APPENDIX I – SHORT-TERM EFFECTIVENESS METRICS

EAST WATERWAY OPERABLE UNIT FEASIBILITY STUDY

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PART 1: AIR EMISSIONS INVENTORY

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1 INTRODUCTION

An air emissions inventory has been conducted in this appendix as one of the measures of short-term effectiveness used for the CERCLA evaluation of alternatives for Sections 9 and 10 of the East Waterway (EW) Feasibility Study (FS). The main objective of this assessment was to estimate and compare the air pollutant emissions expected to result from the implementation of each alternative and includes the following primary components:

- The identification of the major activities associated with the implementation of the alternatives (primarily associated with the combustion of diesel fuel), which result in air pollutant emissions.
- The inventory of air pollutant emissions estimated from these activities over the likely period of time determined for implementation to occur.

This emissions inventory has generally been conducted in accordance with widely-accepted international (WRI/WBCSD 2004) and national (EPA 2005) greenhouse gas (GHG) accounting protocols and guidance. A GHG inventory is a quantification of GHGs emitted to or removed from the atmosphere during a specific period of time associated with a process or project (EPA 2017a). The net carbon emission or sequestration associated with a defined activity is often referred to as the activity's carbon footprint. This inventory considers one GHG (which would contribute to the project's carbon footprint) and seven exhaust air pollutants. In addition to carbon dioxide (CO_2) (the GHG), emissions were estimated for the following air pollutants (which are not GHGs) as part of this inventory:

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

2 OPERATIONAL BOUNDARIES AND SOURCES

The 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). This process involves identifying emissions sources associated with its "operations" (in this case the anticipated activities associated with the implementation of each alternative), and categorizing the resultant emissions as Scope 1 ("direct"), Scope 2 ("indirect"), or Scope 3 ("optional"), which are defined in the subsections below (WRI/WBCSD 2004; EPA 2005[1]).

2.1 Emissions Categories and Sources

2.1.1 Scope 1: Direct Emissions

Scope 1 (direct) emissions are from sources derived from conducting remedial activities and owned or controlled by the reporting entity, (e.g., stationary, mobile, and process-related sources from owned or controlled construction equipment and vehicles).

The following construction activities identified as contributing to direct emissions from diesel fuel combustion were accounted for within the operational boundaries considered in this inventory:

- Site Preparation
  - Equipment mobilization and demobilization
  - Pile removal
- Sediment Removal
  - Open-water dredging (mechanical)
  - Restricted access dredging (under the West Seattle Bridge)
  - Diver-assisted hydraulic dredging (in underpier areas)
  - Sediment pumping (due to hydraulic dredging in underpier areas)
- Sediment Transloading and Disposal

[1] Scope 1, 2, and 3 emissions categories are designations presented in WRI/WBCSD (2004). "Direct," "indirect," and "optional" are associated descriptive terms, as well as corresponding designations presented in EPA (2005).

- Mechanical offloading, which includes the following:
    - Transportation (via tug and barge) of dredged sediments to an offloading area outside the EW
    - Transportation (via rail) of dredged sediments for landfill disposal in eastern Washington state

- Capping/treatment Material Placement:
    - Transportation of materials to the EW, which includes the following:[2]
        - Transportation (via truck) of capping materials (i.e., sand, gravel, or armor stone) from a quarry to an onshore staging area
        - Transportation (via tug and barge) of capping materials from a staging area to the EW
        - Transportation (via rail) of in situ treatment material (activated carbon) from a vendor to the EW
    - Placement of sand for residuals management cover, capping, backfill, and enhanced natural recovery (ENR)
    - Placement of gravel for capping
    - Placement of armor stone for capping
    - Placement of activated carbon for in situ treatment (in underpier areas)
    - Placement of sand for ENR (under low bridges)

- Long-term Monitoring

This inventory estimates engine emissions from construction equipment and vehicles anticipated to be used to implement the activities listed above and during the time period in which each alternative is expected to be implemented. While these activities are not meant to be all-inclusive, they are likely to contribute the majority of emissions associated with the implementation of the alternatives. 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 activities, the effective operation time, and the

[2] See Section 2.1.3 for the basis for inclusion of these activities in Scope 1 (direct) emissions, rather than Scope 3 (optional) emissions.

daily fuel consumption. Because no alternative fuels were specifically identified as a fuel source during the development of alternatives in Section 8 of the FS, this inventory was based entirely on tracking fossil fuel consumption (primarily diesel fuel[3]). However, the opportunities for renewable energy source use in remedial action construction are identified in Part 2 of this appendix, and as discussed therein, could be evaluated and implemented where feasible during remedial design to help reduce the emissions associated with the selected alternative.

2.1.2 Scope 2: Indirect Emissions

Scope 2 (indirect) emissions are a consequence of conducting remedial activities of the reporting entity, but occur at sources owned or controlled by another entity and specifically result from the import or purchase of electricity, heating/cooling, or steam, and related transmission and distribution.

Indirect emissions were estimated in this inventory for the electricity used at the water treatment facility, where hydraulically dredged materials from underpier areas are handled and processed (i.e., treatment of dewatered liquid and contaminants). Other indirect emissions resulting from electricity usage associated with any ancillary activities (e.g., field trailer operations) were not included in this inventory because specific details related to these activities would not be available until remedial design.

2.1.3 Scope 3: Other Indirect Emissions (Optional)

Scope 3 (other indirect) emissions are typically considered optional in terms of reporting (WRI/WBCSD 2004; EPA 2005). These would be emissions that are a consequence of the activities of the reporting entity, but occur from sources not owned or controlled by that entity (and are not part of that entity's direct or indirect emissions). Examples of Scope 3 emission sources might include extraction and production of purchased materials; extraction, production, and transportation of purchased fuels; use of sold products; or employee commuting.

[3] For the purposes of this FS, sulfur content of diesel fuel is assumed to be 15 ppm (ultra-low sulfur diesel).

Emissions of this type have not been included because they were considered beyond the scope of this analysis, and it is unknown to what extent they would be accounted for in any inventories conducted by source entities (i.e., vendors, contractors, etc.).

Another source of emissions often considered as Scope 3 or "optional" is the transportation of purchased materials and waste disposal. While transportation of placement materials (for capping and treatment) and dredged sediments to and from the EW may fall under the control of a contracted entity, the emissions resulting from these activities are of significant magnitude relative to the other direct emissions from dredging activities[4]. Therefore, these emissions are included in this inventory in the direct emissions category because transportation of both capping (via truck and tug/barge) and treatment materials (via rail), and disposal of dredged sediment (via tug/barge and rail) are significant components of the remedial activities.

2.2 Emissions Not Included in This Inventory

The goal of this assessment is to account for the activities expected to contribute the majority of emissions associated with implementation of the alternatives. This approach is appropriate considering the FS-level analysis of alternatives presented in this document. While the major components of each alternative have been generally well defined in Section 8 of the FS, more detailed information pertaining to specific remedial activities will not be developed for the selected alternative until the design stage. Therefore, the activities discussed in the following subsections were considered in the analysis, but were not included in this inventory due to a lack of a basis for estimation at this time (or for other reasons as noted).

2.2.1 Scope 1: Direct Emissions

- Staging area and access road construction activities
- Transloading facility development (i.e., an onshore facility where dredged material would be stockpiled, dewatered, and loaded by rail for upland disposal)
- Any emissions at the Subtitle D landfill related to handling of sediments for disposal

[4] EPA (2005, pages 20 and 21) identifies situations in which "optional" emission activities may be included in the direct emissions category. The discussion in item 2 on page 21 specifically pertains to considering the relevance of the optional emission categories.

2.2.2 Scope 2: Indirect Emissions

- Electricity consumption likely to occur during implementation of an alternative, for example:
  - Indirect emissions from purchased electricity to power field office trailers or similar facilities
  - Heating or cooling energy requirements for any of the above facilities

2.2.3 Scope 3: Other Indirect Emissions (Optional)

- As noted in Section 2.1.3, optional emissions resulting from activities related to the processing of materials that will be used as part of the remediation (e.g., quarrying of riprap [armor stone], refining of diesel fuel, and excavation of gravel or sand from borrow pits) have not been included in this inventory because they were considered beyond the scope of this analysis, and it is unknown to what extent they would be accounted for in any inventories conducted by source entities (i.e., vendors, contractors, etc.).
- Any emissions resulting from employee commuting.

2.2.4 Other Greenhouse Gas Emission Contributions

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[5] (GWP; EPA 2005) and summing the results. In addition to CO_2, nitrous oxide (N_2O) and methane (CH_4) are other GHGs emitted during diesel fuel combustion (EPA 2008) typically included in the CO_2-eq total. As presented in table A-6 of EPA (2008), for all diesel fuel vehicle types tracked as part of this inventory, emission factors (EFs) are 0.26 grams per gallon (g/gal) for N_2O and 0.8 g/gal (or less) for CH_4, while CO_2 has an EF of 10.21 kilograms per gallon (kg/gal) (EPA 2011a). Although the GWPs of N_2O and

[5] 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 Table 6-3 of EPA (2005).

CH_4 are 310 and 21, respectively[6], 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[7]. For this reason, 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), and 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 this inventory.

[6] For every tonne of GHG emitted, the contribution to global warming associated with N_2O and CH_4 are 310 and 21 times higher, respectively, than for CO_2.

[7] 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 310) + (0.8g CH_4 x 21)] = 104.

3 METHODOLOGY

The alternative cost estimates developed in Appendix E of the FS were used as the primary basis for calculating emissions for each alternative. Specific types and number of construction vehicles and equipment, mass of dredged sediment and mass/volume of placement materials, and production rates for each activity were derived from that appendix.

For the direct emissions category, diesel fuel usage estimates were derived for each activity and alternative on a time basis (for construction equipment and vehicles) and on a mass-distance basis (for placement material and dredged sediment transport), and emissions were then calculated using available EFs from various U.S. Environmental Protection Agency (EPA) sources (see Section 3.2).

For the indirect emissions category, emissions expected to result from operation of the water treatment system were calculated (for those alternatives that included a hydraulic dredging component) based on estimated system operation time, an assumed electricity consumption rate, and available EFs (see Section 3.2).

3.1 Emission Calculation Inputs

3.1.1 Direct Emissions

Direct emissions were calculated based on estimating fuel usage associated with the remedial activities described in Section 2.1.1. Table 1 presents the general inputs for direct emission calculations by activity and alternative, including quantities (i.e., dredged sediment and placement material volume) and production rates obtained from Appendix E of the FS, and selected equipment and daily equipment operation rates assumed based on professional judgment and experience from similar projects.

3.1.1.1 Time-based Fuel Usage Estimates

For all direct 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 number

- 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 activity)

Table 2 presents a list of the assumptions for equipment and vehicles and fuel usage per piece of equipment considered in the direct emissions inventory.

3.1.1.2 Mass-Distance-based Fuel Usage Estimates

For activities related to transportation of placement material and dredged sediments, a mass-distance travelled approach was used to estimate total fuel usage. The mass of placement material and dredged sediments, and the distance travelled during transportation via rail, truck, or barge was accounted for, and available ton-mile[8]-based fuel economy factors (EPA 2011a) were used to calculate total fuel usage[9]. Therefore, input parameters to estimate fuel usage due to transportation of capping material (via truck and tug/barge), activated carbon (via rail), and dredged sediment for disposal (via rail) included the mass of materials (in tons) and distances travelled (in miles). Assumptions related to rail, truck, and barge diesel fuel consumption and transport capacity are presented in Tables 3, 4, and 5.

3.1.2 Indirect Emissions

Indirect emissions are related to the generation of electricity that would be purchased during remedial activities, as described in Section 2.1.2. Table 6 presents the general inputs for indirect emission calculation by alternative for the sediment removal activity, including quantities and production rate obtained from Appendix E of the FS. A water treatment system is anticipated to consume electricity for treating the hydraulically dredged materials from underpier areas (which applies only to Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5)). The expected total water treatment operation time and an assumed

[8] A unit of freight transportation is equivalent to a ton of freight moved 1 mile.
[9] This approach (as opposed to calculating fuel usage based on transport time and fuel consumption rates) was corroborated as most appropriate by Vincent Camobreco at EPA (Office of Transportation and Air Quality) (phone conversation between B. Solomon of Anchor QEA and V. Camobreco of EPA, September 26, 2013).

electricity consumption rate of 250 kilowatts (kW) (Table 7) were used to estimate total electricity usage.

3.2 Emission Factor Sources

3.2.1 Direct Emissions

EPA's NONROAD (2017b) and NMIM (2017c) models for estimating emissions from a fleet of construction equipment and vehicles were considered for this inventory. These models allow a user to specify equipment and vehicle type based on pre-defined equipment categories, horsepower, model year, and activity. Upon detailed review of these models, it was noted that available project details at the FS level would not readily align with several required input parameters and, therefore, attempts to accurately assign values to these parameters would introduce a potentially high degree of uncertainty. For example, a major input parameter is equipment and vehicle model years, which will not be known until the design stage for the selected alternative, and cannot accurately be estimated at the FS stage.

Based on correspondence with EPA (2011b), a simpler approach was selected to estimate emissions given the available level of detail regarding equipment and vehicle runtimes, fuel consumption rates, and quantities provided in the cost estimate (Appendix E of the FS). EPA provided a table of air pollutant EFs from the NONROAD model for 2013 (EPA 2013), which contains EFs (in grams of pollutant per gallon of fuel) for various equipment types and horsepower ranges that represent the national average EFs of all equipment and vehicles in use during that year. Finally, the EFs were selected from the 2013 NONROAD table (according to each equipment and vehicle expected to be used during remedial activities) based on horsepower and/or fuel consumption rates, which were determined based on professional judgment and experience on other similar projects. Table 8 presents the EFs for construction equipment and vehicles used in the direct emission inventory.

As described in Section 3.1.1.2, direct emissions associated with the transportation of placement material and dredged sediments were calculated based on tonnage, distance traveled, and diesel fuel economy factors. While national diesel fuel economy and EFs for locomotives were readily available (EPA 2009), such factors for trucks and barges were estimated indirectly by using the CO_2 EF for diesel fuel in kilograms of carbon dioxide per gallon (kg CO_2/gal) (i.e., 10.21 kg CO_2/gal; Table 2 of EPA 2011a) and dividing it by the CO_2 EF specific to trucks and barges in kg CO_2/ton-mile units (Table 9 of EPA 2011a) to derive specific ton-mile/gal fuel economies. The EFs for all air pollutants associated with truck and barge transportation of materials were then selected from the 2013 NONROAD table consistent with the methods described above. Emissions for all placement material and dredged sediment transport activities were based on one-way trips, as the ton-mile-based EFs were calculated from national average freight and fuel totals that were likely to have fuel usage from empty cargo return trips already factored into their values to some degree[10]. Tables 3, 4, and 5 present the EFs specific to rail, truck, and barge transportation of materials used in the direct emission inventory.

3.2.2 Indirect Emissions

The most recent emission rates (2012) for CO_2, NO_X, and SO_2 (in mass per megawatt hour [mass/MWh]) for the Western Electricity Coordinating Council (WECC) Northwest subregion (EPA 2015) were used to calculate indirect emissions from electricity usage for operating a water treatment system associated with the handling of hydraulically dredged materials from underpier areas (Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5))[11]. Table 7 presents the EFs for electricity consumption used in the indirect emission inventory.

[10] This information is based on discussion with EPA (see footnote 9).

[11] See Section 2.2.4 regarding N_2O and CH_4. Based on EFs for electricity generation in the WECC Northwest subregion (EPA 2015), the individual contribution of CO_2 to CO_2-eq was calculated to be nearly 200 times greater than the collective contribution of N_2O and CH_4 (i.e., [665.75 lb CO_2/MWh x 1,000 MWh/GWh] / [(10.38 lb N_2O/GWh x 310) + (12.6 lb CH_4/GWh x 21)] = 191).

4 RESULTS AND DISCUSSION

Results from the air emissions inventory are summarized in Tables 9 through 13. These tables include detailed explanatory notes documenting the assumptions, sources of EFs, and methods of each calculation presented.

Tables 9 and 10 report detailed summaries of the direct and indirect emissions associated with the activities (for each piece of construction equipment and vehicle used) and by alternative. All emissions are presented in metric tons.

Tables 11a and 11b present the estimated total direct and total indirect emissions, respectively, for the air pollutants tracked in this inventory. In the direct emissions category (Table 11a), all action alternatives have total direct emissions across pollutants in a similar order of magnitude, ranging from 16,200 to 22,400 metric tons; however, Alternative 3E(7.5) results in the highest air pollutant emissions because of its large dredge volume, followed by Alternatives 2C+(12), 3B(12), 3C+(12), and 2C+(7.5). In the indirect emissions category (Table 11b), Alternative 3E(7.5) also results in a much higher CO_2 indirect emission total (compared to the other four alternatives) because the largest hydraulically dredged volume is associated with this alternative, which in turn results in the largest volume of water treated, electricity consumed, and therefore, indirect emissions. Across alternatives and emission categories, CO_2 accounts for an approximate average of 99% of the total pollutant mass, with the remaining seven pollutants accounting for 1%. A stacked bar chart under these tables graphically presents the CO_2 emission results by scope.

Table 12 presents direct CO_2 emissions totaled by the activities tracked in this inventory (site preparation, sediment removal, transloading and disposal, material placement, and long-term monitoring). A series of pie charts are also provided under Table 12, depicting the relative contribution to overall CO_2 emissions from these five activity categories[12].
Alternative 3E(7.5) has the largest CO_2 emissions among the alternatives in most activity categories (especially sediment removal [3,100 metric tons] and transloading/disposal

[12] The direct CO_2 emissions contribution estimated from long-term monitoring activities resulted each in less than one-tenth of one percent of the total and, therefore, they are not discernible in the pie charts.

[15,000 metric tons]), for an overall total of 22,700 metric tons. With the exception of Alternative 1A(12) (which addresses underpier areas with MNR), all other alternatives include comparable levels of material placement (for RMC, ENR, capping, and in situ treatment), and therefore, have CO_2 emissions in the material placement activity category on an average of 3,500 metric tons. CO_2 emissions due to site preparation and long-term monitoring activities are very similar among alternatives, since they have the same general assumptions. On average, 70% of the total direct CO_2 emissions were estimated to result from the transloading and disposal, followed by material placement (approximately 20%), and sediment removal (approximately 9%) activities.

In addition, approximately 71% to 79% of the emissions of PM_{10}, $PM_{2.5}$, CO_2, and NOx and 27% to 49% for the remaining air pollutants resulted from the transloading, transportation, and disposal by rail of dredged sediments regardless of the alternative (see Table 9). The mass emitted due to the rail transport and disposal component increases proportionally to the volume of dredged sediments (Alternatives 2C+(7.5) and 3E(7.5) have largest dredge volumes [with more than 1 million cubic yards dredged], followed by Alternatives 3B(12), 3C+(12), 2B(12), 2C+(12), and lastly, by Alternatives 1A(12), 1B(12), and 1C+(12)). Not only are larger volumes of dredged sediment generated for disposal, compared to the volumes of material needed for placement (approximately three to four times), but also the distance travelled is a key factor (284 miles by train [for sediment disposal to landfill] versus 20 miles by truck and barge from quarry to the EW [for material placement]) (Table 1).

