitoring event per dredge day and each work day contains one 10 hr-shift. Assume 210 water quality monitoring events. Assume 23 confirmational sediment sampling events. | 0.04 | 0.04 | 0.10 | 0.14 | 0.02 | 0.02 | 0.0001 | 12.3 |
| | | | ***SUBTOTAL EMISSIONS - CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONEMENTAL MONITORING*** | **0.01** | **0.01** | **0.03** | **0.036** | **0.0041** | **0.0040** | **0.000025** | **2.7** |
| | | | **TOTAL DIRECT AIR EMISSIONS (Metric Tonnes, rounded)** | **6.6** | **8.2** | **34.0** | **85.0** | **3.3** | **3.2** | **0.05** | **5,000** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 2 - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Hydrocarbons (HC)** | **Volatile Organic Compounds (VOCs)** | **Carbon Monoxide (CO)** | **Nitrogen Oxides ($NO_X$)** | **Particulate Matter 10 µm ($PM_{10}$)** | **Particulate Matter 2.5 µm ($PM_{2.5}$)** | **Sulfur Dioxide ($SO_2$)** | **Carbon Dioxide ($CO_2$)** |
| ***SITE PREPARATION*** | | | | | | | | | | | |
| **Equipment Mobilization/Demobilization (8 hours/day)** | | | | | | | | | | | |
| | Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | Assume mobilization/demobilization of 2 derrick rigs and 3 material barges. Assume 8 hrs/day for 4 days per construction season. | 0.0047 | 0.0049 | 0.0214 | 0.115 | 0.00370 | 0.00359 | 0.00014 | 14.9 |
| | | | ***SUBTOTAL EMISSIONS - SITE PREPARATION*** | **0.005** | **0.005** | **0.021** | **0.115** | **0.004** | **0.004** | **0.00014** | **14.9** |
| ***STRUCTURAL WORK*** | | | | | | | | | | | |
| **Timber and Steel Pile Removal and Replacement (10 hrs/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume pile removal or replacement occurs at 25 piles/day. | 0.0008 | 0.0009 | 0.0065 | 0.0201 | 0.0006 | 0.0006 | 0.0000 | 2.6 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0011 | 0.0011 | 0.0049 | 0.0261 | 0.0008 | 0.0008 | 0.0000 | 3.4 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0001 | 0.0004 | 0.00003 | 0.000031 | 0.000001 | 0.1 |
| **Temporary Float Dismantle/Relocation/ Reinstallation, Temporary Shoring of Bulkheads, Outfall Work, and Debris Removal** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume a total of 81 days including 24 days for upland excavation, 5 days for ground restoration, 16 days to install temporary tieback of bulkheads, 15 days for temporary relocation of floats, 4 days for pipe protection, and 12 days for apron/ bank protection. Assume 5 days for identified debris removal. | 0.06 | 0.07 | 0.51 | 1.57 | 0.05 | 0.05 | 0.0019 | 203.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.08 | 0.09 | 0.38 | 2.03 | 0.07 | 0.06 | 0.0024 | 263.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0020 | 0.0021 | 0.011 | 0.03 | 0.0025 | 0.0024 | 0.000040 | 4.3 |
| | | | ***SUBTOTAL EMISSIONS - STRUCTURAL WORK*** | **0.003** | **0.004** | **0.016** | **0.084** | **0.003** | **0.003** | **0.0001** | **10.9** |
| ***SEDIMENT DREDGING*** | | | | | | | | | | | |
| **Open-water Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0462 | 0.0486 | 0.3669 | 1.1337 | 0.0365 | 0.0354 | 0.0013 | 146.7 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0599 | 0.0630 | 0.2739 | 1.4696 | 0.0473 | 0.0459 | 0.0017 | 190.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0015 | 0.0015 | 0.0081 | 0.0249 | 0.0018 | 0.0017 | 0.0000 | 3.1 |
| **Nearshore Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0129 | 0.0136 | 0.1026 | 0.3171 | 0.0102 | 0.0099 | 0.0004 | 41.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0167 | 0.0176 | 0.0766 | 0.4111 | 0.0132 | 0.0128 | 0.0005 | 53.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0023 | 0.0070 | 0.0005 | 0.0005 | 0.00001 | 0.9 |
| **Restricted Access Dredging (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0018 | 0.0019 | 0.0089 | 0.0456 | 0.0014 | 0.0013 | 0.0001 | 5.6 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0034 | 0.0036 | 0.0156 | 0.0839 | 0.0027 | 0.0026 | 0.0001 | 10.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0001 | 0.0001 | 0.0005 | 0.0014 | 0.0001 | 0.0001 | 0.000002 | 0.2 |
| **Contingency Redredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0114 | 0.0120 | 0.0902 | 0.2787 | 0.0090 | 0.0087 | 0.0003 | 36.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0147 | 0.0155 | 0.0673 | 0.3613 | 0.0116 | 0.0113 | 0.0004 | 46.7 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0020 | 0.0061 | 0.0004 | 0.0004 | 0.00001 | 0.8 |
| **Shoreline/ Bank Excavation (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0174 | 0.0184 | 0.0880 | 0.4527 | 0.0138 | 0.0134 | 0.0005 | 55.4 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0339 | 0.0357 | 0.1551 | 0.8326 | 0.0268 | 0.0260 | 0.0010 | 107.7 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0008 | 0.0009 | 0.0046 | 0.0141 | 0.0010 | 0.0010 | 0.00002 | 1.8 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT DREDGING*** | **0.22** | **0.23** | **1.26** | **5.44** | **0.18** | **0.17** | **0.00644** | **700.1** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 2 - Total Emissions (Metric Tonnes): Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | | | | | | | | | | | |
| **Mechanical Offloading (10 hours/day)** | | | | | | | | | | | |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | Assume each work day contains one 10 hr-shift. Assume bulking factor of 5% for mechanical offloading. Assume tug boat transports dredge sediment to an offloading area 5 mi away (one-way). | 0.0111 | 0.0117 | 0.0509 | 0.2732 | 0.0088 | 0.0003 | 0.0003 | 35.4 |
| | 100-ton Crane | Diesel Cranes | | 0.0812 | 0.0855 | 0.6452 | 1.9936 | 0.0642 | 0.0623 | 0.0024 | 258.0 |
| | Front-end Loader | Diesel Rough Terrain Forklifts | | 0.0604 | 0.0636 | 0.1463 | 0.7821 | 0.0258 | 0.0250 | 0.0010 | 103.6 |
| **Upland Transportation and Disposal (10 hours/day)** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume dredged sediments trucked from LDW upper reach to intermodal facility in South Seattle or Tukwila. Assume 10 miles each way (20 miles round trip). Applicable only to the baseline conditions. | 0.2289 | 0.2411 | 1.8192 | 5.6206 | 0.1810 | 0.1755 | 0.0067 | 726.1 |
| | Rail | na | Assume dredged sediments railed from intermodal facility to an off-site landfill disposal facility in Arlington, OR for 300 miles (one-way). | 1.0279 | 1.0824 | 5.1396 | 18.8452 | 0.3426 | 0.3324 | 0.0147 | 1681.9 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | **1.41** | **1.48** | **8** | **28** | **0.62** | **0.60** | **0.02** | **2804.9** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 2 - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_x$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***MATERIAL TRANSPORTATION AND PLACEMENT*** | | | | | | | | | | | |
| **Transportation of Clean Materials to LDW Upper Reach** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume sand, gravelly sand, light riprap and cement are transported 20 miles from quarry to onshore staging area by truck and 20 miles to LDW upper reach by barge. Includes material placement quantity for Upper Reach and cPAH-only RAA remediation activities. | 0.1494 | 0.1573 | 1.1870 | 3.6674 | 0.1181 | 0.1145 | 0.0044 | 473.7 |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | | 0.0290 | 0.0306 | 0.1329 | 0.7130 | 0.0230 | 0.0009 | 0.0008 | 92.3 |
| | Truck (20-ton Freight Truck) | Diesel Onroad Trucks | Assume granular activated carbon (GAC) is transported 150 miles by truck from Ridgefield, WA vendor to LDW upper reach (one-way). | 0.00004 | 0.00004 | 0.0002 | 0.0008 | 0.00004 | 0.00003 | 0.000002 | 0.0597 |
| **Open-water Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0129 | 0.0136 | 0.1024 | 0.3165 | 0.0102 | 0.0099 | 0.0004 | 41.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0167 | 0.0176 | 0.0765 | 0.4103 | 0.0132 | 0.0128 | 0.0005 | 53.1 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0023 | 0.0070 | 0.0005 | 0.0005 | 0.00001 | 0.9 |
| **Open-water Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0127 | 0.0133 | 0.1007 | 0.3110 | 0.0100 | 0.0097 | 0.0004 | 40.2 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0164 | 0.0173 | 0.0751 | 0.4032 | 0.0130 | 0.0126 | 0.0005 | 52.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0022 | 0.0068 | 0.0005 | 0.0005 | 0.000008 | 0.9 |
| **Nearshore Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/ day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0026 | 0.0028 | 0.0210 | 0.0647 | 0.0021 | 0.0020 | 0.000077 | 8.4 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0034 | 0.0036 | 0.0156 | 0.0839 | 0.0027 | 0.0026 | 0.000100 | 10.9 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.00017 | 0.00018 | 0.0009 | 0.0028 | 0.0002 | 0.000198 | 0.0000033 | 0.4 |
| **Nearshore Placement of Gravelly Sand for Backfill and Habitat Layer (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0083 | 0.0087 | 0.0656 | 0.2026 | 0.0065 | 0.0063 | 0.0002 | 26.2 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0107 | 0.0113 | 0.0489 | 0.2627 | 0.0085 | 0.0082 | 0.0003 | 34.0 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0003 | 0.0003 | 0.0014 | 0.0045 | 0.0003 | 0.0003 | 0.00001 | 0.6 |
| **Capping (Gravelly Sand for Chemical Isolation Layer) (10 hours/day)** | | | . | | | | | | | | |
| | 150-ton Crane | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0015 | 0.0016 | 0.0123 | 0.0380 | 0.0012 | 0.0012 | 0.00005 | 4.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0020 | 0.0021 | 0.0092 | 0.0492 | 0.0016 | 0.0015 | 0.00006 | 6.4 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.00005 | 0.00005 | 0.0003 | 0.0008 | 0.00006 | 0.00006 | 0.0000010 | 0.1 |
| **Capping (Light Riprap for Erosion Protection Layer) (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0019 | 0.0020 | 0.0147 | 0.0456 | 0.0015 | 0.0014 | 0.00005 | 5.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0024 | 0.0025 | 0.0110 | 0.0590 | 0.0019 | 0.0018 | 0.00007 | 7.6 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.00006 | 0.00006 | 0.0003 | 0.0010 | 0.00007 | 0.00007 | 0.0000011 | 0.1 |
| **Restricted Access Placement of Sand for Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. Includes material placement quantity for Upper Reach site and cPAH-only RAA remediation activities. | 0.0009 | 0.0010 | 0.0047 | 0.0241 | 0.0007 | 0.0007 | 0.00003 | 2.9 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0018 | 0.0019 | 0.0082 | 0.0443 | 0.0014 | 0.0014 | 0.00005 | 5.7 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0002 | 0.0008 | 0.0001 | 0.0001 | 0.000001 | 0.1 |
| **Restricted Access Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.00003 | 0.00003 | 0.0001 | 0.0007 | 0.00002 | 0.00002 | 0.0000008 | 0.1 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.00005 | 0.00005 | 0.0002 | 0.0013 | 0.00004 | 0.00004 | 0.000002 | 0.2 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.000001 | 0.000001 | 0.00001 | 0.00002 | 0.000002 | 0.000001 | 0.00000002 | 0.0 |
| **Upland Placement of Sand for Residuals Management Cover, and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0019 | 0.0020 | 0.0096 | 0.0494 | 0.0015 | 0.0015 | 0.00006 | 6.0 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0037 | 0.0039 | 0.0169 | 0.0909 | 0.0029 | 0.0028 | 0.00011 | 11.8 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.00009 | 0.00010 | 0.0005 | 0.0015 | 0.00011 | 0.00011 | 0.0000018 | 0.2 |
| **Upland Placement of Gravelly Sand for Backfill, and Amended Cover (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0117 | 0.0123 | 0.0592 | 0.3043 | 0.0093 | 0.0090 | 0.0003 | 37.2 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0228 | 0.0240 | 0.1043 | 0.5597 | 0.0180 | 0.0175 | 0.0007 | 72.4 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0006 | 0.0006 | 0.0031 | 0.0095 | 0.0007 | 0.0007 | 0.00001 | 1.2 |
| | | | ***SUBTOTAL EMISSIONS - MATERIAL TRANSPORTATION AND PLACEMENT*** | **0.31** | **0.33** | **2** | **8** | **0.25** | **0.22** | **0.01** | **997.5** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 2 - Total Emissions (Metric Tonnes) Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SURVEYS*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one survey per day and each work day contains one 10 hr-shift. Assume a total of 252 survey events based on pre-construction (bathy and topo), post- dredge, post- placement, post-construction (bathy and topo), contractor progress surveys for the construction duration, and as-built survey. | 0.006 | 0.01 | 0.03 | 0.107 | 0.0077 | 0.0075 | 0.0001 | 13.4 |
| | | | ***SUBTOTAL EMISSIONS - SURVEYS*** | **0.006** | **0.01** | **0.03** | **0.107** | **0.0077** | **0.0075** | **0.0001** | **13.4** |
| ***CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONMENTAL MONITORING*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one water quality monitoring event per dredge day and each work day contains one 10 hr-shift. Assume 210 water quality monitoring events. Assume 23 confirmational sediment sampling events. | 0.006 | 0.006 | 0.03 | 0.10 | 0.007 | 0.007 | 0.0001 | 12.4 |
| | | | ***SUBTOTAL EMISSIONS - CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONEMENTAL MONITORING*** | **0.001** | **0.002** | **0.01** | **0.024** | **0.0018** | **0.0017** | **0.000025** | **2.7** |
| | | | **TOTAL DIRECT AIR EMISSIONS (Metric Tonnes, rounded)** | **2.1** | **2.2** | **12.0** | **45.0** | **1.2** | **1.1** | **0.05** | **5,000** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 4 - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***SITE PREPARATION*** | | | | | | | | | | | |
| **Equipment Mobilization/Demobilization (8 hours/day)** | | | | | | | | | | | |
| | Tug Boat (800 HP) | Diesel Inboard/Sterndrive (800 HP) | Assume mobilization/demobilization of 2 derrick rigs and 3 material barges. Assume 8 hrs/day for 4 days per construction season. | 0.0010 | 0.0010 | 0.0037 | 0.064 | 0.00059 | 0.00057 | 0.00010 | 14.9 |
| | | | ***SUBTOTAL EMISSIONS - SITE PREPARATION*** | **0.001** | **0.001** | **0.004** | **0.064** | **0.001** | **0.001** | **0.000** | **15** |
| ***STRUCTURAL WORK*** | | | | | | | | | | | |
| **Timber and Steel Pile Removal and Replacement (10 hrs/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume pile removal or replacement occurs at 25 piles/day. | 0.0001 | 0.0001 | 0.0011 | 0.0057 | 0.0000 | 0.0000 | 0.0000 | 2.6094 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0002 | 0.0002 | 0.0008 | 0.0145 | 0.0001 | 0.0001 | 0.0000 | 3.3820 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0000 | 0.0000 | 0.0000 | 0.0552 |
| **Temporary Float Dismantle/Relocation/ Reinstallation, Temporary Shoring of Bulkheads, Outfall Work, and Debris Removal** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. Assume a total of 81 days including 24 days for upland excavation, 5 days for ground restoration, 16 days to install temporary tieback of bulkheads, 15 days for temporary relocation of floats, 4 days for pipe protection, and 12 days for apron/ bank protection. Assume 5 days for identified debris removal. | 0.004 | 0.004 | 0.08 | 0.44 | 0.003 | 0.003 | 0.002 | 203.23 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.02 | 0.02 | 0.06 | 1.13 | 0.01 | 0.01 | 0.002 | 263.41 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0010 | 0.0010 | 0.003 | 0.02 | 0.0002 | 0.0002 | 0.00003 | 4.30 |
| | | | ***SUBTOTAL EMISSIONS - STRUCTURAL WORK*** | **0.001** | **0.001** | **0.003** | **0.047** | **0.0004** | **0.0004** | **0.0001** | **10.9** |
| ***SEDIMENT DREDGING*** | | | | | | | | | | | |
| **Open-water Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0030 | 0.0032 | 0.0592 | 0.3188 | 0.0025 | 0.0024 | 0.0013 | 146.8317 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0125 | 0.0132 | 0.0470 | 0.8165 | 0.0075 | 0.0073 | 0.0013 | 190.3100 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0007 | 0.0008 | 0.0021 | 0.0145 | 0.0001 | 0.0001 | 0.0000 | 3.1072 |
| **Nearshore Dredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0009 | 0.0009 | 0.0166 | 0.0892 | 0.0007 | 0.0007 | 0.0004 | 41.0690 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0035 | 0.0037 | 0.0131 | 0.2284 | 0.0021 | 0.0020 | 0.0004 | 53.2299 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0002 | 0.0002 | 0.0006 | 0.0041 | 0.0000 | 0.0000 | 0.0000 | 0.8691 |
| **Restricted Access Dredging (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0001 | 0.0001 | 0.0023 | 0.0121 | 0.0001 | 0.0001 | 0.0000 | 5.5878 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0007 | 0.0008 | 0.0027 | 0.0466 | 0.0004 | 0.0004 | 0.0001 | 10.8637 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0001 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.1774 |