The impacts of train, truck, and barge transport are based on their specific diesel fuel economies (400, 34, and 213 ton-mile/gal, respectively; see Tables 3, 4, and 5) and the distances that would be required for each activity.

When based on diesel fuel economy, rail transport is nearly twice as efficient as tug/barge transport, and more than ten times more efficient than truck transport. However, when considering combined tonnages and travelled distances for the transport of material, air emissions of rail is larger than that of truck and barge for the EW alternatives. This is reflected in the pie charts under Table 12, where emissions due to transloading and disposal (which is primarily rail transport) are approximately 5 times larger than emissions due to material placement (which is primarily truck and barge transport).

Finally, in order to provide some context regarding the GHG emissions estimated for the alternatives, several comparison equivalencies have been summarized in Table 13. This table illustrates the magnitude of other activities that would result in CO_2 emissions equivalent to the CO emissions estimated for each alternative. Specifically, the number of passenger vehicles that would emit an equivalent quantity of CO_2-eq in 1 year, the number of barrels of oil consumed that would emit an equivalent amount of CO_2, and the number of homes from which the annual energy use would result in an equivalent amount of CO_2 emitted, are presented in this table.

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TABLES

Table 1. General Inputs for Direct Emission Calculation

Activity	Type of Vehicle/ Equipment Used	SCC Description	Notes	Equipment Uptime	Equipment Quantity	Total Daily Diesel Usage (gal/day)	Production Rate (quantity/ day)	One-way Distance (miles)	Quantity Units	Quantities by Alternative								
										1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B12)	3C+(12)	2C+(7.5)	3E(7.5)
SITE PREPARATION																		
Equipment Mobilization/Demobilization (8 hours/day)																		
	Tug Boat (800 HP) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.2	5	120	0.1	na	construction season	9	9	9	10	10	10	10	11	13
Pile Removal (12 hrs/day)																		
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.7	1	101	25	na	# piles	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	Work Boat 1	Two-stroke Outboard (WB)		0.7	1	13	25	na	# piles	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	25	na	# piles	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
SEDIMENT REMOVAL																		
Open-water Dredging (12 hours/day)																		
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12 hr-shift.	0.7	1	109	1,100	na	cy sediment	813,120	813,120	813,120	902,212	902,212	938,455	938,455	1,007,892	1,016,453
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	1,100	na	cy sediment	813,120	813,120	813,120	902,212	902,212	938,455	938,455	1,007,892	1,016,453
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)																		
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12 hr-shift.	0.7	1	109	270	na	cy sediment	0	0	0	0	0	16,651	16,651	0	19,365
	Push Boat	Two-stroke Outboard (PB)		0.7	1	17	270	na	cy sediment	0	0	0	0	0	16,651	16,651	0	19,365
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	270	na	cy sediment	0	0	0	0	0	16,651	16,651	0	19,365
Diver-assited Hydraulic Dredging (Underpier) (8 hours/day)																		
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8 hr-shift.	0.7	1	50	40	na	cy sediment	0	0	7,016	0	7,016	0	7,016	7,016	46,216
	Push Boat 2	Two-stroke Outboard (PB)		0.7	1	11	40	na	cy sediment	0	0	7,016	0	7,016	0	7,016	7,016	46,216
	Work Boat 2	Two-stroke Outboard (WB)		0.7	2	17	40	na	cy sediment	0	0	7,016	0	7,016	0	7,016	7,016	46,216
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)																		
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8 hr-shift.	0.8	6	77	40	na	cy sediment	0	0	7,016	0	7,016	0	7,016	7,016	46,216
SEDIMENT TRANSLOADING AND DISPOSAL																		
Mechanical Offloading (12 hours/day)																		
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12 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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.2	1	na	na	5	cy sediment	813,120	813,120	820,135	902,212	909,228	955,106	962,121	1,014,908	1,082,034
	100-ton Crane	Diesel Cranes		0.7	2	202	1,100	na	cy sediment	813,120	813,120	820,135	902,212	909,228	955,106	962,121	1,014,908	1,082,034
	Front-end Loader	Diesel Rough Terrain Forklifts		0.8	2	77	1,100	na	cy sediment	813,120	813,120	820,135	902,212	909,228	955,106	962,121	1,014,908	1,082,034
	Rail	na		na	1	na	na	284	cy sediment	813,120	813,120	820,135	902,212	909,228	955,106	962,121	1,014,908	1,082,034

Table 1. General Inputs for Direct Emission Calculation

Activity	Type of Vehicle/ Equipment Used	SCC Description	Notes	Equipment Uptime	Equipment Quantity	Total Daily Diesel Usage (gal/day)	Production Rate (quantity/ day)	One-way Distance (miles)	Quantity Units	Quantities by Alternative 1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B12)	3C+(12)	2C+(7.5)	3E(7.5)
CAPPING/TREATMENT MATERIAL PLACEMENT																		
Transportation of Materials to EW																		
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	na	1	na	na	20	ton	375,258	376,075	375,986	361,020	360,935	343,806	343,369	373,192	354,937
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		na	1	na	na	20	ton	375,258	376,075	375,986	361,020	360,935	343,806	343,369	373,192	354,937
	Rail for Activated Carbon	na		na	1	na	na	2,452	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)																		
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12 hr-shift.	0.7	1	101	940	na	cy sand	234,151	234,756	234,690	223,604	223,541	229,661	229,338	232,434	237,720
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	940	na	cy sand	234,151	234,756	234,690	223,604	223,541	229,661	229,338	232,434	237,720
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	940	na	cy sand	234,151	234,756	234,690	223,604	223,541	229,661	229,338	232,434	237,720
Capping (Gravel) (12 hours/day)																		
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12 hr-shift.	0.7	1	101	940	na	cy gravel	20,620	20,620	20,620	20,620	20,620	11,769	11,769	20,708	11,857
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	940	na	cy gravel	20,620	20,620	20,620	20,620	20,620	11,769	11,769	20,708	11,857
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	940	na	cy gravel	20,620	20,620	20,620	20,620	20,620	11,769	11,769	20,708	11,857
Capping (Armor) (12 hours/day)																		
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12 hr-shift.	0.7	1	101	560	na	cy armor stone	30,931	30,931	30,931	30,931	30,931	17,654	17,654	31,062	17,786
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	560	na	cy armor stone	30,931	30,931	30,931	30,931	30,931	17,654	17,654	31,062	17,786
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	560	na	cy armor stone	30,931	30,931	30,931	30,931	30,931	17,654	17,654	31,062	17,786
In situ Treatment (Underpier) (12 hours/day)																		
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12 hr-shift.	0.5	1	24	60	na	cy AC	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	60	na	cy AC	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	60	na	cy AC	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Enhanced Natural Recovery (Low Bridge) (12 hours/day)																		
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12 hr-shift.	0.5	1	24	60	na	cy sand	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.2	1	36	60	na	cy sand	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562
	Work Boat 1	Two-stroke Outboard (WB)		0.7	2	25	60	na	cy sand	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562

***LONG-TERM MONITORING* (12 hours/day)**																		
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.7	1	13	0.1	na	monitoring events	8	8	8	8	8	8	8	8	8

Notes:

1. Quantities and production rates by alternative were obtained from Appendix E (Cost Estimate).
2. Equipment and daily equipment operation rates assumed based on best professional judgment and experience in similar sediment projects.

AC = activated carbon; cy = cubic yard; ENR = enhanced natural recovery; EW = East Waterway; gal = gallon; HP = horse power; hr = hour; na = not applicable; PB = push boat; RMC = residuals management cover; SCC = Standard Classification Code; WB = work boat

Table 2. Equipment Type and Fuel Usage Assumptions per Equipment

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%	8	9	50
Front-end Loader	80%	12	4	38
150-ton Crane 1	70%	12	12	101
150-ton Crane 2	70%	8	12	67
100-ton Crane	70%	12	12	101
Derrick Rig	70%	12	13	109
Telebelt	50%	12	4	24
High-solids Pump	80%	8	2	13
Tug Boat (3,000 HP)	20%	12	40	96
Tug Boat (800 HP)	20%	12	15	36
Tug Boat (800 HP) 2	20%	8	15	24
Push Boat	70%	12	2	17
Push Boat 2	70%	8	2	11
Work Boat 1	70%	12	1.5	13
Work Boat 2	70%	8	1.5	8

Notes:

1. Equipment uptimes (effective operation time) and fuel consumption rates were estimated for each equipment based on best professional judgment and experience on other similar sediment projects.
2. Daily use of equipment is based on assumptions provided in Appendix E (Cost Estimate).
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 1.

gal = gallon; HP = horsepower

Table 3. Rail Transportation Assumptions

Parameter	Value	Unit	Comments/Reference
Diesel fuel economy for train/locomotive	400	ton-mi/gal	National average fuel consumption rate of 400 ton-miles/gallon based from data collected by the Association of American Railroads, as discussed on page 3 of EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025).
Emission Factors			Source: EPA Technical Highlights "Emission Factors for Locomotives" (April 2009; Office of Transportation and Air Quality [OTAQ]; EPA-420-F-09-025)
Hydrocarbons (HC)	0.26	g/bhp-hr	Emission factors for rail transportation (for Tier 2 Locomotives) are available in Table 1 (pg.2) of Line-Haul Emission Factors. Tier 2 corresponds to locomotives manufactured between 2005 and 2011, which is a reasonable assumption by the time the EW project is implemented. Emission factors as following: HC = 0.26 g/bhp-hr, NO_X = 4.95 g/bhp-hr, PM_{10} = 0.18 g/bhp-hr, and CO = 1.28 g/bhp-hr. 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). SO_2 emissions are dependent upon fuel properties and not engine properties (pg.5): SO_2 (g/gal) = (fuel density) x (conversion factor) x (64 g SO_2/32 g S) x (S content of fuel) The current density of diesel fuel is 0.832 kg/L (3,150 g/gal) (http://ies.jrc.ec.europa.eu/uploads/media/TTW_Report_010307.pdf). The current sulfur content of diesel fuel is 15 ppm (ultra-low-sulfur diesel fuel; https://www.epa.gov/aboutepa/reduced-sulfur-content-diesel-fuel). The fraction of fuel sulfur converted to SO_2 is 97.8% (pg.5). Therefore, SO_2 (g/gal) = (3,150 g/gal) x (0.978) x (64 g SO_2 / 32 g S) x (15e-6) = 0.092 g/gal The CO_2 emission factor is 10.21 kg CO_2/gal, as in Table 2 - "CO_2 Emissions for Transportation Fuels for Road Vehicles, Locomotives, and Aircraft" from Emission Factors for Greenhouse Gas Inventories November 2011)
	5.41	g/gal	
Volatile Organic Compounds (VOCs)	0.27	g/bhp-hr	
	5.69	g/gal	
Carbon Monoxide (CO)	1.28	g/bhp-hr	
	26.62	g/gal	
Nitrous Oxides (NO_X)	4.95	g/bhp-hr	
	102.96	g/gal	
Particulate Matter 10 µm (PM_{10})	0.18	g/bhp-hr	
	3.74	g/gal	
Particulate Matter 2.5 µm ($PM_{2.5}$)	0.1746	g/bhp-hr	
	3.63	g/gal	
Sulfur Dioxide (SO_2)	0.092	g/gal	
Carbon Dioxide (CO_2)	10,210	g/gal	
Distance from shore to Subtitle D landfill (Roosevelt, WA)	284	miles	Sediment is assumed to be transferred from an on-shore offloading facility in Seattle, WA to the landfill in Roosevelt, WA.
Distance from activated carbon vendor (Toledo, OH) to EW	2452	miles	Activated carbon is assumed to be transported from a vendor in Toledo, OH to EW.

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
bph = usable power; EW = East Waterway; g = gram; gal = gallon; hr = hour; kg = kilogram; L = liter; mi = mile; ppm = parts per million

Table 4. Truck Transportation Assumptions

Parameter	Value	Unit	Comments/Reference
Dump Truck			Assumed truck capacity and fuel consumption based on 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 diesel fuel	10.21	kg CO_2/gal	Source: Table 2 - "CO_2 Emissions for Transportation Fuels for Road Vehicles, Locomotives, and Aircraft" from *Emission Factors for Greenhouse Gas Inventories,* November 2011
CO_2 emission factor for trucks	0.297	kg CO_2/ton-mile	Source: Table 9 - "Product Transport Emission Factors" from *Emission Factors for Greenhouse Gas Inventories* November 2011
Diesel fuel economy for trucks	34	ton-mile/gallon	Calculated as 10.21 kg/gal / 0.297 kg/ton-mi ≈ 34 ton-mile / gal
Emission Factors			Estimates of average in-use emission factors and other information from EPA's NONROAD2008a model for the 2013 calendar year (includes all model years present in the 2013 fleet). This information is found in the MS Excel File "2013 National Avg emissions factors.xls", which was provided by an EPA NONROAD representative. Emission factors from the NONROAD08 spreadsheet were chosen based on equipment type and estimated fuel consumption rate, which is based on horsepower (HP).
Hydrocarbons (HC)	3.02	g/gal	
Volatile Organic Compounds (VOCs)	3.18	g/gal	
Carbon Monoxide (CO)	18.05	g/gal	
Nitrous Oxides (NO_X)	44.56	g/gal	
Particulate Matter 10 µm (PM_{10})	2.92	g/gal	
Particulate Matter 2.5 µm ($PM_{2.5}$)	2.92	g/gal	
Sulfur Dioxide (SO_2)	0.18	g/gal	
Carbon Dioxide (CO_2)	10,210	g/gal	

Notes:

1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
2. Emission factors are deduced by interpolating fuel consumption rate of 13 gal/hour for a dump truck into the 2013 EPA NONROAD Emission Factors.

g = gram; gal = gallon; hp = horsepower; hr = hour; kg = kilogram; mi = mile

Table 5. Barge Transportation Assumptions

Parameter	Value	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. Empty tug/barges typically consume 15 gal/hour. 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" http://www.epa.gov/ttn/chief/conference/ei11/poster/agyei.pdf
Average power	3000	hp	
Fuel consumption	40	gal/hr	
CO_2 emission factor for diesel fuel	10.21	kg CO_2/gal	Source: Table 2 - "CO2 Emissions for Transportation Fuels for Road Vehicles, Locomotives, and Aircraft" from *Emission Factors for Greenhouse Gas Inventories* November 2011)
CO_2 emission factor for boats	0.048	kg CO_2/ton-mile	Source: Table 9 - "Product Transport Emission Factors" from *Emission Factors for Greenhouse Gas Inventories* November 2011
Diesel fuel economy for boats	213	ton-mile / gallon	Calculated as 10.21 kg/gal / 0.048 kg/ton-mi ≈ 213 ton-mile/gal
Emission Factors			Estimates of average in-use emission factors and other information from EPA's NONROAD2008a model for the 2013 calendar year (includes all model years present in the 2013 fleet). This information is found in the MS Excel File "2013 National Avg emissions factors.xls", which was provided by an EPA NONROAD representative. Emission factors from the NONROAD08 spreadsheet were chosen based on equipment type and estimated fuel consumption rate, which is based on horsepower (hp).
Hydrocarbons (HC)	4.88	g/gal	
Volatile Organic Compounds (VOCs)	5.14	g/gal	
Carbon Monoxide (CO)	20.07	g/gal	
Nitrous Oxides (NO_X)	117.05	g/gal	
Particulate Matter 10 µm (PM_{10})	2.14	g/gal	
Particulate Matter 2.5 µm ($PM_{2.5}$)	2.14	g/gal	
Sulfur Dioxide (SO_2)	0.28	g/gal	
Carbon Dioxide (CO_2)	10,210	g/gal	
Distance from EW to offloading area (LaFarge) - for open-water dredging activity	5	miles	Sediment is assumed to be transported by barge to an offloading area in Lafarge, which is 5 miles from middle point of the EW. LaFarge is currently approved by EPA as an offloading area of dredged sediment for other local projects.
Distance from shore to EW - for material placement activity	20	miles	Sand, gravel, and armor are assumed to be transported by barge from shore to EW.

Notes:
1. Ton-mile is a unit of freight transportation equivalent to a ton of freight moved 1 mile.
2. Emission factors are deduced by interpolating fuel consumption rate of 40 gal/hour for a tug/barge into the 2013 EPA NONROAD Emission Factors.
EW = East Waterway; g = gram; gal = gallon; hp = horsepower; hr = hour; kg = kilogram; mi = mile

Table 6. General Inputs for Indirect Emission Calculation

Activity	Type of Equipment	Notes	Electricity Consumption Rate (kW)	Production Rate (quantity/ day)	Quantity Units	Quantity Inputs by Alternative								
						1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
SEDIMENT REMOVAL														
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)														
	Water Treatment System	Assumed one 8-hour shift. Assumed electricity usage for water treatment of hydraulically dredged sediments.	250	40	cy sediment	0	0	7,016	0	7,016	0	7,016	7,016	46,216

Notes:

1. Quantities and production rate by alternative were obtained from Appendix E (Cost Estimate).

cy = cubic yard; kW = kilowatt

Table 7. Electricity Assumptions

Parameter	Value	Unit	Comments/Reference
Energy consumption rate	250	kW	Estimated consumption rate of 250 kW of the water treatment system for hydraulically dredged sediments based on best professional judgement and experience on other similar sediment projects.
Emission Factors			Source: EPA guidance document "The Emissions & Generation Resource Integrated Database, Technical Support Document for eGRID with Year 2012 Data (eGRID2012) " (Office of Atmospheric Programs, Clean Air Markets Division, October 2015). (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html) Subregion: NWPP (WECC Northwest). Emission factors in lb/MWh units are converted to g/MWh for consistency of overall emission inventory.
Carbon Dioxide (CO_2)	665.75	lb/MWh	
	301977.5	g/MWh	
Nitrous Oxides (NO_X)	0.7240	lb/MWh	
	328.4	g/MWh	
Sulfur Dioxide (SO_2)	0.7587	lb/MWh	
	344.1	g/MWh	

Notes:

g = gram; hr = hour; kW = kilowatt; lb = pound; MWh = megawatt-hour; NWPP = North West Power Pool; WECC = Western Electricity Coordinating Council

Table 8. Emission Factors for Construction Equipment and Vehicles

Type of Vehicle/Equipment Used	SCC Description	Fuel Consumption Rate (gal/hour)	Emission Factors (g/gal)							
			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)
Work Boat	Two-stroke Outboard (WB)	1.5	423.15	437.53	982.49	29.01	8.72	8.72	1.55	7,556
Push Boat	Two-stroke Outboard (PB)	2	321.77	332.71	1,009.34	37.16	6.36	6.36	1.62	7,885
100-ton Crane, 150-ton Crane, Derrick Rig	Diesel Cranes	12	4.01	4.23	22.03	75.76	3.05	3.05	0.19	10,261
Hydraulic Excavator	Diesel Excavators	9	3.46	3.64	17.63	49.06	3.09	3.09	0.18	10,263
Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)	15	5.26	5.54	19.98	110.88	2.12	2.12	0.28	10,257
Telebelt	Diesel Other Material Handling Equipment	4	13.32	14.02	54.23	95.51	8.48	8.48	0.19	10,231
High Solids Pump	Diesel Pumps	2	9.88	10.41	49.40	89.34	8.96	8.96	0.20	10,242
Front-end Loader	Diesel Rough Terrain Forklifts	4	5.06	5.33	24.53	64.55	5.26	5.26	0.19	10,257

Notes:

1. Estimates of average in-use emission factors and other information from EPA's NONROAD model for the 2013 calendar year (includes all model years present in the 2013 fleet). This information is found in the MS Excel File "2013 National Avg emissions factors.xls", which was provided by an EPA NONROAD official (EPA 2013b). Emission factors from the NONROAD spreadsheet were derived based on selected equipment type, and estimated fuel consumption rate (according to designated horsepower).
2. Emission factors are deduced by interpolating the fuel consumption rate (gal/hour) for the specific equipment (based on its SCC description) into the NONROAD excel spreadsheet.