| **Contingency Redredging (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0007 | 0.0008 | 0.0145 | 0.0784 | 0.0006 | 0.0006 | 0.0003 | 36.0965 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0031 | 0.0032 | 0.0115 | 0.2007 | 0.0019 | 0.0018 | 0.0003 | 46.7850 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0002 | 0.0002 | 0.0005 | 0.0036 | 0.0000 | 0.0000 | 0.0000 | 0.7639 |
| **Shoreline/ Bank Excavation (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0011 | 0.0012 | 0.0223 | 0.1204 | 0.0009 | 0.0009 | 0.0004 | 55.4561 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0071 | 0.0075 | 0.0266 | 0.4626 | 0.0043 | 0.0041 | 0.0007 | 107.8157 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0004 | 0.0004 | 0.0012 | 0.0082 | 0.0001 | 0.0001 | 0.0000 | 1.7603 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT DREDGING*** | **0.03** | **0.04** | **0** | **2.41** | **0.02** | **0.02** | **0.01** | **701** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 4 - Total Emissions (Metric Tonnes) Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | | | | | | | | | | | |
| **Mechanical Offloading (10 hours/day)** | | | | | | | | | | | |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | Assume each work day contains one 10 hr-shift. Assume bulking factor of 5% for mechanical offloading. Assume tug boat transports dredge sediment to an offloading area 5 mi away (one-way). | 0.0024 | 0.0026 | 0.0092 | 0.1594 | 0.0015 | 0.0004 | 0.0003 | 37.1276 |
| | 100-ton Crane | Diesel Cranes | | 0.0053 | 0.0056 | 0.1041 | 0.5606 | 0.0044 | 0.0042 | 0.0024 | 258.1954 |
| | Front-end Loader | Diesel Rough Terrain Forklifts | | 0.0022 | 0.0023 | 0.0418 | 0.2254 | 0.0018 | 0.0017 | 0.0007 | 103.8246 |
| **Upland Transportation and Disposal (10 hours/day)** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume dredged sediments trucked from LDW upper reach to intermodal facility in South Seattle or Tukwila. Assume 10 miles each way (20 miles round trip). Applicable only to the baseline conditions. | 0.0151 | 0.0159 | 0.2934 | 1.5806 | 0.0123 | 0.0120 | 0.0067 | 726.0609 |
| | Rail | na | Assume dredged sediments railed from intermodal facility to an off-site landfill disposal facility in Arlington, OR for 300 miles (one-way). | 0.4797 | 0.5051 | 5.1396 | 4.4543 | 0.1028 | 0.0997 | 0.0147 | 1681.9031 |
| | | | ***SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING, UPLAND TRANSPORTATION, AND DISPOSAL*** | **0.50** | **0.53** | **6** | **7** | **0.12** | **0.12** | **0.02** | **2,807** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 4 - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_x$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***MATERIAL TRANSPORTATION AND PLACEMENT*** | | | | | | | | | | | |
| **Transportation of Clean Materials to LDW Upper Reach** | | | | | | | | | | | |
| | Truck (20-ton Dump Truck) | Diesel Off-highway Trucks | Assume sand, gravelly sand, light riprap and cement are transported 20 miles from quarry to onshore staging area by truck and 20 miles to LDW upper reach by barge. Includes material placement quantity for Upper Reach and cPAH-only RAA remediation activities. | 0.0098 | 0.0104 | 0.1914 | 1.0313 | 0.0081 | 0.0078 | 0.0044 | 473.7444 |
| | Tug Boat (3,000 HP) | Diesel Inboard/Sterndrive (3,000 HP) | | 0.0061 | 0.0064 | 0.0228 | 0.3962 | 0.0037 | 0.0009 | 0.0008 | 92.2865 |
| | Truck (20-ton Freight Truck) | Diesel Onroad Trucks | Assume granular activated carbon (GAC) is transported 150 miles by truck from Ridgefield, WA vendor to LDW upper reach (one-way). | 0.00002 | 0.00002 | 0.0001 | 0.0003 | 0.00001 | 0.00001 | 0.000002 | 0.0597 |
| **Open-water Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0008 | 0.0009 | 0.0165 | 0.0890 | 0.0007 | 0.0007 | 0.0004 | 40.9905 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0035 | 0.0037 | 0.0131 | 0.2280 | 0.0021 | 0.0020 | 0.0003 | 53.1281 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0002 | 0.0002 | 0.0006 | 0.0041 | 0.0000 | 0.0000 | 0.0000 | 0.8674 |
| **Open-water Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0008 | 0.0009 | 0.0162 | 0.0875 | 0.0007 | 0.0007 | 0.0004 | 40.2847 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0034 | 0.0036 | 0.0129 | 0.2240 | 0.0021 | 0.0020 | 0.0003 | 52.2134 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0002 | 0.0002 | 0.0006 | 0.0040 | 0.0000 | 0.0000 | 0.0000 | 0.8525 |
| **Nearshore Placement of Sand for Residuals Management Cover and Enhanced Natural Recovery (10 hours/ day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0002 | 0.0002 | 0.0034 | 0.0182 | 0.0001 | 0.0001 | 0.0001 | 8.3852 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0007 | 0.0008 | 0.0027 | 0.0466 | 0.0004 | 0.0004 | 0.0001 | 10.8682 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0001 | 0.0001 | 0.0002 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.3549 |
| **Nearshore Placement of Gravelly Sand for Backfill and Habitat Layer (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0005 | 0.0006 | 0.0106 | 0.0570 | 0.0004 | 0.0004 | 0.0002 | 26.2439 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0022 | 0.0024 | 0.0084 | 0.1459 | 0.0013 | 0.0013 | 0.0002 | 34.0149 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0001 | 0.0001 | 0.0004 | 0.0026 | 0.0000 | 0.0000 | 0.0000 | 0.5554 |
| **Capping (Gravelly Sand for Chemical Isolation Layer) (10 hours/day)** | | | . | | | | | | | | |
| | 150-ton Crane | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0001 | 0.0001 | 0.0020 | 0.0107 | 0.0001 | 0.0001 | 0.0000 | 4.9164 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0004 | 0.0004 | 0.0016 | 0.0273 | 0.0003 | 0.0002 | 0.0000 | 6.3722 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0000 | 0.0000 | 0.0000 | 0.0972 |
| **Capping (Light Riprap for Erosion Protection Layer) (10 hours/day)** | | | | | | | | | | | |
| | 150-ton Crane | Diesel Cranes | Assume each work day contains one 10-hr shift. | 0.0001 | 0.0001 | 0.0024 | 0.0128 | 0.0001 | 0.0001 | 0.0001 | 5.8997 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0005 | 0.0005 | 0.0019 | 0.0328 | 0.0003 | 0.0003 | 0.0001 | 7.6466 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.0000 | 0.0000 | 0.0000 | 0.1166 |
| **Restricted Access Placement of Sand for Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. Includes material placement quantity for Upper Reach site and cPAH-only RAA remediation activities. | 0.0001 | 0.0001 | 0.0022 | 0.0120 | 0.0001 | 0.0001 | 0.0001 | 5.5282 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0004 | 0.0004 | 0.0014 | 0.0246 | 0.0002 | 0.0002 | 0.0000 | 5.7321 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0001 | 0.0004 | 0.0000 | 0.0000 | 0.0000 | 0.0936 |
| **Restricted Access Placement of Gravelly Sand for Backfill (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0000 | 0.0000 | 0.0001 | 0.0003 | 0.0000 | 0.0000 | 0.0000 | 0.1580 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0000 | 0.0000 | 0.0000 | 0.0007 | 0.0000 | 0.0000 | 0.0000 | 0.1639 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0027 |
| **Upland Placement of Sand for Residuals Management Cover, and Enhanced Natural Recovery (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0002 | 0.0002 | 0.0046 | 0.0247 | 0.0002 | 0.0002 | 0.0001 | 11.3543 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0008 | 0.0008 | 0.0029 | 0.0505 | 0.0005 | 0.0005 | 0.0001 | 11.7731 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0000 | 0.0000 | 0.0001 | 0.0009 | 0.0000 | 0.0000 | 0.0000 | 0.1922 |
| **Upland Placement of Gravelly Sand for Backfill, and Amended Cover (10 hours/day)** | | | | | | | | | | | |
| | Hydraulic Excavator | Diesel Excavators | Assume each work day contains one 10-hr shift. | 0.0014 | 0.0015 | 0.0282 | 0.1518 | 0.0012 | 0.0011 | 0.0006 | 69.8986 |
| | Push Boat | Diesel Inboard/Sterndrive (800 HP) | | 0.0048 | 0.0050 | 0.0179 | 0.3110 | 0.0029 | 0.0028 | 0.0005 | 72.4770 |
| | Work Boat | Two-stroke Outboard (WB) | | 0.0003 | 0.0003 | 0.0008 | 0.0055 | 0.0001 | 0.0001 | 0.0000 | 1.1833 |
| | | | ***SUBTOTAL EMISSIONS - MATERIAL TRANSPORTATION AND PLACEMENT*** | **0.04** | **0.04** | **0** | **3** | **0.03** | **0.02** | **0.01** | **1,038** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

| Construction Activity | Type of Vehicle/Equipment Used | SCC Description | Notes | Tier 4 - Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrogen Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| ***SURVEYS*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one survey per day and each work day contains one 10 hr-shift. Assume a total of 252 survey events based on pre-construction (bathy and topo), post- dredge, post- placement, post-construction (bathy and topo), contractor progress surveys for the construction duration, and as-built survey. | 0.00 | 0.00 | 0.01 | 0.063 | 0.0006 | 0.0006 | 0.0001 | 13.4 |
| | | | ***SUBTOTAL EMISSIONS - SURVEYS*** | **0.00** | **0.00** | **0.01** | **0.063** | **0.0006** | **0.0006** | **0.0001** | **13.4** |
| ***CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONMENTAL MONITORING*** | | | | | | | | | | | |
| | Work Boat | Two-stroke Outboard (WB) | Assume one water quality monitoring event per dredge day and each work day contains one 10 hr-shift. Assume 210 water quality monitoring events. Assume 23 confirmational sediment sampling events. | 0.00 | 0.00 | 0.01 | 0.06 | 0.00 | 0.00 | 0.00 | 12.37 |
| | | | ***SUBTOTAL EMISSIONS - CONFIRMATIONAL SEDIMENT SAMPLING AND ENVIRONEMENTAL MONITORING*** | **0.00** | **0.00** | **0.00** | **0.014** | **0.0001** | **0.0001** | **0.0000** | **2.7** |
| | | | **TOTAL DIRECT AIR EMISSIONS (Metric Tonnes, rounded)** | **1** | **1** | **6** | **14** | **0.2** | **0.2** | **0.04** | **5,100** |