CO = carbon monoxide; CO_2 = carbon dioxide; g = gram; gal = gallon; HP = horsepower; 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 compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	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)
				Alternative 1A(12) - Total Emissions (tonnes)							
SITE PREPARATION											
Equipment Mobilization/Demobilization (8 hours/day)											
	Tug Boat (800 HP) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0663	0.0698	0.2518	1.397	0.02677	0.02677	0.00348	129.2
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.303**	**0.315**	**0.865**	**1.877**	**0.047**	**0.047**	**0.005**	**189**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3241	0.3412	1.7786	6.1157	0.2464	0.2464	0.0153	828.2630
	Work Boat 1	Two-stroke Outboard (WB)		7.8823	8.1503	18.3016	0.5403	0.1624	0.1624	0.0289	140.7597
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat 2	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 2	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**8.21**	**8.49**	**20**	**6.66**	**0.41**	**0.41**	**0.04**	**969**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1398	0.1472	0.5753	3.3559	0.0614	0.0614	0.0079	292.7231
	100-ton Crane	Diesel Cranes		0.5983	0.6300	3.2835	11.2905	0.4549	0.4549	0.0282	1529.1010
	Front-end Loader	Diesel Rough Terrain Forklifts		0.2872	0.3025	1.3928	3.6645	0.2988	0.2988	0.0108	582.3185
	Rail	na		4.6832	4.9314	23.0557	89.1605	3.2422	3.1449	0.0797	8841.5807
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**5.71**	**6.01**	**28**	**107**	**4.06**	**3.96**	**0.13**	**11,246**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 1A(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6596	0.6945	3.9408	9.7287	0.6379	0.6379	0.0390	2229.0318
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1721	0.1812	0.7080	4.1300	0.0756	0.0756	0.0098	360.2476
	Rail for Activated Carbon	na		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.1008	0.1061	0.5532	1.9023	0.0766	0.0766	0.0048	257.6390
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0472	0.0497	0.1792	0.9943	0.0190	0.0190	0.0025	91.9765
	Work Boat 1	Two-stroke Outboard (WB)		2.6562	2.7465	6.1673	0.1821	0.0547	0.0547	0.0097	47.4333
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0089	0.0093	0.0487	0.1675	0.0067	0.0067	0.0004	22.6889
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0042	0.0044	0.0158	0.0876	0.0017	0.0017	0.0002	8.0999
	Work Boat 1	Two-stroke Outboard (WB)		0.2339	0.2419	0.5431	0.0160	0.0048	0.0048	0.0009	4.1772
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0224	0.0235	0.1227	0.4218	0.0170	0.0170	0.0011	57.1273
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0105	0.0110	0.0397	0.2205	0.0042	0.0042	0.0005	20.3943
	Work Boat 1	Two-stroke Outboard (WB)		0.5890	0.6090	1.3675	0.0404	0.0121	0.0121	0.0022	10.5176
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0043	0.0045	0.0176	0.0310	0.0027	0.0027	0.0001	3.3177
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0026	0.0027	0.0097	0.0539	0.0010	0.0010	0.0001	4.9891
	Work Boat 1	Two-stroke Outboard (WB)		0.1441	0.1490	0.3345	0.0099	0.0030	0.0030	0.0005	2.5729
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**4.66**	**4.83**	**14**	**18**	**0.92**	**0.92**	**0.07**	**3,120**
***LONG-TERM MONITORING* (12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**19**	**20**	**64**	**130**	**5.4**	**5.3**	**0.25**	**16,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 1B(12) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0663	0.0698	0.2518	1.397	0.02677	0.02677	0.00348	129.2
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3033**	**0.3153**	**0.8646**	**1.8768**	**0.0465**	**0.0465**	**0.0054**	**189.1842**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3241	0.3412	1.7786	6.1157	0.2464	0.2464	0.0153	828.2630
	Work Boat 1	Two-stroke Outboard (WB)		7.8823	8.1503	18.3016	0.5403	0.1624	0.1624	0.0289	140.7597
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat 2	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 2	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**8.2**	**8.5**	**20**	**7**	**0.41**	**0.41**	**0.044**	**969**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1398	0.1472	0.5753	3.3559	0.0614	0.0614	0.0079	292.7231
	100-ton Crane	Diesel Cranes		0.5983	0.6300	3.2835	11.2905	0.4549	0.4549	0.0282	1529.1010
	Front-end Loader	Diesel Rough Terrain Forklifts		0.2872	0.3025	1.3928	3.6645	0.2988	0.2988	0.0108	582.3185
	Rail	na		4.6832	4.9314	23.0557	89.1605	3.2422	3.1449	0.0797	8841.5807
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**5.7**	**6.0**	**28**	**107**	**4.1**	**4.0**	**0.13**	**11,246**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 1B(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6610	0.6960	3.9494	9.7499	0.6393	0.6393	0.0391	2233.8843
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1725	0.1816	0.7096	4.1390	0.0758	0.0758	0.0098	361.0318
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9064
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.1011	0.1064	0.5547	1.9073	0.0768	0.0768	0.0048	258.3048
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0473	0.0498	0.1797	0.9968	0.0191	0.0191	0.0025	92.2142
	Work Boat 1	Two-stroke Outboard (WB)		2.6631	2.7536	6.1832	0.1825	0.0549	0.0549	0.0097	47.5559
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0089	0.0093	0.0487	0.1675	0.0067	0.0067	0.0004	22.6889
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0042	0.0044	0.0158	0.0876	0.0017	0.0017	0.0002	8.0999
	Work Boat 1	Two-stroke Outboard (WB)		0.2339	0.2419	0.5431	0.0160	0.0048	0.0048	0.0009	4.1772
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0224	0.0235	0.1227	0.4218	0.0170	0.0170	0.0011	57.1273
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0105	0.0110	0.0397	0.2205	0.0042	0.0042	0.0005	20.3943
	Work Boat 1	Two-stroke Outboard (WB)		0.5890	0.6090	1.3675	0.0404	0.0121	0.0121	0.0022	10.5176
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0043	0.0045	0.0176	0.0310	0.0027	0.0027	0.0001	3.3177
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0026	0.0027	0.0097	0.0539	0.0010	0.0010	0.0001	4.9891
	Work Boat 1	Two-stroke Outboard (WB)		0.1441	0.1490	0.3345	0.0099	0.0030	0.0030	0.0005	2.5729
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.8**	**6.0**	**17**	**23**	**1.1**	**1.1**	**0.08**	**3,649**
LONG-TERM MONITORING (12 hours/day)											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**20**	**21**	**67**	**140**	**5.6**	**5.5**	**0.26**	**16,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 1C+(12) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0663	0.0698	0.2518	1.397	0.02677	0.02677	0.00348	129.2
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3033**	**0.3153**	**0.8646**	**1.8768**	**0.0465**	**0.0465**	**0.0054**	**189.1842**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3241	0.3412	1.7786	6.1157	0.2464	0.2464	0.0153	828.2630
	Work Boat 1	Two-stroke Outboard (WB)		7.8823	8.1503	18.3016	0.5403	0.1624	0.1624	0.0289	140.7597
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0306	0.0322	0.1559	0.4337	0.0273	0.0273	0.0016	90.7183
	Push Boat 2	Two-stroke Outboard (PB)		0.6321	0.6536	1.9827	0.0730	0.0125	0.0125	0.0032	15.4892
	Work Boat 2	Two-stroke Outboard (WB)		1.2468	1.2892	2.8950	0.0855	0.0257	0.0257	0.0046	22.2654
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.1331	0.1402	0.6655	1.2034	0.1206	0.1206	0.0026	137.9580
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**10.2**	**10.6**	**26**	**8**	**0.59**	**0.59**	**0.056**	**1,235**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1410	0.1485	0.5803	3.3849	0.0619	0.0619	0.0080	295.2488
	100-ton Crane	Diesel Cranes		0.6034	0.6354	3.3119	11.3879	0.4588	0.4588	0.0285	1542.2941
	Front-end Loader	Diesel Rough Terrain Forklifts		0.2897	0.3051	1.4048	3.6961	0.3014	0.3014	0.0109	587.3427
	Rail	na		4.7236	4.9739	23.2546	89.9298	3.2702	3.1721	0.0804	8917.8661
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**5.8**	**6.1**	**29**	**108**	**4.1**	**4.0**	**0.13**	**11,343**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 1C+(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6609	0.6959	3.9485	9.7476	0.6391	0.6391	0.0391	2233.3547
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1724	0.1816	0.7094	4.1380	0.0757	0.0757	0.0098	360.9462
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9066
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.1010	0.1064	0.5545	1.9067	0.0768	0.0768	0.0048	258.2321
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0473	0.0498	0.1796	0.9966	0.0191	0.0191	0.0025	92.1883
	Work Boat 1	Two-stroke Outboard (WB)		2.6623	2.7528	6.1815	0.1825	0.0548	0.0548	0.0097	47.5425
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0089	0.0093	0.0487	0.1675	0.0067	0.0067	0.0004	22.6889
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0042	0.0044	0.0158	0.0876	0.0017	0.0017	0.0002	8.0999
	Work Boat 1	Two-stroke Outboard (WB)		0.2339	0.2419	0.5431	0.0160	0.0048	0.0048	0.0009	4.1772
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0224	0.0235	0.1227	0.4218	0.0170	0.0170	0.0011	57.1273
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0105	0.0110	0.0397	0.2205	0.0042	0.0042	0.0005	20.3943
	Work Boat 1	Two-stroke Outboard (WB)		0.5890	0.6090	1.3675	0.0404	0.0121	0.0121	0.0022	10.5176
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0043	0.0045	0.0176	0.0310	0.0027	0.0027	0.0001	3.3177
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0026	0.0027	0.0097	0.0539	0.0010	0.0010	0.0001	4.9891
	Work Boat 1	Two-stroke Outboard (WB)		0.1441	0.1490	0.3345	0.0099	0.0030	0.0030	0.0005	2.5729
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.8**	**6.0**	**17**	**23**	**1.1**	**1.1**	**0.08**	**3,648**
LONG-TERM MONITORING (12 hours/day)											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**22**	**23**	**73**	**140**	**5.9**	**5.8**	**0.27**	**16,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2B(12) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0737	0.0776	0.2798	1.552	0.02974	0.02974	0.00387	143.6
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3107**	**0.3231**	**0.8926**	**2.0320**	**0.0495**	**0.0495**	**0.0058**	**203.5435**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3596	0.3786	1.9735	6.7857	0.2734	0.2734	0.0170	919.0148
	Work Boat 1	Two-stroke Outboard (WB)		8.7460	9.0434	20.3069	0.5995	0.1802	0.1802	0.0320	156.1825
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat 2	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 2	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**9.1**	**9.4**	**22**	**7**	**0.45**	**0.45**	**0.049**	**1,075**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1552	0.1634	0.6384	3.7236	0.0681	0.0681	0.0088	324.7964
	100-ton Crane	Diesel Cranes		0.6638	0.6990	3.6433	12.5275	0.5047	0.5047	0.0313	1696.6426
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3187	0.3356	1.5454	4.0660	0.3316	0.3316	0.0120	646.1223
	Rail	na		5.1963	5.4717	25.5818	98.9298	3.5974	3.4895	0.0884	9810.3414
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**6**	**6.7**	**31**	**119**	**4.5**	**4.4**	**0.14**	**12,478**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2B(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6345	0.6682	3.7913	9.3596	0.6137	0.6137	0.0375	2144.4572
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1656	0.1743	0.6812	3.9733	0.0727	0.0727	0.0094	346.5789
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9064
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0963	0.1014	0.5283	1.8166	0.0732	0.0732	0.0045	246.0342
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0451	0.0474	0.1711	0.9495	0.0182	0.0182	0.0024	87.8336
	Work Boat 1	Two-stroke Outboard (WB)		2.5366	2.6228	5.8895	0.1739	0.0523	0.0523	0.0093	45.2968
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0089	0.0093	0.0487	0.1675	0.0067	0.0067	0.0004	22.6889
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0042	0.0044	0.0158	0.0876	0.0017	0.0017	0.0002	8.0999
	Work Boat 1	Two-stroke Outboard (WB)		0.2339	0.2419	0.5431	0.0160	0.0048	0.0048	0.0009	4.1772
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0224	0.0235	0.1227	0.4218	0.0170	0.0170	0.0011	57.1273
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0105	0.0110	0.0397	0.2205	0.0042	0.0042	0.0005	20.3943
	Work Boat 1	Two-stroke Outboard (WB)		0.5890	0.6090	1.3675	0.0404	0.0121	0.0121	0.0022	10.5176
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0076	0.0080	0.0308	0.0543	0.0048	0.0048	0.0001	5.8170
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0045	0.0047	0.0170	0.0946	0.0018	0.0018	0.0002	8.7473
	Work Boat 1	Two-stroke Outboard (WB)		0.2526	0.2612	0.5865	0.0173	0.0052	0.0052	0.0009	4.5111
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.8**	**6.0**	**17**	**23**	**1.1**	**1.1**	**0.08**	**3,535**
LONG-TERM MONITORING **(12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**22**	**23**	**72**	**150**	**6.1**	**6.0**	**0.27**	**17,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2C+(12) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0737	0.0776	0.2798	1.552	0.02974	0.02974	0.00387	143.6
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3107**	**0.3231**	**0.8926**	**2.0320**	**0.0495**	**0.0495**	**0.0058**	**203.5435**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3596	0.3786	1.9735	6.7857	0.2734	0.2734	0.0170	919.0148
	Work Boat 1	Two-stroke Outboard (WB)		8.7460	9.0434	20.3069	0.5995	0.1802	0.1802	0.0320	156.1825
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0306	0.0322	0.1559	0.4337	0.0273	0.0273	0.0016	90.7183
	Push Boat 2	Two-stroke Outboard (PB)		0.6321	0.6536	1.9827	0.0730	0.0125	0.0125	0.0032	15.4892
	Work Boat 2	Two-stroke Outboard (WB)		1.2468	1.2892	2.8950	0.0855	0.0257	0.0257	0.0046	22.2654
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.1331	0.1402	0.6655	1.2034	0.1206	0.1206	0.0026	137.9580
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**11.1**	**11.5**	**28**	**9**	**0.64**	**0.64**	**0.061**	**1,342**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1564	0.1646	0.6433	3.7526	0.0687	0.0687	0.0089	327.3221
	100-ton Crane	Diesel Cranes		0.6690	0.7044	3.6716	12.6249	0.5086	0.5086	0.0316	1709.8357
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3212	0.3382	1.5574	4.0976	0.3342	0.3342	0.0121	651.1466
	Rail	na		5.2367	5.5143	25.7808	99.6990	3.6254	3.5167	0.0891	9886.6268
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**6**	**7**	**32**	**120**	**4.5**	**4.4**	**0.14**	**12,575**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2C+(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6344	0.6680	3.7904	9.3574	0.6135	0.6135	0.0375	2143.9541
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1655	0.1743	0.6810	3.9724	0.0727	0.0727	0.0094	346.4976
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9066
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0962	0.1013	0.5282	1.8161	0.0732	0.0732	0.0045	245.9652
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0450	0.0474	0.1711	0.9492	0.0182	0.0182	0.0024	87.8090
	Work Boat 1	Two-stroke Outboard (WB)		2.5358	2.6221	5.8879	0.1738	0.0522	0.0522	0.0093	45.2841
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0089	0.0093	0.0487	0.1675	0.0067	0.0067	0.0004	22.6889
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0042	0.0044	0.0158	0.0876	0.0017	0.0017	0.0002	8.0999
	Work Boat 1	Two-stroke Outboard (WB)		0.2339	0.2419	0.5431	0.0160	0.0048	0.0048	0.0009	4.1772
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0224	0.0235	0.1227	0.4218	0.0170	0.0170	0.0011	57.1273
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0105	0.0110	0.0397	0.2205	0.0042	0.0042	0.0005	20.3943
	Work Boat 1	Two-stroke Outboard (WB)		0.5890	0.6090	1.3675	0.0404	0.0121	0.0121	0.0022	10.5176
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0076	0.0080	0.0308	0.0543	0.0048	0.0048	0.0001	5.8170
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0045	0.0047	0.0170	0.0946	0.0018	0.0018	0.0002	8.7473
	Work Boat 1	Two-stroke Outboard (WB)		0.2526	0.2612	0.5865	0.0173	0.0052	0.0052	0.0009	4.5111
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.8**	**6.0**	**17**	**23**	**1.1**	**1.1**	**0.08**	**3,534**
LONG-TERM MONITORING (12 hours/day)											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**24**	**25**	**78**	**150**	**6.3**	**6.2**	**0.29**	**18,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