**Table L-8**
**Detailed Summary of Direct Emissions by Construction Activity**

Notes:
1. Total emissions for construction equipment/vehicle are calculated as total daily diesel usage (gal/day) / production rate (units/day) x units x emission factor (g/gal) x (1E-6 metric ton/g).
2. Total emissions for rail transportation are calculated as total diesel usage (gal) x emission factor (g/gal) x (1E-6 metric ton/g).
   2a. Total diesel usage for train (gal) is calculated as total tonnage-distance covered (ton-mi) / train fuel economy (ton-mi/gal).
   2b. Total tonnage-distance covered (ton-mi) is calculated as tonnage transported (metric ton) x one-way distance.
3. Total emissions for truck transportation are calculated as total diesel usage (gal) x emission factor (g/gal) x (1E-6 metric ton/g).
   3a. Total diesel usage for trucks (gal) is calculated as total tonnage-distance covered (ton-mi) / truck fuel economy (ton-mi/gal).
   3b. Total tonnage-distance covered (ton-mi) is calculated as tonnage transported (metric ton) x one-way distance.
4. Total emissions for barge transportation are calculated as total diesel usage (gal) x emission factor (g/gal) x (1E-6 metric ton/g).
   4a. Total diesel usage for boats (gal) is calculated as total tonnage-distance covered (ton-mi) / barge fuel economy (ton-mi/gal).
   4b. Total tonnage-distance covered (ton-mi) is calculated as tonnage transported (metric ton) x one-way distance.

CO: carbon monoxide
$CO_2$: carbon dioxide
cy: cubic yard
GAC: granular activated carbon
gal: gallon
HP: horsepower
na: not applicable
$NO_X$: nitrogen oxides (NO and $NO_2$)
PB: push boat
$PM_{2.5}$: particulate matter less that 2.5 microns in diameter
$PM_{10}$: particulate matter less than 10 microns in diameter
SCC: Standard Classification Code
$SO_2$: sulfur dioxide
VOC: volatile organic compound
WB: work boat

**Table L-9**
**High-Level Summary of Direct Emissions by Construction Activity For Baseline and Local Average Market Conditions**

| Construction Activity | Total Emissions (Metric Tonnes) Baseline Conditions | | | | | | | | Total Emissions (Metric Tonnes) Local Average Market Conditions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrous Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrous Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| Site Preparation | 0.02 | 0.02 | 0.08 | 0.23 | 0.01 | 0.01 | 0.00 | 14.81 | 0.02 | 0.02 | 0.08 | 0.23 | 0.01 | 0.01 | 0.00 | 14.81 |
| Structural Work | 0.48 | 0.50 | 2.07 | 6.35 | 0.29 | 0.28 | 0.00 | 475.03 | 0.46 | 0.48 | 1.90 | 5.89 | 0.27 | 0.26 | 0.00 | 475.11 |
| Sediment Dredging | 0.70 | 0.74 | 2.97 | 9.30 | 0.42 | 0.41 | 0.01 | 697.84 | 0.67 | 0.70 | 2.77 | 8.76 | 0.40 | 0.39 | 0.01 | 709.03 |
| Sediment Transloading, Upland Transportation, and Disposal | 1.44 | 1.52 | 7.93 | 27.80 | 0.64 | 0.62 | 0.02 | 2804.83 | 0.61 | 0.65 | 5.90 | 7.08 | 0.19 | 0.18 | 0.02 | 2078.93 |
| Material Transportation and Placement | 0.70 | 0.73 | 3.48 | 10.85 | 0.45 | 0.44 | 0.01 | 996.36 | 0.54 | 0.57 | 2.37 | 7.90 | 0.33 | 0.32 | 0.01 | 1004.53 |
| Surveys | 0.04 | 0.04 | 0.11 | 0.16 | 0.02 | 0.02 | 0.00 | 13.26 | 0.04 | 0.04 | 0.11 | 0.16 | 0.02 | 0.02 | 0.00 | 13.26 |
| Confirmational Sediment Sampling and Environmental Monitoring | 0.04 | 0.04 | 0.10 | 0.14 | 0.02 | 0.02 | 0.00 | 12.26 | 0.04 | 0.04 | 0.10 | 0.14 | 0.02 | 0.02 | 0.00 | 12.26 |

Notes:
1. See Table L-1 for baseline and local average market conditions and equipment assumptions for direct air emissions inventory.
CO: carbon monoxide
$CO_2$: carbon dioxide
HC: hydrocarbon
HP: horsepower
$NO_X$: nitrogen oxides (NO and NO2)
$PM_{2.5}$: particulate matter less that 2.5 microns in diameter
$PM_{10}$: particulate matter less than 10 microns in diameter
$SO_2$: sulfur dioxide;
VOC: volatile organic compound

**Table L-10**
**High-Level Summary of Direct Emissions by Equipment Type For Baseline and Local Average Market Conditions**

| Vehicle or Equipment Type | Total Emissions (Metric Tonnes) | | | | | | | | Total Emissions (Metric Tonnes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline Conditions | | | | | | | | Local Average Market Conditions | | | | | | | |
| | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrous Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) | Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrous Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
| Dredging/Material Placement Crane | 0.34 | 0.35 | 1.82 | 5.64 | 0.22 | 0.22 | 0.01 | 556 | 0.271 | 0.285 | 1.356 | 4.408 | 0.172 | 0.167 | 0.005 | 555.729 |
| Transload/Disposal Crane | 0.16 | 0.16 | 0.85 | 2.62 | 0.10 | 0.10 | 0.00 | 258 | 0.058 | 0.132 | 0.629 | 2.045 | 0.080 | 0.077 | 0.002 | 257.812 |
| Hydraulic Excavator | 0.03 | 0.04 | 0.17 | 0.88 | 0.03 | 0.03 | 0.00 | 107 | 0.028 | 0.029 | 0.148 | 0.766 | 0.022 | 0.021 | 0.001 | 115.445 |
| Front-end Loader | 0.06 | 0.06 | 0.15 | 0.78 | 0.03 | 0.03 | 0.00 | 104 | 0.031 | 0.033 | 0.094 | 0.504 | 0.014 | 0.013 | 0.001 | 103.732 |
| Vessels (Tug Boat, Push Boat, and Work Boat) | 1.50 | 1.58 | 5.80 | 17.41 | 0.87 | 0.84 | 0.01 | 1108 | 1.50 | 1.58 | 5.80 | 17.41 | 0.87 | 0.84 | 0.01 | 1108.20 |
| Rail Transportation | 1.03 | 1.08 | 5.14 | 18.85 | 0.34 | 0.33 | 0.01 | 1682 | 0.480 | 0.505 | 5.140 | 4.454 | 0.103 | 0.100 | 0.015 | 1681.903 |
| Truck Transportation | 0.38 | 0.40 | 3.01 | 9.29 | 0.30 | 0.29 | 0.01 | 1199.86 | 0.02 | 0.03 | 0.48 | 2.61 | 0.02 | 0.02 | 0.01 | 1199.86 |

Notes:
1. See Table L-1 for baseline and local average market conditions and equipment assumptions for direct air emissions inventory.
CO: carbon monoxide
$CO_2$: carbon dioxide
HC: hydrocarbon
HP: horsepower
$NO_X$: nitrogen oxides (NO and NO2)
$PM_{2.5}$: particulate matter less that 2.5 microns in diameter
$PM_{10}$: particulate matter less than 10 microns in diameter
$SO_2$: sulfur dioxide;
VOC: volatile organic compound

**Table L-11**
**Relative Change in Total Emissions Between Baseline and Local Average Market Conditions**

| Construction Activity | Relative Reduction In Total Emissions<br>Baseline Conditions - Average Market Condition<br>Hydrocarbons (HC) | Volatile Organic Compounds (VOCs) | Carbon Monoxide (CO) | Nitrous Oxides ($NO_X$) | Particulate Matter 10 µm ($PM_{10}$) | Particulate Matter 2.5 µm ($PM_{2.5}$) | Sulfur Dioxide ($SO_2$) | Carbon Dioxide ($CO_2$) |
|---|---|---|---|---|---|---|---|---|
| Site Preparation | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Structural Work | 5.0% | 5.0% | 8.3% | 7.2% | 6.6% | 6.6% | 0.0% | 0.0% |
| Sediment Dredging | 4.2% | 4.2% | 6.7% | 5.9% | 5.5% | 5.5% | -0.7% | -1.6% |
| Sediment Transloading, Upland Transportation, and Disposal | 57.4% | 57.4% | 25.6% | 74.5% | 70.4% | 70.4% | 27.3% | 25.9% |
| Material Transportation and Placement | 22.5% | 22.5% | 31.9% | 27.2% | 27.6% | 27.6% | -0.9% | -0.8% |
| Surveys | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Confirmational Sediment Sampling and Environmental Monitoring | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

Notes:
1. Relative change in total emission calculation based on: (Total Emissions for Baseline - Total Emissions for Market)/(Total Emissions for Baseline). Negative percentage change indicates relative increase in total emissions; positive percentage change indicates relative decreased in total emissions.
CO: carbon monoxide
$CO_2$: carbon dioxide
HC: hydrocarbon
HP: horsepower
$NO_X$: nitrogen oxides (NO and NO2)
$PM_{2.5}$: particulate matter less that 2.5 microns in diameter
$PM_{10}$: particulate matter less than 10 microns in diameter
$SO_2$: sulfur dioxide;
VOC: volatile organic compound

**Table L-12**
**Material Use and Waste Generation Summary**

| Material Use and Waste Generation | Activity Type | Activity | Quantity |
|---|---|---|---|
| **Raw Materials** | **Material Placement[1]** | Clean Raw Materials (sand, gravelly sand, and light riprap armor) Volume (cy) | 73,800 |
| | **Structural Work** | Replaced Number of Timber Piles | 3 |
| | | Replaced Number of Steel Piles | 3 |
| | | Unload and Temporary Shoring of Bulkheads (LF) | 408 |
| **Waste Generated** | **Sediment Dredging** | Disposed Dredge Contaminated Sediment Volume (cy) | 107,500 |
| | **Debris Removal** | Debris Removed (ton) | 650 |
| | **Structural Work** | Removed Number of Timber Piles | 17 |
| | | Removed Number of Steel Piles | 3 |

Notes:
1. Includes all material placement quantities required for the upper reach and cPAH-only RAA remediation activities.
2. Volumes are rounded to the nearest hundred.
cPAH: carcinogenic polycyclic aromatic hydrocarbon
cy: cubic yard
RAA: remedial action area
sf: square foot

**Table L-13**
**Diesel Energy Consumption Summary**

| Activity | Task | Quantity of Material (cy) | Number of Work Days | Total Daily Diesel Usage (gal/day) | Volume of Diesel Consumed (gal) |
|---|---|---|---|---|---|
| Structural Work | Timber and Steel Pile Removal and Replacement | -- | 1 | 312 | 312 |
| | Timber Bulkhead Removal/Replacement, Temporary Float Dismantle/Relocation/ Reinstallation, Outfall Work, and Debris Removal | -- | 81 | 312 | 25,248 |
| Sediment Removal | Open-Water Dredging | 64,374 | 59 | 312 | 18,390 |
| | Nearshore Dredging | 11,458 | 17 | 312 | 5,299 |
| | Restricted Access Dredging | 1,670 | 4 | 340 | 1,359 |
| | Contingency Re-Dredging | 10,071 | 15 | 312 | 4,676 |
| | Shoreline/Bank Excavation | 19,892 | 34 | 340 | 11,550 |
| Sediment Offloading, Transloading, Upland Transportation, and Disposal | Mechanical Offloading | 113,198 | 103 | 560 | 57,680 |
| | Upland Transportation and Disposal | 113,198 | -- | - | 136,223 |
| Material Transportation and Placement | Transportation of Clean Raw Materials (sand, gravelly sand, gravel, light riprap and cement) to LDW Upper Reach | 74,048 | -- | -- | 19,546 |
| | Transportation of GAC to LDW Upper Reach Site | 11.0 | -- | -- | 20 |
| | Open-water Placement | 35,896 | 33 | 312 | 10,286 |
| | Nearshore Material Placement | 13,802 | 14 | 315 | 4,406 |
| | Capping | 2,351 | 4 | 312 | 1,247 |
| | Restricted Access Placement | 1,269 | 5 | 340 | 1,699 |
| | Upland Material Placement | 20,462 | 26 | 340 | 8,832 |
| Other Construction Activities | Surveys | -- | 252 | 3 | 756 |
| | Confirmational Sediment Sampling and Environmental Monitoring | -- | 233 | 3 | 699 |
| | | | **Total Diesel Consumed (gal)** | | **308,300** |

Notes:
1. The volume of diesel consumed for upland transportation and disposal and transportation of clean raw materials is based on the quantity of material, distance travelled, and the fuel economy by the equipment used.
cy: cubic yard
GAC: granular activated carbon
gal: gallon
gal/day: gallon/day
LDW: Lower Duwamish Waterway