				Alternative 3B(12) - Total Emissions (tonnes)							
Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0737	0.0776	0.2798	1.552	0.02974	0.02974	0.00387	143.6
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3107**	**0.3231**	**0.8926**	**2.0320**	**0.0495**	**0.0495**	**0.0058**	**203.5435**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3740	0.3938	2.0527	7.0583	0.2844	0.2844	0.0177	955.9320
	Work Boat 1	Two-stroke Outboard (WB)		9.0973	9.4066	21.1227	0.6236	0.1874	0.1874	0.0333	162.4565
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0270	0.0285	0.1484	0.5102	0.0206	0.0206	0.0013	69.1013
	Push Boat	Two-stroke Outboard (PB)		0.3334	0.3447	1.0457	0.0385	0.0066	0.0066	0.0017	8.1695
	Work Boat 1	Two-stroke Outboard (WB)		0.6576	0.6800	1.5269	0.0451	0.0135	0.0135	0.0024	11.7435
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat 2	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 2	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**10.5**	**10.9**	**26**	**8**	**0.51**	**0.51**	**0.056**	**1,207**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1642	0.1730	0.6758	3.9419	0.0721	0.0721	0.0093	343.8381
	100-ton Crane	Diesel Cranes		0.7027	0.7400	3.8569	13.2620	0.5343	0.5343	0.0332	1796.1106
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3374	0.3553	1.6360	4.3044	0.3510	0.3510	0.0127	684.0021
	Rail	na		5.5010	5.7925	27.0816	104.7296	3.8084	3.6941	0.0936	10385.4860
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**7**	**7**	**33**	**126**	**4.8**	**4.7**	**0.15**	**13,209**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 3B(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6043	0.6363	3.6105	8.9133	0.5844	0.5844	0.0357	2042.2047
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1577	0.1660	0.6487	3.7839	0.0693	0.0693	0.0089	330.0533
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9064
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0989	0.1041	0.5426	1.8659	0.0752	0.0752	0.0047	252.6989
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0463	0.0487	0.1758	0.9752	0.0187	0.0187	0.0024	90.2129
	Work Boat 1	Two-stroke Outboard (WB)		2.6053	2.6938	6.0491	0.1786	0.0537	0.0537	0.0095	46.5238
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0051	0.0053	0.0278	0.0956	0.0039	0.0039	0.0002	12.9500
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0024	0.0025	0.0090	0.0500	0.0010	0.0010	0.0001	4.6231
	Work Boat 1	Two-stroke Outboard (WB)		0.1335	0.1381	0.3100	0.0092	0.0028	0.0028	0.0005	2.3842
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0128	0.0134	0.0700	0.2408	0.0097	0.0097	0.0006	32.6062
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0060	0.0063	0.0227	0.1258	0.0024	0.0024	0.0003	11.6403
	Work Boat 1	Two-stroke Outboard (WB)		0.3362	0.3476	0.7805	0.0230	0.0069	0.0069	0.0012	6.0031
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0076	0.0080	0.0308	0.0543	0.0048	0.0048	0.0001	5.8170
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0045	0.0047	0.0170	0.0946	0.0018	0.0018	0.0002	8.7473
	Work Boat 1	Two-stroke Outboard (WB)		0.2526	0.2612	0.5865	0.0173	0.0052	0.0052	0.0009	4.5111
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.4**	**5.6**	**16**	**22**	**1.0**	**1.0**	**0.07**	**3,373**
***LONG-TERM MONITORING* (12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**23**	**24**	**77**	**160**	**6.4**	**6.3**	**0.29**	**18,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 3C+(12) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0737	0.0776	0.2798	1.552	0.02974	0.02974	0.00387	143.6
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3107**	**0.3231**	**0.8926**	**2.0320**	**0.0495**	**0.0495**	**0.0058**	**203.5435**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.3740	0.3938	2.0527	7.0583	0.2844	0.2844	0.0177	955.9320
	Work Boat 1	Two-stroke Outboard (WB)		9.0973	9.4066	21.1227	0.6236	0.1874	0.1874	0.0333	162.4565
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0270	0.0285	0.1484	0.5102	0.0206	0.0206	0.0013	69.1013
	Push Boat	Two-stroke Outboard (PB)		0.3334	0.3447	1.0457	0.0385	0.0066	0.0066	0.0017	8.1695
	Work Boat 1	Two-stroke Outboard (WB)		0.6576	0.6800	1.5269	0.0451	0.0135	0.0135	0.0024	11.7435
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0306	0.0322	0.1559	0.4337	0.0273	0.0273	0.0016	90.7183
	Push Boat 2	Two-stroke Outboard (PB)		0.6321	0.6536	1.9827	0.0730	0.0125	0.0125	0.0032	15.4892
	Work Boat 2	Two-stroke Outboard (WB)		1.2468	1.2892	2.8950	0.0855	0.0257	0.0257	0.0046	22.2654
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.1331	0.1402	0.6655	1.2034	0.1206	0.1206	0.0026	137.9580
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**12.5**	**13.0**	**32**	**10**	**0.70**	**0.70**	**0.068**	**1,474**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1655	0.1742	0.6808	3.9709	0.0727	0.0727	0.0094	346.3637
	100-ton Crane	Diesel Cranes		0.7079	0.7454	3.8852	13.3594	0.5382	0.5382	0.0334	1809.3037
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3399	0.3579	1.6481	4.3360	0.3536	0.3536	0.0128	689.0264
	Rail	na		5.5414	5.8350	27.2805	105.4989	3.8363	3.7212	0.0943	10461.7714
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**7**	**7**	**33**	**127**	**4.8**	**4.7**	**0.15**	**13,306**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 3C+(12) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6035	0.6355	3.6060	8.9020	0.5837	0.5837	0.0357	2039.6140
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1575	0.1658	0.6479	3.7791	0.0692	0.0692	0.0089	329.6346
	Rail for Activated Carbon	na		0.2420	0.2548	1.1914	4.6076	0.1675	0.1625	0.0041	456.9066
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0987	0.1040	0.5419	1.8632	0.0751	0.0751	0.0047	252.3435
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0462	0.0487	0.1755	0.9738	0.0187	0.0187	0.0024	90.0860
	Work Boat 1	Two-stroke Outboard (WB)		2.6016	2.6901	6.0405	0.1783	0.0536	0.0536	0.0095	46.4584
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0051	0.0053	0.0278	0.0956	0.0039	0.0039	0.0002	12.9500
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0024	0.0025	0.0090	0.0500	0.0010	0.0010	0.0001	4.6231
	Work Boat 1	Two-stroke Outboard (WB)		0.1335	0.1381	0.3100	0.0092	0.0028	0.0028	0.0005	2.3842
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0128	0.0134	0.0700	0.2408	0.0097	0.0097	0.0006	32.6062
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0060	0.0063	0.0227	0.1258	0.0024	0.0024	0.0003	11.6403
	Work Boat 1	Two-stroke Outboard (WB)		0.3362	0.3476	0.7805	0.0230	0.0069	0.0069	0.0012	6.0031
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0259	0.0273	0.1056	0.1859	0.0165	0.0165	0.0004	19.9174
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0154	0.0162	0.0584	0.3238	0.0062	0.0062	0.0008	29.9508
	Work Boat 1	Two-stroke Outboard (WB)		0.8650	0.8944	2.0083	0.0593	0.0178	0.0178	0.0032	15.4460
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0076	0.0080	0.0308	0.0543	0.0048	0.0048	0.0001	5.8170
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0045	0.0047	0.0170	0.0946	0.0018	0.0018	0.0002	8.7473
	Work Boat 1	Two-stroke Outboard (WB)		0.2526	0.2612	0.5865	0.0173	0.0052	0.0052	0.0009	4.5111
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.4**	**5.6**	**16**	**22**	**1.0**	**1.0**	**0.07**	**3,370**
***LONG-TERM MONITORING* (12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**25**	**26**	**83**	**160**	**6.6**	**6.5**	**0.30**	**18,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2C+(7.5) - Total Emissions (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) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0810	0.0853	0.3078	1.707	0.03271	0.03271	0.00426	158.0
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3181**	**0.3309**	**0.9206**	**2.1872**	**0.0525**	**0.0525**	**0.0062**	**218**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.4017	0.4230	2.2046	7.5806	0.3054	0.3054	0.0190	1026.6628
	Work Boat 1	Two-stroke Outboard (WB)		9.7704	10.1026	22.6856	0.6697	0.2013	0.2013	0.0358	174.4769
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Push Boat	Two-stroke Outboard (PB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Work Boat 1	Two-stroke Outboard (WB)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.0306	0.0322	0.1559	0.4337	0.0273	0.0273	0.0016	90.7183
	Push Boat 2	Two-stroke Outboard (PB)		0.6321	0.6536	1.9827	0.0730	0.0125	0.0125	0.0032	15.4892
	Work Boat 2	Two-stroke Outboard (WB)		1.2468	1.2892	2.8950	0.0855	0.0257	0.0257	0.0046	22.2654
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.1331	0.1402	0.6655	1.2034	0.1206	0.1206	0.0026	137.9580
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**12.2**	**12.6**	**30.6**	**10.0**	**0.7**	**0.7**	**0.1**	**1467.6**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1745	0.1838	0.7181	4.1887	0.0767	0.0767	0.0099	365.3668
	100-ton Crane	Diesel Cranes		0.7467	0.7863	4.0984	14.0924	0.5677	0.5677	0.0353	1908.5706
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3585	0.3775	1.7385	4.5739	0.3730	0.3730	0.0135	726.8296
	Rail	na		5.8454	6.1552	28.7773	111.2871	4.0468	3.9254	0.0994	11035.7530
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**7.1**	**7.5**	**35.3**	**134.1**	**5.1**	**4.9**	**0.2**	**14036.5**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 2C+(7.5) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.656	0.691	3.919	9.675	0.634	0.634	0.039	2216.761
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.171	0.180	0.704	4.107	0.075	0.075	0.010	358.264
	Rail for Activated Carbon	na		0.254	0.268	1.252	4.841	0.176	0.171	0.004	480.042
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.100	0.105	0.549	1.888	0.076	0.076	0.005	255.750
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.047	0.049	0.178	0.987	0.019	0.019	0.002	91.302
	Work Boat 1	Two-stroke Outboard (WB)		2.637	2.726	6.122	0.181	0.054	0.054	0.010	47.086
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.009	0.009	0.049	0.168	0.007	0.007	0.000	22.785
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.004	0.004	0.016	0.088	0.002	0.002	0.000	8.134
	Work Boat 1	Two-stroke Outboard (WB)		0.235	0.243	0.545	0.016	0.005	0.005	0.001	4.195
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.022	0.024	0.123	0.424	0.017	0.017	0.001	57.370
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.011	0.011	0.040	0.221	0.004	0.004	0.001	20.481
	Work Boat 1	Two-stroke Outboard (WB)		0.591	0.612	1.373	0.041	0.012	0.012	0.002	10.562
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.027	0.029	0.111	0.195	0.017	0.017	0.000	20.926
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.016	0.017	0.061	0.340	0.007	0.007	0.001	31.467
	Work Boat 1	Two-stroke Outboard (WB)		0.909	0.940	2.110	0.062	0.019	0.019	0.003	16.228
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.008	0.009	0.034	0.060	0.005	0.005	0.000	6.391
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.005	0.005	0.019	0.104	0.002	0.002	0.000	9.610
	Work Boat 1	Two-stroke Outboard (WB)		0.278	0.287	0.644	0.019	0.006	0.006	0.001	4.956
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**6.0**	**6.2**	**18**	**23**	**1.1**	**1.1**	**0.08**	**3,662**
***LONG-TERM MONITORING* (12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.30	0.31	0.69	0.020	0.0062	0.0062	0.0011	5.3
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.30**	**0.31**	**0.69**	**0.020**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**26**	**27**	**85**	**170**	**7.00**	**6.80**	**0.31**	**19,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	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)
				Alternative 3E(7.5) - Total Emissions (tonnes)							
SITE PREPARATION											
Equipment Mobilization/Demobilization (8 hours/day)											
	Tug Boat (800 HP) 2	Diesel Inboard/Sterndrive (800 HP)	Assume mobilization of 2 derrick rigs and 3 material barges, mob/demob on an annual basis. Assume 8 hrs/day for 35 days per construction season.	0.0958	0.1008	0.3637	2.0179	0.0387	0.0387	0.0050	186.6718
Pile Removal (12 hrs/day)											
	150-ton Crane 1	Diesel Cranes	Assume each work day contains one 12-hr shift. Assume pile removal occurs at 25 piles/day.	0.0162	0.0170	0.0888	0.3055	0.0123	0.0123	0.0008	41.3718
	Work Boat 1	Two-stroke Outboard (WB)		0.2133	0.2205	0.4952	0.0146	0.0044	0.0044	0.0008	3.8084
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0076	0.0080	0.0288	0.1597	0.0031	0.0031	0.0004	14.7696
			SUBTOTAL EMISSIONS - SITE PREPARATION	**0.3328**	**0.3464**	**0.9765**	**2.4977**	**0.0584**	**0.0584**	**0.0070**	**247**
SEDIMENT REMOVAL											
Open-water Dredging (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.4051	0.4266	2.2233	7.6450	0.3080	0.3080	0.0191	1035.3832
	Work Boat 1	Two-stroke Outboard (WB)		9.8534	10.1884	22.8783	0.6754	0.2030	0.2030	0.0361	175.9588
Restricted Access Dredging (Under the West Seattle Bridge) (12 hours/day)											
	Derrick Rig	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0314	0.0331	0.1726	0.5934	0.0239	0.0239	0.0015	80.3629
	Push Boat	Two-stroke Outboard (PB)		0.3877	0.4009	1.2162	0.0448	0.0077	0.0077	0.0020	9.5008
	Work Boat 1	Two-stroke Outboard (WB)		0.7648	0.7908	1.7757	0.0524	0.0158	0.0158	0.0028	13.6573
Hydraulic Dredging (Underpiers) (8 hours/day)											
	Hydraulic Excavator	Diesel Excavators	Assume each work day contains one 8-hr shift.	0.2014	0.2120	1.0269	2.8571	0.1797	0.1797	0.0105	597.6081
	Push Boat 2	Two-stroke Outboard (PB)		4.1637	4.3053	13.0612	0.4809	0.0823	0.0823	0.0209	102.0351
	Work Boat 2	Two-stroke Outboard (WB)		8.2135	8.4928	19.0706	0.5630	0.1692	0.1692	0.0301	146.6739
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)											
	High-solids Pump	Diesel Pumps	Assume each work day contains one 8-hr shift.	0.8771	0.9235	4.3839	7.9272	0.7948	0.7948	0.0173	908.8004
			SUBTOTAL EMISSIONS - SEDIMENT REMOVAL	**24.8982**	**25.7735**	**65.8086**	**20.8391**	**1.7842**	**1.7842**	**0.1403**	**3070**
SEDIMENT TRANSLOADING AND DISPOSAL											
Mechanical Offloading (12 hours/day)											
	Tug Boat (3,000 HP)	Diesel Inboard/Sterndrive (3,000 HP)	Assume each work day contains one 12-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). Assume sediment disposal by rail to landfill in eastern WA for 284 mi (one-way).	0.1861	0.1959	0.7656	4.4658	0.0817	0.0817	0.0106	389.5321
	100-ton Crane	Diesel Cranes		0.7961	0.8383	4.3695	15.0244	0.6053	0.6053	0.0376	2034.8028
	Front-end Loader	Diesel Rough Terrain Forklifts		0.3822	0.4025	1.8535	4.8764	0.3977	0.3977	0.0144	774.9019
	Rail	na		6.2320	6.5623	30.6806	118.6476	4.3145	4.1850	0.1060	11765.6541
			SUBTOTAL EMISSIONS - SEDIMENT TRANSLOADING AND DISPOSAL	**7.5964**	**7.9990**	**37.6691**	**143.0142**	**5.3992**	**5.2697**	**0.1686**	**14965**

Table 9. Detailed Summary of Direct Emissions By Activity and Alternative

Activity	Type of Vehicle/Equipment Used	SCC Description	Notes	Alternative 3E(7.5) - Total Emissions (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)
CAPPING/TREATMENT MATERIAL PLACEMENT											
Transportation of Materials to EW											
	Dump Truck (20-ton) for sand, gravel, and armor	Diesel Off-highway Trucks	Assume sand, gravel, and armor are transported 20 miles from quarry to shore by truck and 20 miles to the site by barge. Assume activated carbon is transported from Toledo (OH) to site by train for a 2,452 mi distance (one-way).	0.6239	0.6569	3.7274	9.2019	0.6033	0.6033	0.0369	2108.3287
	Tug Boat (3,000 HP) for sand, gravel, and armor	Diesel Inboard/Sterndrive (3,000 HP)		0.1628	0.1714	0.6697	3.9064	0.0715	0.0715	0.0092	340.7400
	Rail for Activated Carbon	na		0.2543	0.2677	1.2518	4.8409	0.1760	0.1708	0.0043	480.0451
Residuals Management Cover, Capping, Backfill, and Enhanced Natural Recovery (Sand) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.1023	0.1078	0.5617	1.9313	0.0778	0.0778	0.0048	261.5665
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0479	0.0504	0.1819	1.0094	0.0193	0.0193	0.0025	93.3786
	Work Boat 1	Two-stroke Outboard (WB)		2.6967	2.7884	6.2613	0.1848	0.0556	0.0556	0.0099	48.1564
Capping (Gravel) (12 hours/day)											
	100-ton Crane	Diesel Cranes	Assume each work day contains one 12-hr shift.	0.0051	0.0054	0.0280	0.0963	0.0039	0.0039	0.0002	13.0467
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0024	0.0025	0.0091	0.0503	0.0010	0.0010	0.0001	4.6576
	Work Boat 1	Two-stroke Outboard (WB)		0.1345	0.1391	0.3123	0.0092	0.0028	0.0028	0.0005	2.4020
Capping (Armor) (12 hours/day)											
	100-ton Crane	Diesel Excavators	Assume each work day contains one 12-hr shift.	0.0129	0.0135	0.0705	0.2426	0.0098	0.0098	0.0006	32.8498
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0060	0.0063	0.0228	0.1268	0.0024	0.0024	0.0003	11.7273
	Work Boat 1	Two-stroke Outboard (WB)		0.3387	0.3502	0.7864	0.0232	0.0070	0.0070	0.0012	6.0479
In situ Treatment (Activated Carbon, Underpier) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0272	0.0287	0.1109	0.1953	0.0173	0.0173	0.0004	20.9261
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0161	0.0170	0.0613	0.3402	0.0065	0.0065	0.0008	31.4676
	Work Boat 1	Two-stroke Outboard (WB)		0.9088	0.9397	2.1100	0.0623	0.0187	0.0187	0.0033	16.2282
Enhanced Natural Recovery (Low Bridge) (12 hours/day)											
	Telebelt	Diesel Other Material Handling Equip.	Assume each work day contains one 12-hr shift.	0.0083	0.0088	0.0339	0.0597	0.0053	0.0053	0.0001	6.3908
	Tug Boat (800 HP)	Diesel Inboard/Sterndrive (800 HP)		0.0049	0.0052	0.0187	0.1039	0.0020	0.0020	0.0003	9.6102
	Work Boat 1	Two-stroke Outboard (WB)		0.2775	0.2870	0.6444	0.0190	0.0057	0.0057	0.0010	4.9561
			SUBTOTAL EMISSIONS - MATERIAL PLACEMENT	**5.6303**	**5.8459**	**16.8622**	**22.4036**	**1.0859**	**1.0806**	**0.0766**	**3493**
***LONG-TERM MONITORING* (12 hours/day)**											
	Work Boat 1	Two-stroke Outboard (WB)	Assume each work day contains one 12 hr-shift. Assume a total of 8 monitoring events based on: a pre-construction baseline sampling, a construction monitoring/confirmational sampling, and long-term monitoring at years 1, 3, 5, 10, 15, and 20.	0.2986	0.3087	0.6932	0.0205	0.0062	0.0062	0.0011	5.3318
			SUBTOTAL EMISSIONS - LONG-TERM MONITORING	**0.2986**	**0.3087**	**0.6932**	**0.0205**	**0.0062**	**0.0062**	**0.0011**	**5.3**
			TOTAL EMISSIONS (metric tons, rounded)	**39**	**40**	**120**	**190**	**8.3**	**8.2**	**0.39**	**22,000**

General 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.