# Figures

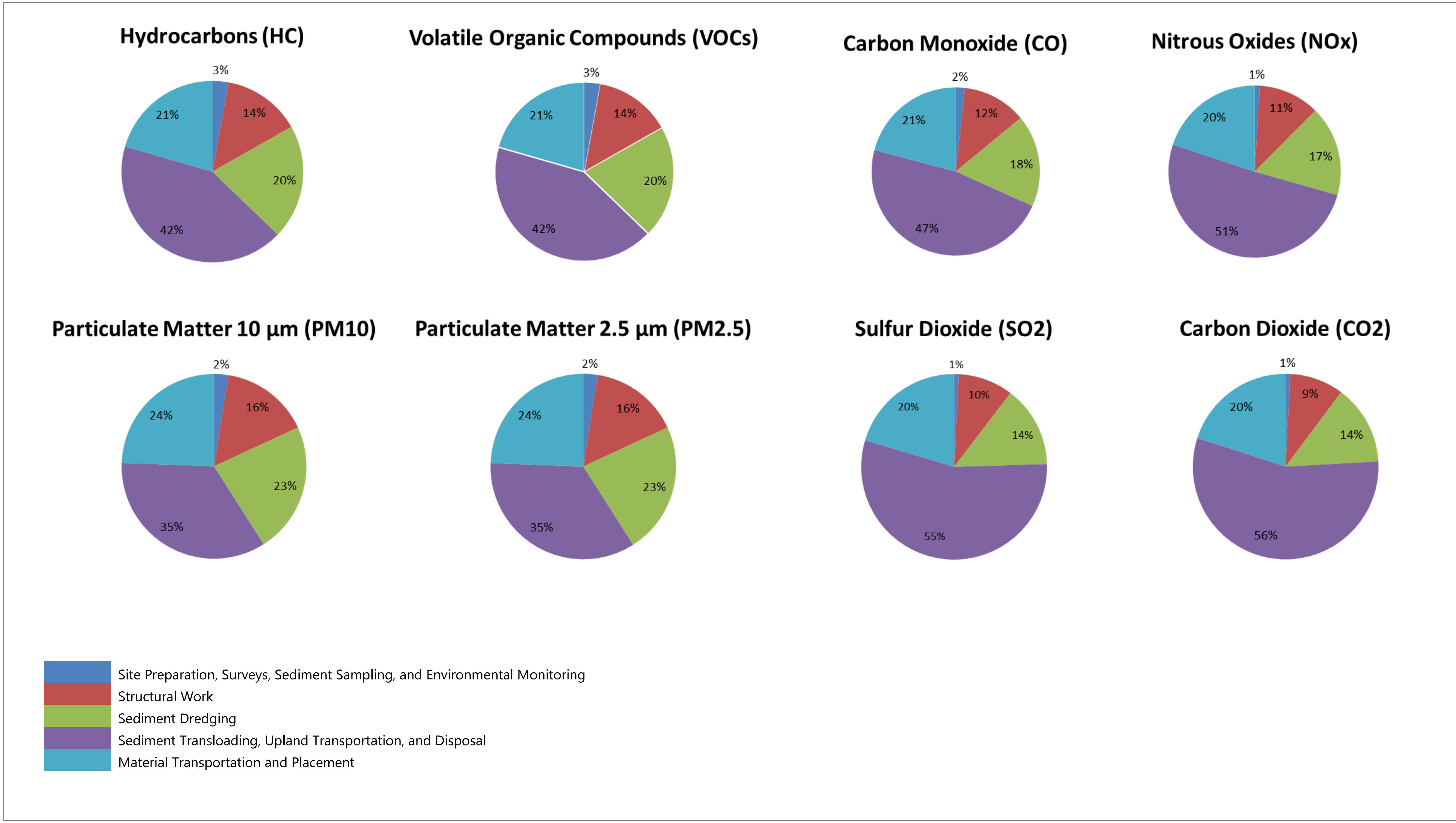


**Figure L-1**
**High-Level Summary of Direct Emissions by Construction Activity – Baseline Conditions**

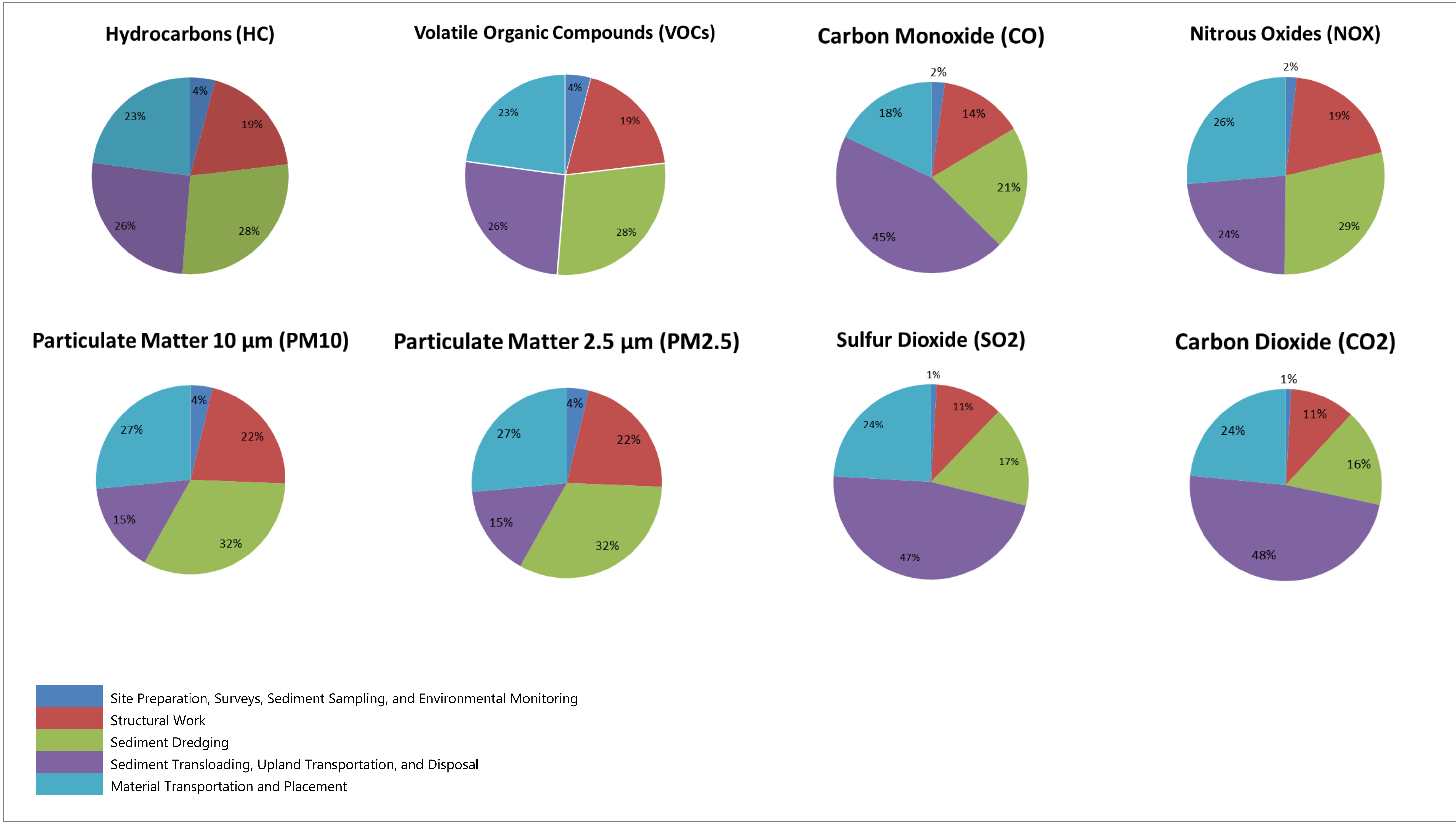


**Figure L-2**
**High-Level Summary of Direct Emissions by Construction Activity – Local Average Market