AC = activated carbon; CO = carbon monoxide; CO_2 = carbon dioxide; cy = cubic yard; ENR = enhanced natural recovery; GAC = granular activated carbon; gal = gallon; HP = horse power; 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; RMC = residuals management cover; SCC = Standard Classification Code; SO_2 = sulfur dioxide; VOC = volatile organic compounds; WB = work boat

Table 10. Detailed Summary of Indirect Emissions By Activity and Alternative

						Alternative 1C+(12) - Total Emissions (metric tons)			Alternative 2C+(12) - Total Emissions (metric tons)			Alternative 3C+(12) - Total Emissions (metric tons)			Alternative 2C+(7.5) - Total Emissions (metric tons)			Alternative 3E(7.5) - Total Emissions (metric tons)		
Activity	Type of Equipment	Notes	Electricity Consumption Rate (kW)	Production Rate (quantity/day)	Quantity Units	Carbon Dioxide (CO_2)	Nitrogen Oxides (NOx)	Sulfur Dioxide (SO_2)	Carbon Dioxide (CO_2)	Nitrogen Oxides (NOx)	Sulfur Dioxide (SO_2)	Carbon Dioxide (CO_2)	Nitrogen Oxides (NOx)	Sulfur Dioxide (SO_2)	Carbon Dioxide (CO_2)	Nitrogen Oxides (NOx)	Sulfur Dioxide (SO_2)	Carbon Dioxide (CO_2)	Nitrogen Oxides (NOx)	Sulfur Dioxide (SO_2)
SEDIMENT REMOVAL																				
Sediment Pumping (For Underpier Hydraulic Dredging) (8 hours/day)																				
	Water Treatment System	Assumed one 8-hour shift. Assumed electricity usage for water treatment of hydraulically dredged sediments.	250	40	cy sediment	110	0.12	0.12	110	0.12	0.12	110	0.12	0.12	110	0.12	0.12	700	0.76	0.80

Notes:

1. Total emissions due to operation of water treatment are calculated as total operation time (hrs) x electricity operation rate (kW) x 1 MWh/ 1000 kWh x emission factor (g/MWh) x (1E-6 metric ton/g).
2. Total operation time (hrs) is calculated as volume hydraulically dredged (cy) / production rate (cy/d) x operation time (hrs/d).

cy = cubic yard; g = gram; kW = kilowatt; MWh = megawatt hour; NO_X = nitrogen oxides (NO and NO_2); SO_2 = sulfur dioxide

Table 11a. Total Direct Emissions by Alternative

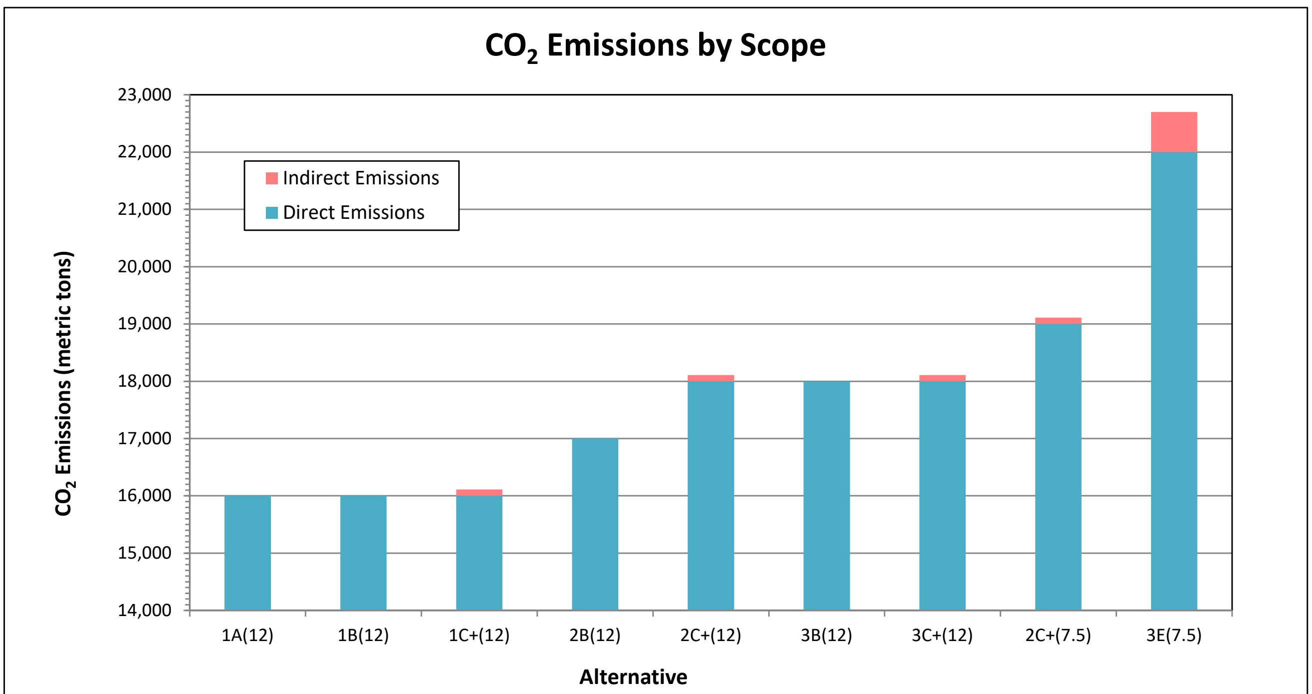
Alternative	Emissions (metric tons)							
	Hydrocarbons (HC)	Volatile Organic Compounds (VOCs)	Carbon Monoxide (CO)	Nitrous Oxides (NO_X)	Particulate Matter 10 µm (PM_{10})	Particulate Matter 2.5 µm ($PM_{2.5}$)	Sulfur Dioxide (SO_2)	Carbon Dioxide (CO_2)
1A(12)	19	20	64	130	5.4	5.3	0.25	16,000
1B(12)	20	21	67	140	5.6	5.5	0.26	16,000
1C+(12)	22	23	73	140	5.9	5.8	0.27	16,000
2B(12)	22	23	72	150	6.1	6.0	0.27	17,000
2C+(12)	24	25	78	150	6.3	6.2	0.29	18,000
3B(12)	23	24	77	160	6.4	6.3	0.29	18,000
3C+(12)	25	26	83	160	6.6	6.5	0.30	18,000
2C+(7.5)	26	27	85	170	7.0	6.8	0.31	19,000
3E(7.5)	39	40	120	190	8.3	8.2	0.39	22,000

Note:
1. Total direct emissions are rounded to two significant figures, as presented in Table 9.

Table 11b. Total Indirect Emissions by Alternative

Alternative	Emissions (metric tons)		
	Carbon Dioxide (CO_2)	Nitrogen Oxides (NO_X)	Sulfur Dioxide (SO_2)
1C+(12)	110	0.12	0.12
2C+(12)	110	0.12	0.12
3C+(12)	110	0.12	0.12
2C+(7.5)	110	0.12	0.12
3E(7.5)	700	0.76	0.80

Notes:
1. Total indirect emissions account only for emissions from the water treatment associated with hydraulic dredging (Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5)).
2. Total indirect emissions are rounded to two significant figures, as presented in Table 10.



CO = carbon monoxide; CO_2 = carbon dioxide; $CO_{2\text{-eq}}$ = carbon dioxide equivalents; NO_X = nitrogen oxides (NO and NO_2); $PM_{2.5}$ = 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 compounds

Table 12. Direct CO_2 Emissions by Alternative and Contribution by Activity

Activity	CO_2 Emissions (metric tons)									Contribution (%)								
	Alternative									Alternative								
	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Site Preparation	190	190	190	200	200	200	200	220	250	1.24%	1.21%	1.19%	1.12%	1.11%	1.12%	1.10%	1.13%	1.14%
Sediment Removal	970	970	1200	2100	1300	1200	1500	1500	3100	6.4%	6.2%	7.5%	11.8%	7.2%	6.7%	8.3%	7.7%	14.2%
Transloading and Disposal	11000	11000	11000	12000	13000	13000	13000	14000	15000	72.1%	69.8%	68.8%	67.4%	72.2%	73.0%	71.8%	72.1%	68.6%
Material Placement	3100	3600	3600	3500	3500	3400	3400	3700	3500	20.3%	22.8%	22.5%	19.7%	19.4%	19.1%	18.8%	19.0%	16.0%
Long-term Monitoring	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.02%
Total CO_2 Emissions	**16,000**	**16,000**	**16,100**	**17,000**	**18,100**	**18,000**	**18,100**	**19,100**	**22,700**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Note:

1. Direct CO_2 emissions (totals and subtotals) are rounded to two significant figures.
2. Pie chart size is proportional to total direct CO_2 emissions for each alternative.

CO_2 = carbon dioxide

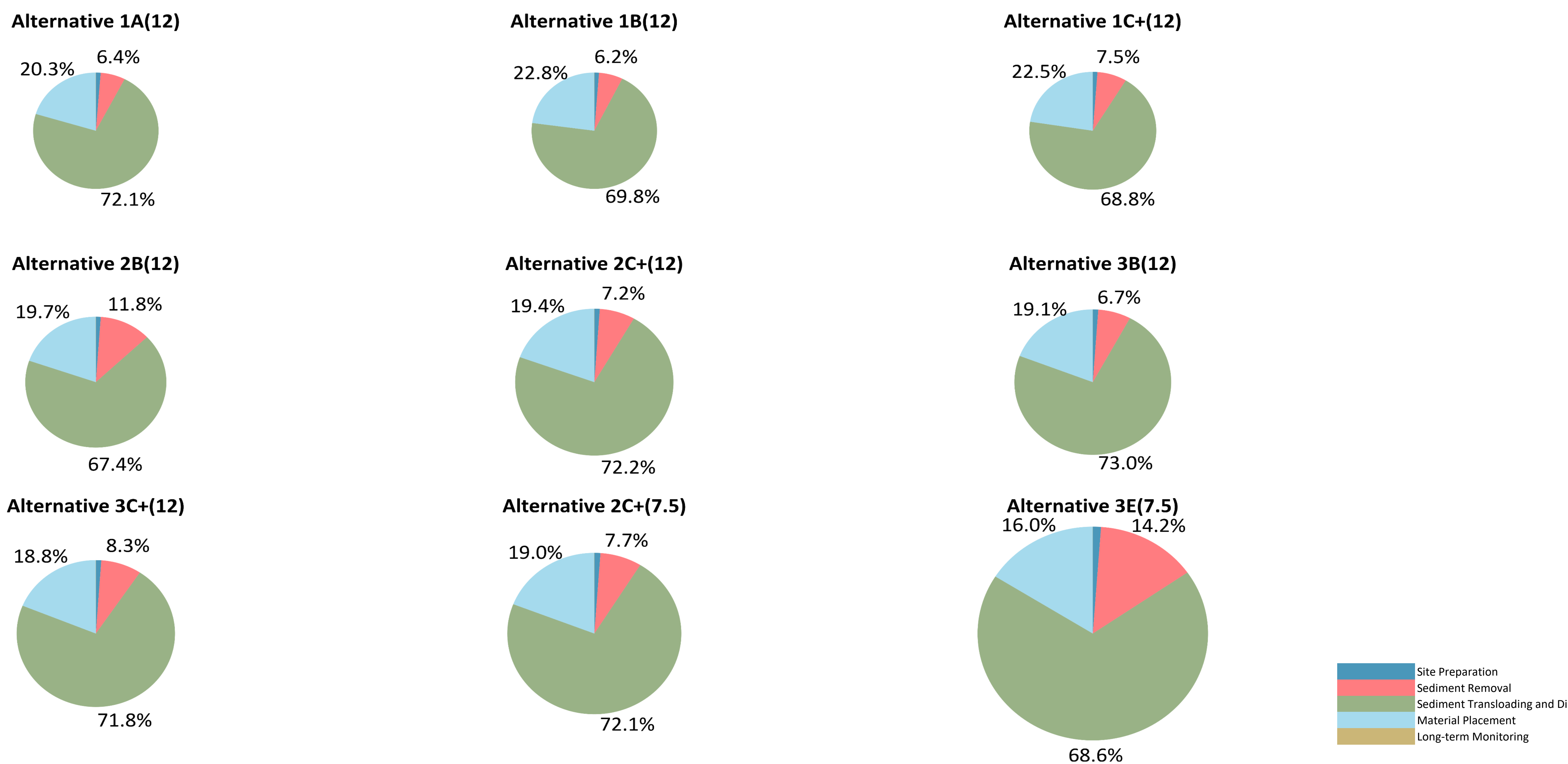


Table 13. Equivalencies of Total CO_2 Emissions

Alternative	Estimated Total CO_2 Emissions (metric tons)[b]	Equivalents to Alternative Emissions[a]		
		Number of Passenger Vehicles with Annual CO_2-eq Emissions[c]	Number of Barrels of Oil Consumed Resulting in CO_2 Emissions[d]	Number of Homes with CO_2 Emissions Due to Annual Energy Usage[e]
1A(12)	16,000	3,300	37,000	1,700
1B(12)	16,000	3,300	37,000	1,700
1C+(12)	16,100	3,400	37,000	1,700
2B(12)	17,000	3,500	40,000	1,800
2C+(12)	18,100	3,800	42,000	1,900
3B(12)	18,000	3,800	42,000	1,900
3C+(12)	18,100	3,800	42,000	1,900
2C+(7.5)	19,100	4,000	44,000	2,000
3E(7.5)	22,700	4,700	53,000	2,400

Notes:

a. Values presented were generated from EPA's Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/cleanrgy/energy-resources/calculator.html), and have been rounded herein. More detailed information regarding how each calculation is derived are available at http://www.epa.gov/cleanrgy/energy-resources/refs.html.

b. Total direct and indirect CO_2 emissions by alternative available in Tables 11a and 11b.

c. Emission rate utilized is 4.8 metric tons CO_2/vehicle/year.

d. Emission rate utilized is 0.43 metric tons CO_2/barrel oil.

e. Emission rate utilized is 9.47 metric tons CO_2/home/year.

CO_2 = carbon dioxide

PART 2: OTHER SHORT-TERM EFFECTIVENESS METRICS

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1 INTRODUCTION

Six key short-term effectiveness metrics are presented in this appendix as some of the measures of this criterion used for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation of alternatives for Sections 9 and 10 of the East Waterway (EW) Feasibility Study (FS). The primary goal of the metrics presented in this appendix is to evaluate and compare the potential impacts of the alternatives to human health and the environment during the construction phase of the remedial action; these impacts include effects on workers and the community and environmental impacts that result from construction and implementation. Other short-term effectiveness metrics, such as the length of time until RAOs are achieved, are described in detail in Section 9. A secondary objective is to identify potential best practices to help mitigate these impacts. This analysis derived metrics associated with the following factors:

- Transportation impacts associated with material hauling
- Workplace accidents during remedial activities, as expected number of injuries and fatalities
- Energy consumption
- Depleted natural resources
- Consumed landfill capacity
- Carbon footprint

Air pollutant emissions are also a key metric for evaluating the short-term effectiveness of the alternatives. An emissions inventory is presented and discussed separately in Part 1 of this appendix. An evaluation of these metrics for each alternative is also presented in Section 9.1.2.3 (Short-term Effectiveness) of the FS.

The U.S. Environmental Protection Agency (EPA) *Region 10 Superfund, RCRA, LUST, and Brownfields Clean and Green Policy* (Clean and Green Policy; EPA 2010a) states that the environmental benefits of federal cleanup programs may be enhanced by promoting technologies and practices that are sustainable. Specific objectives of the Clean and Green Policy are to: 1) protect human health and the environment by achieving remedial action goals; 2) support sustainable human and ecological use and reuse of remediated land; 3) minimize impacts to water quality and water resources; 4) reduce air pollutant emissions and greenhouse gas (GHG) production; 5) minimize material use and waste production; and 6) conserve natural resources and energy. While the selection of a preferred alternative is based on the overall evaluation of nine criteria to address the CERCLA statutory requirements (short-term effectiveness being one of them), EPA's green remediation policies and guidelines will only be consulted for the selected alternative in the development of specific mitigation measures and in the adoption of sustainable practices during the remedial design phase. Best management practices (BMPs) are available for this purpose.

2 METHODOLOGY

2.1 Remedial Activities Evaluated

The following remedial activities associated with the alternatives under consideration for the EW were identified as contributing to the six key short-term effectiveness metrics and were accounted for in this analysis:

- Sediment Removal
  - Open-water dredging (mechanical)
  - Restricted access dredging (under the West Seattle Bridge)
  - Diver-assisted hydraulic dredging (in underpier areas)
  - Water treatment (due to hydraulic dredging in underpier areas)
- Sediment Transloading and Disposal
  - Mechanical offloading, which includes the following:
    - Transportation (via tug and barge) of dredged sediments to an offloading area outside the EW
    - Transportation (via rail) of dredged sediments for landfill disposal in eastern Washington state
- Capping/treatment Material Placement:
  - Transportation of materials to the EW, which includes the following:
    - Transportation (via truck) of capping materials (i.e., sand, gravel, or armor stone) from a quarry to an onshore staging area
    - Transportation (via tug and barge) of capping materials from a staging area to the EW
    - Transportation (via rail) of in situ treatment material (activated carbon) from a vendor to the EW
  - Placement of sand for residuals management cover (RMC), capping, backfill, and enhanced natural recovery (ENR)
  - Placement of gravel for capping
  - Placement of armor stone for capping
  - Placement of activated carbon for in situ treatment (in underpier areas)
  - Placement of sand for ENR (under low bridges)
- Long-term Monitoring

2.2 Assumptions of Short-term Effectiveness Metrics

Local transportation impacts (i.e., traffic, noise, and air pollution) from the implementation of the alternatives can cause important temporary adverse effects to human health and the environment within the EW and its surrounding community. These transportation impacts are quantified in this appendix as a proportion to the number of truck, train, and barge miles estimated for support of material hauling operations, both for the disposal of contaminated sediment and for the transportation of ENR (sand), capping (sand, gravel, and armor stone), and in situ treatment materials (activated carbon) to the EW. Sediment is assumed to be barged to an offloading area (assumed to be 5 miles from the EW) and disposed of by train at a landfill in eastern Washington (assumed to be in Roosevelt, Washington, 284 miles away). Capping material is assumed to be transported by truck from a local quarry to an onshore staging area (assumed to be 20 miles away) and then barged to the EW (20 miles). In situ treatment material is assumed to be transported by rail from an activated carbon vendor located in Toledo, Ohio (2,452 miles away).

Workplace accidents represent the expected number of work-related injuries and fatalities during the remedial activities. This information is calculated using the duration of the remedial activities (based on volume estimates [see FS Appendix F], estimated production rates [see FS Appendix E]), and the rates of accident (injury/fatality) per worker per year from the U.S. Department of Labor (DOL; 2014a, 2014b) for workplace activities similar to those planned for the remediation of the EW. The remedial activities considered for workplace accident estimates were dredging, sediment disposal, and transportation of capping and treatment material by truck, barge, and train. In particular, hydraulic dredging (assumed to occur in underpier areas of the EW for certain alternatives) represents a difficult and a potentially dangerous activity to implement from a worker health and safety perspective because it is a diver-assisted procedure. The risks for injury and fatality during construction increase with every hour of diver assistance for hydraulic dredging activities. A specific fatality rate per diver per year was used for this purpose based on commercial diving safety information, available from the Occupational Safety and Health Administration (OSHA).

Energy consumption refers to thermal and electrical energy used during the implementation of alternatives. All of the construction equipment and vehicles participating in the remedial activities are assumed to be operated using diesel fuels; therefore, thermal energy consumption arises from its combustion (based on the average heating value for diesel fuel of 158 megajoules per gallon [MJ/gal]). Thermal energy consumption is directly related to the total amount of diesel fuel consumed during the activity and the specific fuel consumption rate of the equipment or vehicle. Electrical energy consumption is related to the electricity purchased from the grid and is estimated as the product of equipment power demand and utilization time. The water treatment system associated with hydraulic dredging is the only equipment assumed to be operated with electricity.

Depleted natural resources refer to the consumption of materials such as sand, gravel, and armor stone for in-water placement (e.g., capping, backfilling, RMC, or ENR).

Landfill capacity consumed represents the utilization of landfill space, which is directly proportional (1.2 times, assuming a 20% bulking factor) to the volume of dredged material removed and disposed of in the landfill.

Carbon footprint is defined as the forested area necessary to absorb the carbon dioxide (CO_2) produced during the remedial activities, based on the sequestration rate for Douglas fir. Carbon is stored by plants as they photosynthesize atmospheric CO_2 into plant biomass. Subsequently, some of this plant biomass is indirectly stored as soil organic carbon during decomposition processes. The sequestration rate is a function of the form of biomass, and is usually estimated as 2.02 grams (g) CO_2/g biomass, assuming 55% carbon in the total biomass of Douglas fir (Zhou and Hemstrom 2009) and the annual vegetation growth rate for Douglas fir, whose sequestration rate is 2.06 tons of CO_2 sequestered per acre per year (EPA 2010b).

2.3 Input Data

General and site-specific data were compiled to perform the short-term effectiveness analyses. While general data comprise generic factors and constants found in databases and literature, the site-specific data relate to the manner in which the alternatives are assumed to be implemented (e.g., type and capacity of equipment and vehicles, labor requirements, production rates, fuel consumption rates, and transportation distances).

The alternative cost estimates developed in Appendix E of the FS were used as the primary basis for calculating short-term effectiveness metrics for each alternative; dredged sediment and material placement volumes and production rates for each activity were derived from that appendix.

General data used for the calculations were obtained mostly from EPA (2010b), DOL (2014a, 2014b), OSHA (2012), and Zhou and Hemstrom (2009). General and site-specific input data, classified by the remedial activities, are reported in Tables 1 through 6.

3 RESULTS AND DISCUSSION

3.1 Output Data

Output of the six key short-term effectiveness metrics are summarized in Tables 1 through 6, and Figures 1 through 6 present graphical results the for the alternatives.

Transportation impacts in terms of truck, barge, and train miles are reported in Table 1 and Figure 1. The biggest impact due to material hauling is by truck transport operations. Alternatives 1B(12) and 1C+(12) have the largest number of truck transportation miles (approximately 126,200 truck miles), closely followed by Alternatives 1A(12) and 2C+(7.5), based on similar capping material volumes that are assumed to be hauled between a local quarry to an onshore staging area. Alternatives 2C+(7.5) and 3E(7.5) result in the largest number of train transportation miles, with approximate averages of 94,000 and 100,000 miles, respectively (Table 1), closely followed by Alternatives 2B(12), 2C+(12), 3B(12), and 3C+(12), due to the disposal of large amounts of contaminated sediment at the regional landfill. Impacts from barge transportation of materials (from EW to the offloading area for the dredged sediment, and from the onshore staging area to the EW for capping materials) range between 12,500 and 13,800 miles across the alternatives.

Short-term effectiveness analyses associated with the alternatives should consider safety risks and concerns. Although managed via OSHA and other agencies, workplace accidents are a realistic outcome of remediation, and the number of injuries and fatalities are assumed to be proportional to the duration of the remedial activities. The number of injuries among alternatives is estimated to range between 2.5 and 4, primarily associated with dredging, sediment disposal, and transportation of capping and treatment material by truck, barge, and train (Table 2). For underpier areas, the EW FS assumes use of diver-assisted hydraulic dredging for Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5), which has the same safety considerations as standard hydraulic dredging, but with significant additional technical issues and safety concerns associated with divers performing underwater dredging (especially high risk for death during construction). Based on SRI chemical data (FS Section 2), volume estimates (Appendix F), and estimated production rates (Appendix E), diver-assisted hydraulic dredging is estimated to occur for 2 years under Alternatives 1C+(12), 2C+(12), 3C+(12), and 2C+(7.5), and 12 years under

Alternative 3E(7.5). Approximately 0.017 diver fatalities have been estimated for the sediment removal activities in Alternative 3E(7.5) (the highest fatality number among alternatives, Figure 2), which represents 88% of the fatalities associated with all dredging work and 58% of the total number of fatalities during overall construction of this alternative, due to the large volume of sediment targeted for hydraulic dredging (approximately 46,200 cubic yards [cy]).

Energy required during the implementation of the alternatives is based on diesel fuel combustion and includes not only the energy consumed to remove sediment and disposed of at a landfill, but also to transport and place all capping and in situ treatment materials at the EW (Table 3). The first two remedial activities equally contribute to a combined approximate of 66% of the total energy consumption, while the latter two activities account for an additional 33% (long-term monitoring is only 1% of the total consumed energy). Figure 3 shows that the increasing total energy consumption across the alternatives, ranging from approximately 1.1 x 10^8 MJ (for Alternative 1A(12), due to including capping, ENR, and monitored natural recovery) to approximately 1.4 x 10^8 MJ (for Alternative 3E(7.5), because of its large removal volume). Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5) include removal in underpier areas, which will be conducted with diver-assisted hydraulic dredging. A water treatment system, associated with hydraulically-dredged sediments, is assumed to treat dewatered liquid and contaminants from the dredged material, and will be operated with electricity. Electrical energy consumption associated with hydraulic dredging is not expected to significantly contribute to the overall energy consumption of Alternatives 1C+(12), 2C+(12), 3C+(12), and 2C+(7.5) (approximately 0.1%), but is higher for Alternative 3E(7.5) (approximately 6%).

Materials such as sand, gravel, and armor stone are assumed to be used for capping, backfilling, RMC, and ENR. Based on preliminary cap modeling in Appendix D, a 5-foot-thick cap has been estimated for the EW FS, representing 1.5 feet of armor, 1 foot of filter material, and 2.5 feet of isolation material. Table 4 and Figure 4 show the volumes of natural resources depleted for in-water placement, which are generally in the same range across alternatives, varying between 260,183 cy (for Alternative 3C+(12)) to 287,117 cy (for Alternative 1B(12)).

The landfill capacity consumed increases in proportion to the dredge volume of the alternatives. In general, Alternative 3E(7.5) results in the largest use of landfill space, with an average volume of 1,300,000 cy, based on a total removal volume of 1,080,000 cy and a 20% bulking factor (Table 5). Alternatives 1A(12) and 1B(12) (with approximately 810,000 cy removed) and 1C+(12) (with approximately 820,000 cy removed) have the smallest removal volumes across the alternatives, and, therefore, the smallest landfill capacity consumed (approximately 970,000 and 980,000 cy, respectively; Figure 5).

The carbon footprint for each alternative in Table 6 is expressed as area-year, where 1 acre represents the amount of CO_2 sequestered by 1 acre of Douglas fir forest for 1 year. Alternative 3E(7.5) has the largest carbon footprint (approximately 5,369 acre-year) based on its CO_2 emissions (22,700 metric tons) and longest period of construction (13 years). Figure 6 depicts Alternatives 1A(12) and 1B(12) with the smallest carbon footprint (3,784 acres-year each alternative) because of only 16,000 metric tons of CO_2 emissions and their 9-year construction timeframes.

3.2 Best Management Practices

The EPA *Principles for Greener Cleanups* (2009) outlines the agency's policy for evaluating and minimizing the environmental footprint of activities undertaken when cleaning up a contaminated site. Use of the BMPs recommended in EPA's green remediation guidance can help to apply the principles on a routine basis, while maintaining the cleanup objectives, ensuring protectiveness of a remedy in the EW OU, and improving its environmental outcome.

EPA's publication *Clean Fuel & Emission Technologies for Site Cleanup* (EPA 2010c) identifies a number of BMPs for reducing air pollutant emissions. These BMPs generally fall into four categories, as follows:

- Effective operation and maintenance to ensure efficiency of vehicles and field equipment
- Advanced diesel technologies
- Alternative fuels and fuel additives
- Fuel-efficient or alternative fuel vehicles

All of these BMPs are potentially applicable for the alternatives in the EW to reduce CO_2, particulate, and other air pollutant emissions (Part 1 of this appendix). Using biodiesel is one example of an alternate fuel for reducing emissions in smaller construction equipment (e.g., front-end loaders); however, higher grades of biodiesel are impractical for use in large-scale equipment because it removes deposits within the fuel tank and fuel lines, clogs existing filters, and thereby creates waste and safety issues (NBB 2010). Also, electric dredges could reduce emissions associated with dredging activities; however, this technology is relatively new and not widely used; it might not be applicable to the EW because of navigation restrictions (e.g., shore power). Examples of advanced diesel technologies include retrofitting diesel engines with diesel particulate filters. Fuel-efficient or alternative fuel vehicles, such as small trucks or hybrid cars, may be considered for site management and monitoring activities.

Additional BMPs that can be specified during remedial design to further minimize the environmental footprint of the preferred alternative include the following (EPA 2008a, 2008b, 2010a, 2010c):

- Recycle uncontaminated materials removed from the EW (i.e., metals, construction debris, tires, etc.).
- Limit on-site vehicle speed on land to reduce particle suspension and increase fuel efficiency.
- Select fuel-efficient equipment and vehicles and alternative fuel vehicles (e.g., electric, hybrid, or compressed natural gas).
- Select suitable types of equipment and vehicles capable of handling alternative fuels (e.g., ultra-low sulfur diesel or biomass-based renewable fuel) and fuel additives (e.g., emulsified diesel or cetane enhancers) to improve fuel economy and lower GHG emissions.
- Select equipment fitted with advanced emission control systems (e.g., diesel oxidation catalyst, diesel particulate matter filter, partial diesel particulate filter, diesel multi-stage filter, or selective catalytic reduction).
- Select lower GHG-emitting fuel sources (e.g., biodiesel) for small equipment and trucks.
- Impose idling restrictions on construction equipment to increase fuel efficiency and reduce GHG emissions.
- Provide alternatives to diesel-powered generators for use during construction.

- Analyze various alternative technologies that could reduce energy consumption, waste, and emissions.
- Select fuel efficient modes of transportation for movement of materials (e.g., rail and barge versus truck transport).
- Select equipment and processes that minimize water use, and promote reuse and water conservation.
- Select reused, reusable, recycled, and recyclable materials to the greatest extent practical.
- Conduct and document routine equipment and vehicle maintenance.
- Accurately delineate contaminated sediment and sediment management areas to minimize dredging volume.
- Perform construction sequentially in a manner intended to reduce unnecessary movement of construction equipment.
- Select a landfill that collects methane.
- Incorporate sustainable site design.

A number of the operation and maintenance BMPs may be applicable to all of the alternatives during construction. These include the following:

- Reduce vehicle idling.
- Maintain equipment.
- Follow transportation and site management plans that emphasize fuel efficiency and proper fuel handling.
- Obtain materials and equipment locally to minimize shipping and mobilization distance.
- Encourage construction personnel to carpool to and from the site.

Another aspect of construction is ensuring the safety of all personnel. To prevent accidents, safety BMPs such as the following could be used:

- Complete a safety plan and ensure that all personnel are familiar with it.
- Provide proper safety equipment.
- Perform daily safety tailgate meetings to discuss potential hazards.
- Perform regular safety audits.
- Maintain a site safety officer on site at all times.

4 REFERENCES

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TABLES

Table 1. Transportation Impacts

Activity/Parameter	Units	Alternative [a]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
SEDIMENT DISPOSAL [b]										
Total Dredge Volume [c]	cy	853,776	853,776	861,142	947,323	954,689	1,002,861	1,010,227	1,065,653	1,136,135
Distance from EW to Offloading Area	miles	5	5	5	5	5	5	5	5	5
Distance from Offloading Area to Landfill	miles	284	284	284	284	284	284	284	284	284
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Railcar Capacity [d]	cy	67	67	67	67	67	67	67	67	67
SUBTOTAL TRANSPORTATION - SEDIMENT DISPOSAL (miles)	***Barge***	**5,300**	**5,300**	**5,400**	**5,900**	**6,000**	**6,300**	**6,300**	**6,700**	**7,100**
	Rail	**72,400**	**72,400**	**73,000**	**80,300**	**80,900**	**85,000**	**85,600**	**90,300**	**96,300**
CAPPING/TREATMENT MATERIAL TRANSPORTATION [e]										
Capping Material Volume	cy	285,701	286,307	286,241	275,155	275,092	259,084	258,761	284,204	267,363
Sand Material Volume (Low Bridges)	cy	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562
In situ Treatment Material (Activated Carbon) Volume (Underpiers)	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Distance from Quarry to Shore (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Shore to EW (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Vendor in OH to EW (for Activated Carbon)	miles	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452
Truck Capacity	cy	13	13	13	13	13	13	13	13	13
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Railcar Capacity [d]	cy	67	67	67	67	67	67	67	67	67
SUBTOTAL TRANSPORTATION - CAPPING/TREATMENT MATERIAL TRANSPORTATION (miles)	***Truck***	**125,900**	**126,200**	**126,200**	**121,600**	**121,500**	**114,500**	**114,400**	**125,600**	**118,200**
	Barge	**7,200**	**7,200**	**7,200**	**6,900**	**6,900**	**6,500**	**6,500**	**7,100**	**6,700**
	Rail	**0**	**3,600**	**3,600**	**3,600**	**3,600**	**3,600**	**3,600**	**3,700**	**3,700**

TOTAL TRANSPORTATION IMPACTS (miles)	***Truck***	**125,900**	**126,200**	**126,200**	**121,600**	**121,500**	**114,500**	**114,400**	**125,600**	**118,200**
	Barge	**12,500**	**12,500**	**12,600**	**12,800**	**12,900**	**12,800**	**12,800**	**13,800**	**13,800**
	Rail	**72,400**	**76,000**	**76,600**	**83,900**	**84,500**	**88,600**	**89,200**	**94,000**	**100,000**

Notes:

a. Quantities and production rates by alternative were obtained from Appendix E.

b. Dredged sediments are assumed to be hauled to an offloading area outside of the EW (by barge) and disposed of at a Subtitle D landfill in Roosevelt, Washington (by rail).

c. Assumes bulking factor of 5% for mechanical offloading.

d. Rail transportation assumes that all trains will consist of a full unit train of 100 railcars.

e. Capping materials are assumed to be transported from a local quarry to an onshore staging area by truck, and then to the EW by barge.

cy - cubic yard; EW - East Waterway

Table 2. Predicted Workplace Accidents

Activity/Parameter	Units	Alternative [g]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
SEDIMENT REMOVAL										
Open-water Dredge Volume	cy	813,120	813,120	813,120	902,212	902,212	938,455	938,455	1,007,892	1,016,453
Production Rate	cy/d	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Restricted Access Dredge Volume (Under West Seattle Bridge)	cy	0	0	0	0	0	16,651	16,651	0	19,365
Production Rate	cy/d	270	270	270	270	270	270	270	270	270
Diver-Assisted Hydraulic Dredge Volume (Underpiers)	cy	0	0	7,016	0	7,016	0	7,016	7,016	46,216
Production Rate	cy/d	40	40	40	40	40	40	40	40	40
Working Days per Season	days	100	100	100	100	100	100	100	100	100
Number of Construction Equipment Operators - Open-water Dredging	worker	3	3	3	3	3	3	3	3	3
Number of Divers - Underpier Dredging [a]	diver	0	0	1	0	1	0	1	1	1
Number of Construction Equipment Operators - Underpier Dredging [a]	worker	0	0	5	0	5	0	5	5	5
Injury Rate for Heavy and Civil Engineering Construction [b]	injuries/worker/year	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Fatality Rate for Operating Engineers and Other Construction Equipment Operators [c]	fatalities/worker/year	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075
Fatality Rate for Commercial Diving [d]	fatalities/diver/year	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
	Predicted Injuries	**0.67**	**0.67**	**0.82**	**0.74**	**0.90**	**0.82**	**0.98**	**0.98**	**1.94**
SUBTOTAL PREDICTED ACCIDENTS -	***Predicted Fatalities - Open-water Dredging***	**0.0017**	**0.0017**	**0.0017**	**0.0018**	**0.0018**	**0.0021**	**0.0021**	**0.0021**	**0.0022**
SEDIMENT REMOVAL	***Predicted Fatalities - Underpier Dredging***	**0**	**0**	**0.0023**	**0**	**0.0023**	**0.0000**	**0.0026**	**0.0026**	**0.0170**
	Total Predicted Fatalities	**0.0017**	**0.0017**	**0.0040**	**0.0018**	**0.0042**	**0.0021**	**0.0046**	**0.0046**	**0.0193**
SEDIMENT TRANSLOADING AND DISPOSAL										
Total Dredge Volume [e]	cy	853,776	853,776	861,142	947,323	954,689	1,002,861	1,010,227	1,065,653	1,136,135
Offloading Rate	cy/d	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Distance from EW to Offloading Area	miles	5	5	5	5	5	5	5	5	5
Distance from Offloading Area to Landfill [f]	miles	284	284	284	284	284	284	284	284	284
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Tug Speed	mi/hr	5	5	5	5	5	5	5	5	5
Railcar Capacity	cy	67	67	67	67	67	67	67	67	67
Train Speed	mi/hr	50	50	50	50	50	50	50	50	50
Working Hours per Day	hours	12	12	12	12	12	12	12	12	12
Working Days per Season	days	100	100	100	100	100	100	100	100	100
Number of Construction/Water Equipment Operators	worker	3	3	3	3	3	3	3	3	3
Number of Rail Operators	worker	8	8	8	8	8	8	8	8	8
Injury Rate for Heavy and Civil Engineering Construction [b]	injuries/worker/year	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Fatality Rate for Operating Engineers and Other Construction Equipment Operators [c]	fatalities/worker/year	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075
Injury Rate for Inland Water Freight Transportation	injuries/worker/year	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Fatality Rate for Water Transportation	fatalities/worker/year	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
Injury Rate for Rail Transportation [a]	injuries/worker/year	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Fatality Rate for Rail Transportation [c]	fatalities/worker/year	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
SUBTOTAL PREDICTED ACCIDENTS -	***Predicted Injuries***	**0.59**	**0.59**	**0.60**	**0.66**	**0.66**	**0.70**	**0.70**	**0.74**	**0.79**
SEDIMENT TRANSLOADING AND DISPOSAL	***Predicted Fatalities***	**0.0023**	**0.0023**	**0.0023**	**0.0025**	**0.0025**	**0.0027**	**0.0027**	**0.0028**	**0.0030**