Conditions**

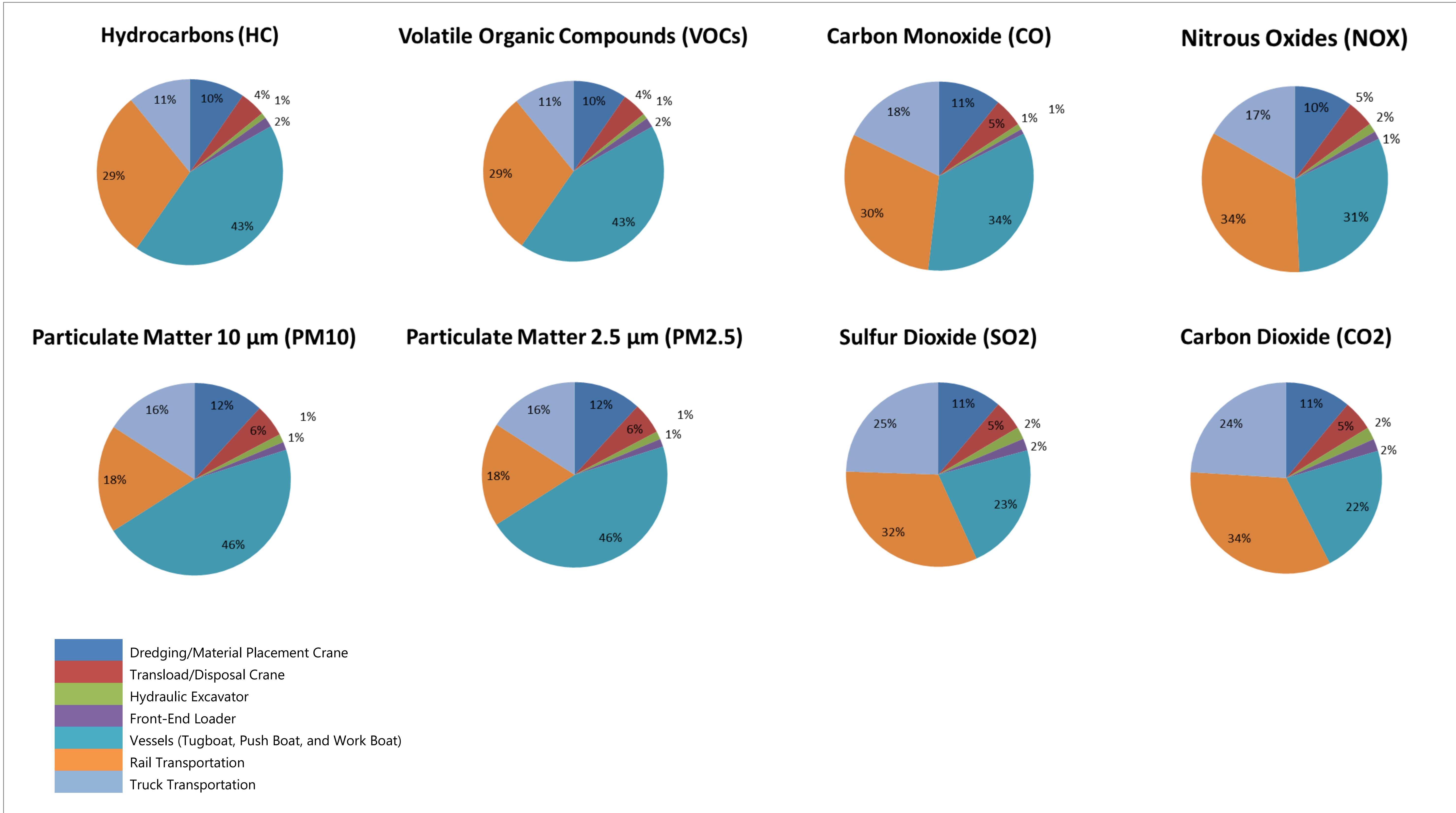




**Figure L-3**
**High-Level Summary of Direct Emissions by Equipment Type – Baseline Conditions**

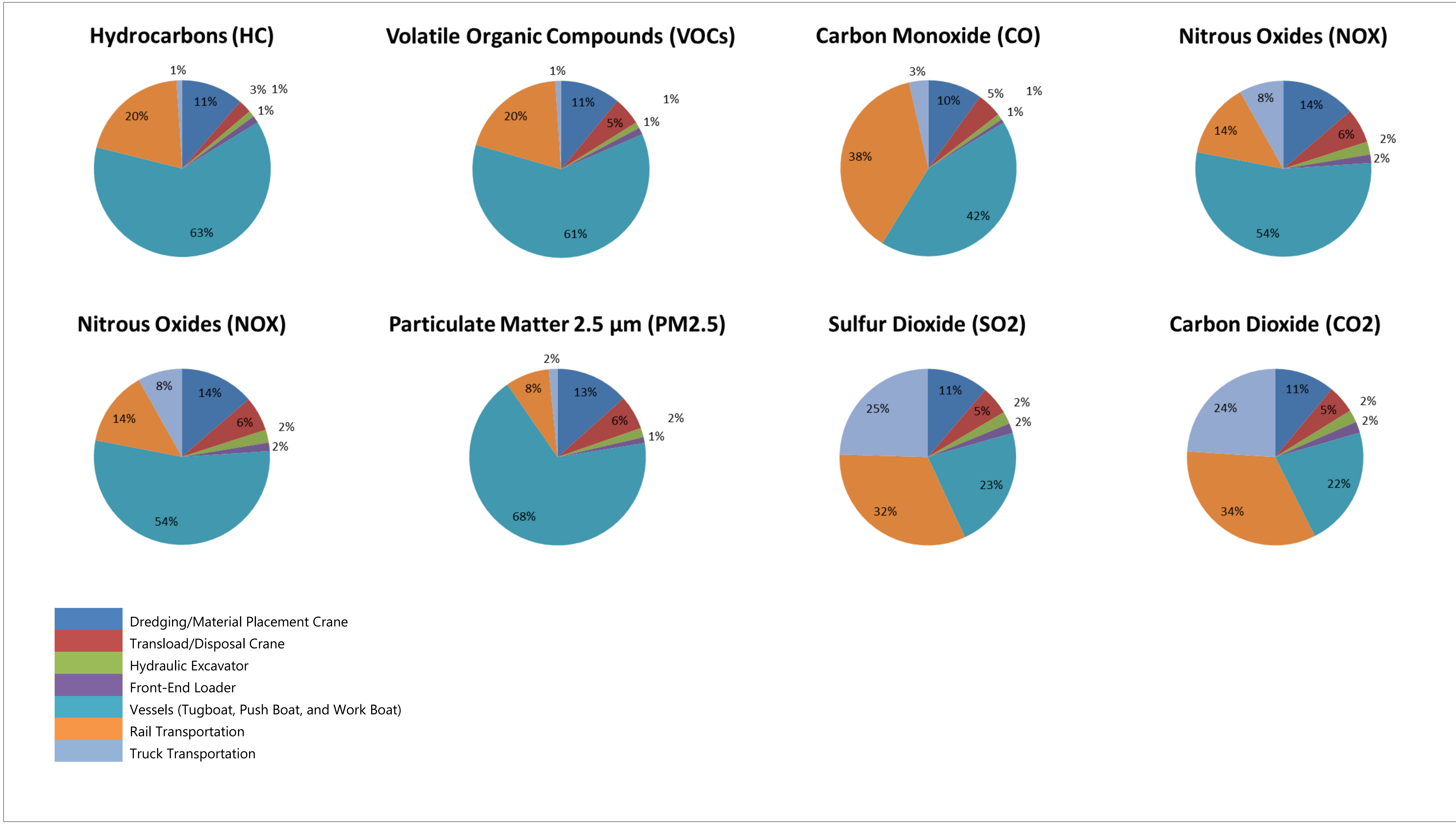


**Figure L-4**
**High-Level Summary of Direct Emissions by Equipment Type – Local Average Market Conditions**