Table 2. Predicted Workplace Accidents

Activity/Parameter	Units	Alternative [g]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
CAPPING/TREATMENT MATERIAL TRANSPORTATION										
Capping Material Volume	cy	285,701	286,307	286,241	275,155	275,092	259,084	258,761	284,204	267,363
Sand Material Volume (Low Bridges)	cy	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562
In situ Treatment Material (Activated Carbon) Volume (Underpiers)	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Distance from Quarry to Shore (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Shore to EW (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Vendor in OH to EW (for Activated Carbon)	miles	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452
Truck Capacity	cy	13	13	13	13	13	13	13	13	13
Truck Speed	mi/hr	40	40	40	40	40	40	40	40	40
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Tug Speed	mi/hr	5	5	5	5	5	5	5	5	5
Railcar Capacity	cy	67	67	67	67	67	67	67	67	67
Train Speed	mi/hr	50	50	50	50	50	50	50	50	50
Working Hours per Day	hours	12	12	12	12	12	12	12	12	12
Working Days per Season	days	100	100	100	100	100	100	100	100	100
Number of Truck Operators	worker	7	7	7	7	7	7	7	7	7
Number of Water Equipment Operators	worker	2	2	2	2	2	2	2	2	2
Number of Train Operators	worker	8	8	8	8	8	8	8	8	8
Injury Rate for General Freight Trucking, local [b]	injuries/worker/year	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Fatality Rate for Truck Transportation [c]	fatalities/worker/year	0.000239	0.000239	0.000239	0.000239	0.000239	0.000239	0.000239	0.000239	0.000239
Injury Rate for Inland Water Freight Transportation [b]	injuries/worker/year	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Fatality Rate for Water Transportation [c]	fatalities/worker/year	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
Injury Rate for Rail Transportation [b]	injuries/worker/year	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Fatality Rate for Rail Transportation [c]	fatalities/worker/year	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
SUBTOTAL PREDICTED ACCIDENTS -	***Predicted Injuries***	**0.84**	**0.86**	**0.86**	**0.82**	**0.82**	**0.78**	**0.78**	**0.85**	**0.80**
CAPPING/TREATMENT MATERIAL TRANSPORTATION	***Predicted Fatalities***	**0.0051**	**0.0052**	**0.0052**	**0.0050**	**0.0050**	**0.0047**	**0.0047**	**0.0051**	**0.0048**
CAPPING/TREATMENT MATERIAL PLACEMENT										
Sand Capping Volume	cy	234,151	234,756	234,690	223,604	223,541	229,661	229,338	232,434	237,720
Production Rate	cy/d	940	940	940	940	940	940	940	940	940
Gravel Capping Volume	cy	20,620	20,620	20,620	20,620	20,620	11,769	11,769	20,708	11,857
Production Rate	cy/d	940	940	940	940	940	940	940	940	940
Armor Stone Capping Volume	cy	30,931	30,931	30,931	30,931	30,931	17,654	17,654	31,062	17,786
Production Rate	cy/d	560	940	940	940	940	940	940	940	940
In situ Treatment Material Volume	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Production Rate	cy/d	60	60	60	60	60	61	60	60	60
Sand Material Volume (Low Bridges)	cy	811	811	811	1,421	1,421	1,421	1,421	1,562	1,562
Production Rate	cy/d	60	60	60	60	60	61	60	60	60
Working Days per Season	days	100	100	100	100	100	100	100	100	100
Number of Construction Equipment Operators	worker	3	3	3	3	3	4	3	3	3
Injury Rate for Heavy and Civil Engineering Construction [b]	injuries/worker/year	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Fatality Rate for Operating Engineers and Other Construction Equipment Operators [c]	fatalities/worker/year	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075	0.000075
SUBTOTAL PREDICTED ACCIDENTS -	***Predicted Injuries***	**0.31**	**0.36**	**0.36**	**0.36**	**0.36**	**0.45**	**0.34**	**0.37**	**0.36**
MATERIAL PLACEMENT	***Predicted Fatalities***	**0.0008**	**0.0009**	**0.0009**	**0.0009**	**0.0009**	**0.0011**	**0.0009**	**0.0009**	**0.0009**

Table 2. Predicted Workplace Accidents

Activity/Parameter	Units	Alternative [g] 1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
LONG-TERM MONITORING										
Construction Seasons	year	9	9	9	10	10	10	10	11	13
Number of Monitoring Events	event	8	8	8	8	8	8	8	8	8
Number of Water Equipment Operators	worker	3	3	3	3	3	4	3	3	3
Injury Rate for Inland Water Freight Transportation [b]	injuries/worker/year	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Fatality Rate for Water Transportation [c]	fatalities/worker/year	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
SUBTOTAL PREDICTED ACCIDENTS - LONG-TERM MONITORING	***Predicted Injuries***	**0.0776**	**0.0776**	**0.0776**	**0.0863**	**0.0863**	**0.1150**	**0.0863**	**0.0949**	**0.1121**
	Predicted Fatalities	**0.0010**	**0.0010**	**0.0010**	**0.0012**	**0.0012**	**0.0016**	**0.0012**	**0.0013**	**0.0015**
TOTAL PREDICTED ACCIDENTS	***Total Predicted Injuries***	**2.49**	**2.55**	**2.71**	**2.67**	**2.83**	**2.87**	**2.89**	**3.04**	**4.00**
	Total Predicted Fatalities	**0.011**	**0.011**	**0.013**	**0.011**	**0.014**	**0.012**	**0.014**	**0.015**	**0.030**

Notes:

a. A diving crew for underpier dredging includes the diver, tender, responder/backup diver, boat operator, and two workers for the pump, dredge, lines, and other construction duties.

b. Source: U.S. Department of Labor, Bureau of Labor Statistics (Industry Injury and Illness Data for 2014, Supplemental News Release Tables [Injury cases - rates, counts, and percent relative standard errors - detailed industry - 2014 SNR05]). http://www.bls.gov/iif/oshsum.htm#14Summary_News_Release

c. Source: U.S. Department of Labor, Bureau of Labor Statistics (Census of Fatal Occupational Injuries, 2007-2012). http://www.bls.gov/iif/oshcfoi1.htm

d. An average of 6 to 13 diving fatalities occur each year, which corresponds to a risk of between 28 and 50 deaths per 1,000 workers over a working lifetime of 45 years (U.S. Department of Labor, Occupational Safety and Health Administration [Commercial Diving Safety; https://www.osha.gov/archive/oshinfo/priorities/diving.html]).

e. A bulking factor of 5% is included in the total dredge volume for mechanical offloading.

f. Sediment is assumed to be transferred from the intermodal station in Seattle, Washington, to a Subtitle D landfill in Roosevelt, Washington.

g. Quantities and production rates by alternative were obtained from Appendix E.

cy - cubic yard; d - day; EW - East Waterway

Table 3. Energy Consumption

Activity/Parameter	Units	Alternative[a]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
SEDIMENT REMOVAL										
Open-water Dredge Volume	cy	813,120	813,120	813,120	902,212	902,212	938,455	938,455	1,007,892	1,016,453
Production Rate	cy/d	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Restricted Access Dredge Volume	cy	0	0	0	0	0	16,651	16,651	0	19,365
Production Rate	cy/d	270	270	270	270	270	270	270	270	270
Underpier Dredge Volume	cy	0	0	7,016	0	7,016	0	7,016	7,016	46,216
Production Rate	cy/d	40	40	40	40	40	40	40	40	40
Working Hours per Day - Open-water Dredging	hours	12	12	12	12	12	12	12	12	12
Working Hours per Day - Underpier Dredging	hours	8	8	8	8	8	8	8	8	8
Fuel Consumption - Derrick Crane	gal/hr	25	25	25	25	25	25	25	25	25
Electricity Consumption - Water Treatment	KW	250	250	250	250	250	250	250	250	250
Energy Content of Diesel Fuel	MJ/gal	158	158	158	158	158	158	158	158	158
SUBTOTAL ENERGY CONSUMPTION - SEDIMENT REMOVAL (MJ)		**3.5E+07**	**3.5E+07**	**3.6E+07**	**3.9E+07**	**4.0E+07**	**4.3E+07**	**4.5E+07**	**4.5E+07**	**5.6E+07**
SEDIMENT TRANSLOADING AND DISPOSAL										
Total Dredge Volume[b]	cy	853,776	853,776	861,142	947,323	954,689	1,002,861	1,010,227	1,065,653	1,136,135
Offloading Rate	cy/d	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Distance from EW to Offloading Area	miles	5	5	5	5	5	5	5	5	5
Distance from Offloading Area to Landfill[c]	miles	284	284	284	284	284	284	284	284	284
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Tug Speed	mi/hr	5	5	5	5	5	5	5	5	5
Railcar Capacity	cy	67	67	67	67	67	67	67	67	67
Working Hours per Day	hours	12	12	12	12	12	12	12	12	12
Fuel Consumption - Derrick Crane	gal/hr	25	25	25	25	25	25	25	25	25
Fuel Consumption - Tug	gal/hr	85	85	85	85	85	85	85	85	85
Fuel Consumption - Railcar	gal/mi	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Energy Content of Diesel Fuel	MJ/gal	158	158	158	158	158	158	158	158	158
SUBTOTAL ENERGY CONSUMPTION - SEDIMENT TRANSLOADING AND DISPOSAL (MJ)		**3.5E+07**	**3.5E+07**	**3.6E+07**	**3.9E+07**	**3.9E+07**	**4.1E+07**	**4.2E+07**	**4.4E+07**	**4.7E+07**

Table 3. Energy Consumption

Activity/Parameter	Units	Alternative[a]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
CAPPING/TREATMENT MATERIAL TRANSPORTATION										
Capping Material Volume	cy	285,701	286,307	286,241	275,155	275,092	259,084	258,761	284,204	267,363
Sand Material Volume (Low Bridges)	cy	811	811	811	1421	1421	1421	1421	1562	1562
In situ Treatment Material Volume	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Distance from Quarry to Shore (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Shore to EW (for Capping Material)	miles	20	20	20	20	20	20	20	20	20
Distance from Vendor in OH to EW (for Activated Carbon)	miles	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452	2,452
Truck Capacity	cy	13	13	13	13	13	13	13	13	13
Truck Speed	mi/hr	40	40	40	40	40	40	40	40	40
Barge Capacity	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Tug Speed	mi/hr	5	5	5	5	5	5	5	5	5
Railcar Capacity	cy	67	67	67	67	67	67	67	67	67
Fuel Consumption - Truck	gal/mi	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fuel Consumption - Tug	gal/hr	85	85	85	85	85	85	85	85	85
Fuel Consumption - Railcar	gal/mi	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Energy Content of Diesel Fuel	MJ/gal	158	158	158	158	158	158	158	158	158
SUBTOTAL ENERGY CONSUMPTION - CAPPING/TREATMENT MATERIAL TRANSPORTATION (MJ)		**2.3E+07**	**2.3E+07**	**2.3E+07**	**2.2E+07**	**2.2E+07**	**2.1E+07**	**2.1E+07**	**2.3E+07**	**2.2E+07**
CAPPING/TREATMENT MATERIAL PLACEMENT										
Sand Capping Volume	cy	234,151	234,756	234,690	223,604	223,541	229,661	229,338	232,434	237,720
Production Rate	cy/d	940	940	940	940	940	940	940	940	940
Gravel Capping Volume	cy	20,620	20,620	20,620	20,620	20,620	11,769	11,769	20,708	11,857
Production Rate	cy/d	940	940	940	940	940	940	940	940	940
Armor Stone Capping Volume	cy	30,931	30,931	30,931	30,931	30,931	17,654	17,654	31,062	17,786
Production Rate	cy/d	560	940	940	940	940	940	940	940	940
In situ Treatment Material Volume	cy	0	4,867	4,867	4,867	4,867	4,867	4,867	5,113	5,113
Production Rate	cy/d	60	60	60	60	60	61	60	60	60
Sand Material Volume (Low Bridges)	cy	811	811	811	1421	1421	1421	1421	1562	1562
Production Rate	cy/d	60	60	60	60	60	60	60	60	60
Working Hours per Day	hours	12	12	12	12	12	12	12	12	12
Fuel Consumption - Derrick Crane	gal/hr	25	25	25	25	25	25	25	25	25
Energy Content of Diesel Fuel	MJ/gal	158	158	158	158	158	158	158	158	158
SUBTOTAL ENERGY CONSUMPTION - MATERIAL PLACEMENT (MJ)		**1.6E+07**	**1.9E+07**	**1.9E+07**	**1.9E+07**	**1.9E+07**	**1.8E+07**	**1.8E+07**	**2.0E+07**	**1.9E+07**

Table 3. Energy Consumption

Activity/Parameter	Units	Alternative[a]								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
LONG-TERM MONITORING										
Number of Monitoring Events	event	8	8	8	8	8	8	8	8	8
Working Hours per Day	hours	12	12	12	12	12	12	12	12	12
Fuel Consumption - Tug	gal/hr	85	85	85	85	85	85	85	85	85
Energy Content of Diesel Fuel	MJ/gal	158	158	158	158	158	158	158	158	158
SUBTOTAL ENERGY CONSUMPTION - LONG-TERM MONITORING (MJ)		**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**	**1.3E+06**
TOTAL ENERGY CONSUMPTION (MJ)		**1.11E+08**	**1.14E+08**	**1.15E+08**	**1.21E+08**	**1.22E+08**	**1.25E+08**	**1.27E+08**	**1.33E+08**	**1.44E+08**

Notes:

a. Quantities and production rates by alternative were obtained from Appendix E.

b. A bulking factor of 5% is included in the total dredge volume for mechanical offloading.

c. Sediment is assumed to be transferred from the intermodal station in Seattle, Washington, to a Subtitle D landfill in Roosevelt, Washington.

cy - cubic yard; d - day; EW - East Waterway; gal - gallon; hr - hour; kW - kilowatt-hour; mi - mile; MJ - megajoule

Table 4. Depleted Natural Resources

Parameter	Units	Alternative								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Sand, Gravel and Armor Stone Used for Placement	cy	286,512	287,117	287,051	276,576	276,513	260,506	260,183	285,766	268,925

Table 5. Consumed Landfill Capacity

Parameter	Units	Alternative								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Total Removal Volume	cy	810,000	810,000	820,000	900,000	910,000	960,000	960,000	1,010,000	1,080,000
Landfill Capacity Consumed	cy	970,000	970,000	980,000	1,080,000	1,090,000	1,150,000	1,150,000	1,210,000	1,300,000

Note:

a. The landfill capacity consumed is proportional to the volume of dredged material removed and disposed of in the landfill (assuming a 20% bulking factor).

Table 6. Carbon Footprint

Parameter	Units	Alternative								
		1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
CO_2 emissions	tonnes	16,000	16,000	16,100	17,000	18,100	18,000	18,100	19,100	22,700
CO_2 absorbed	g CO_2/g biomass	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Sequestration rate for Douglas fir in Pacific Northwest	tons CO_2/acre-year	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Construction timeframe	year	9	9	9	10	10	10	10	11	13
Carbon Footprint (acres-years)		**3,784**	**3,784**	**3,808**	**4,021**	**4,281**	**4,257**	**4,281**	**4,518**	**5,369**

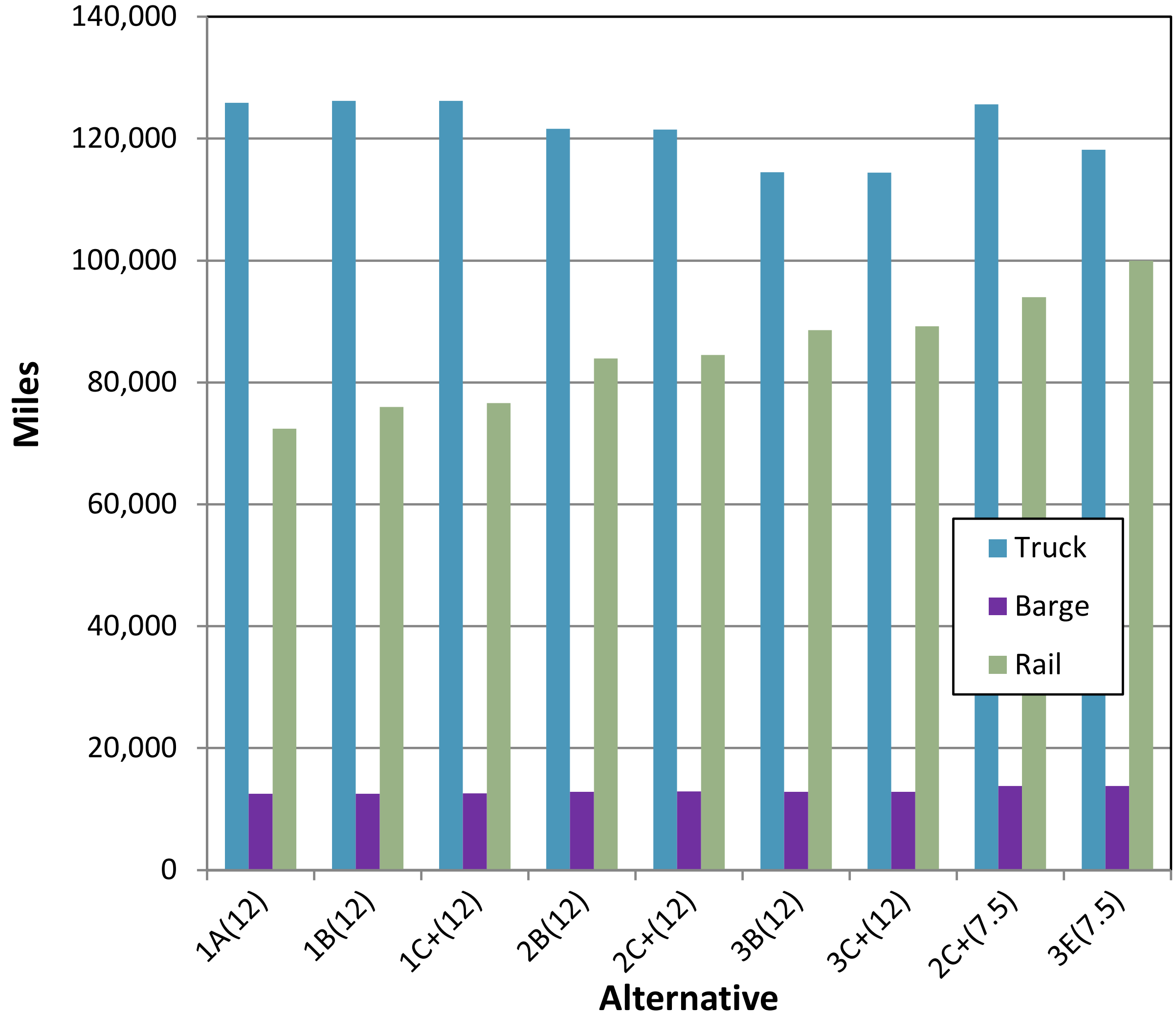
Notes:

a. Total direct and indirect CO_2 emissions by alternative available in Appendix I, Part 1, Tables 11a and 11b.

b. The Douglas fir growth rate represent the amount of CO_2 sequestered by 1 acre of Douglas fir forest for 1 year.

CO_2 - carbon dioxide; cy - cubic yard; g - gram

FIGURES



Note:
Impacts from truck transportation could be effectively reduced by increased barge transportation.

Figure 1
Transportation Impacts
Feasibility Study - Appendix I, Part 2
East Waterway Study Area

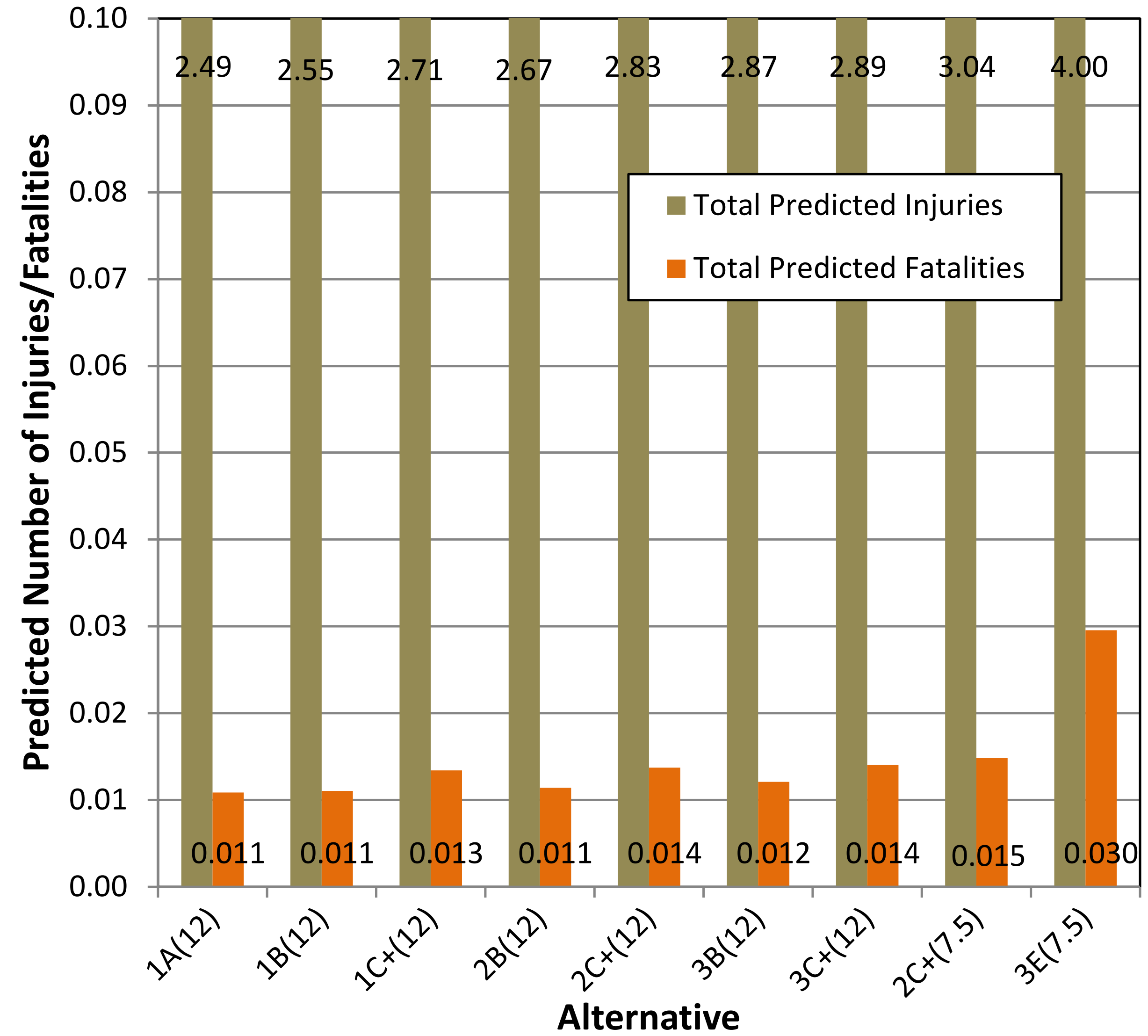


Figure 2
Predicted Workplace Accidents
Feasibility Study - Appendix I, Part 2
East Waterway Study Area

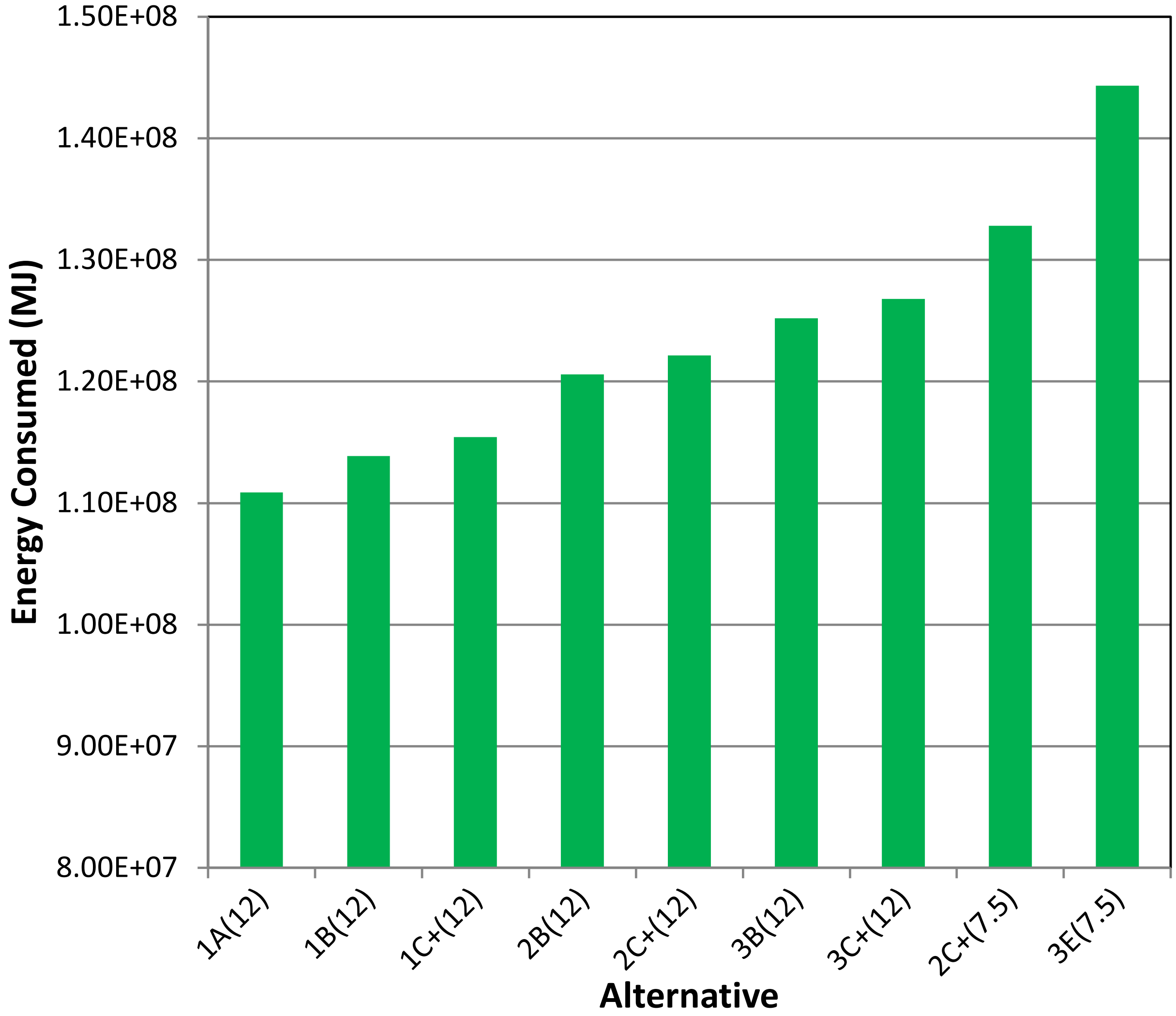


Figure 3
Energy Consumption
Feasibility Study - Appendix I, Part 2
East Waterway Study Area

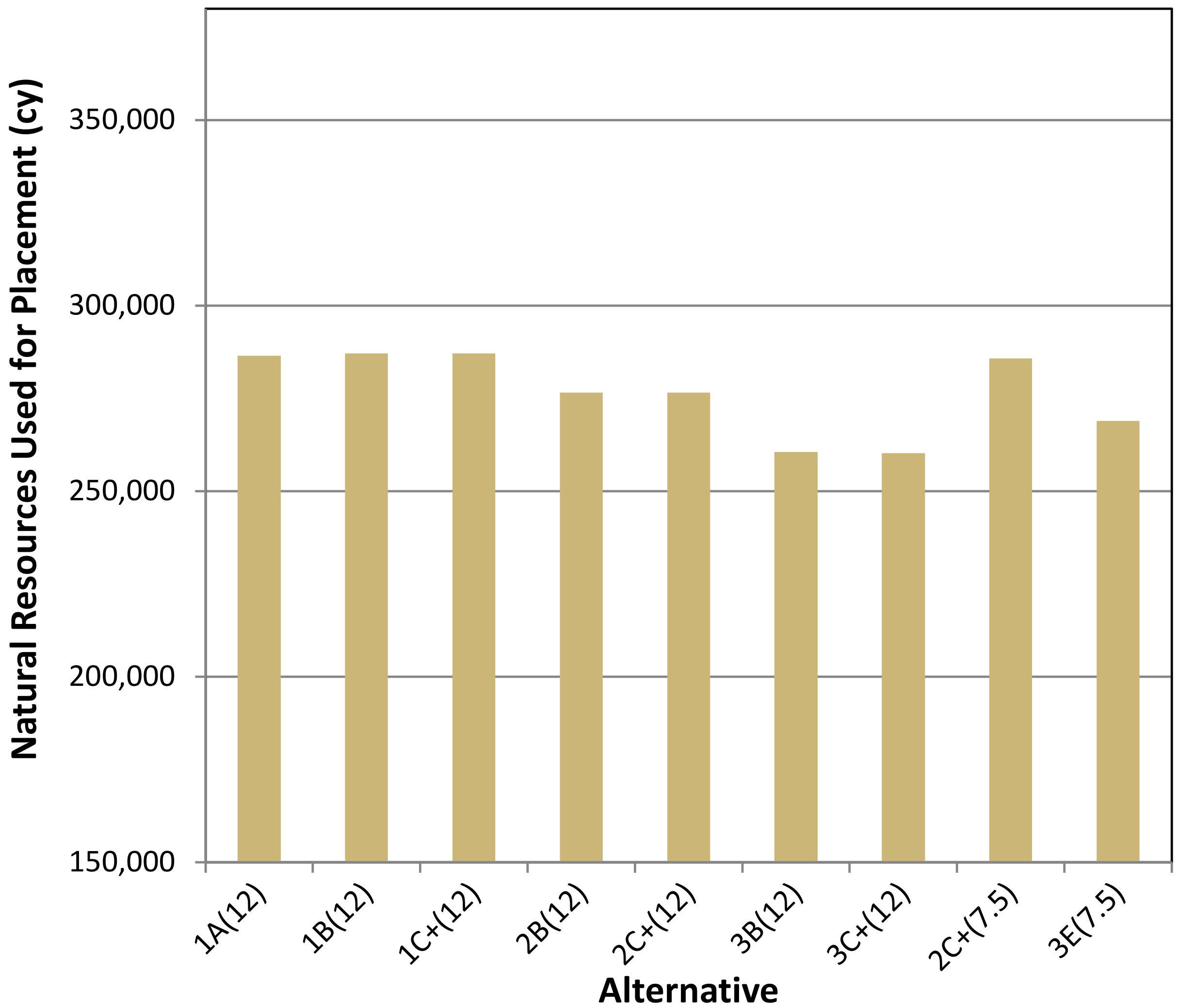


Figure 4
Depleted Natural Resources
Feasibility Study - Appendix I, Part 2
East Waterway Study Area

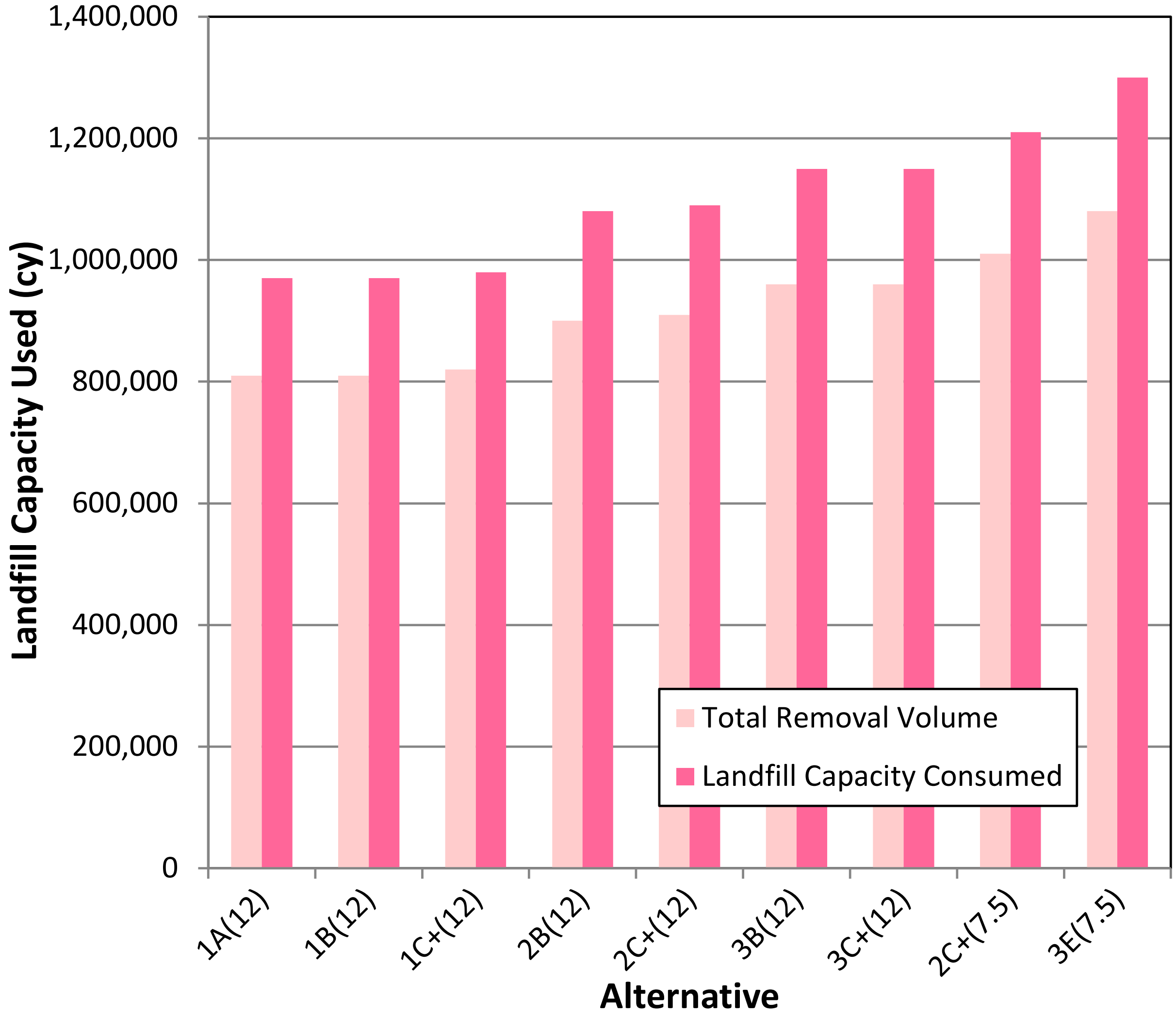


Figure 5
Consumed Landfill Capacity
Feasibility Study - Appendix I, Part 2
East Waterway Study Area

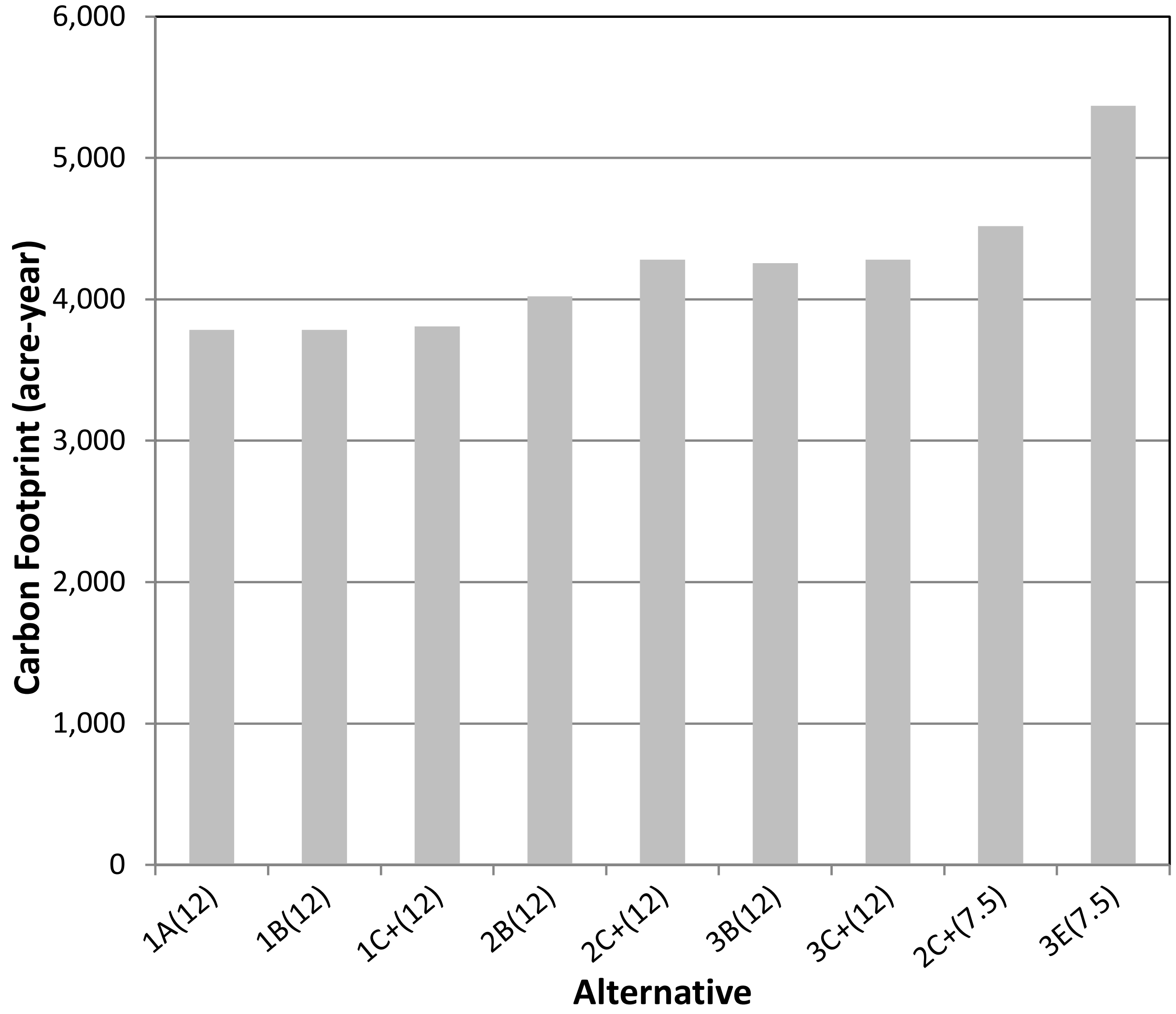


Figure 6
Carbon Footprint
Feasibility Study - Appendix I, Part 2
East Waterway Study Area