King County
Wastewater Treatment Division
Department of Natural Resources and Parks
King Street Center, KSC-NR-0512
201 South Jackson Street
Seattle, WA 98104-3855

January 14, 2014

TO: Christie True, Director, Department of Natural Resources and Parks (DNRP)

FM: Pam Elardo, Division Director, Wastewater Treatment Division (WTD), DNRP

RE: Analysis of Transport Alternatives for Lower Duwamish Cleanup

Attached is a truck trip analysis for the Lower Duwamish Waterway Cleanup project conducted by Heffron Transportation, Inc. for King County DNRP.

The Environmental Protection Agency's (EPA) Feasibility Study for the cleanup of the Lower Duwamish Waterway (LDW) estimated the number of potential truck trips that could be generated under each of the cleanup alternatives the agency evaluated. The EPA assumed 100% of the material would be transported by truck. King County and others acknowledge that the actual cleanup may include transport of material through a variety of transport modes (truck/rail/barge).

In the fall of 2013, after discussions with Duwamish River Cleanup Coalition, King County hired Heffron Transportation, Inc. to perform an analysis of potential truck trip generation and truck trip distribution during the future cleanup of the Duwamish River.

Our interests:

- Improve understanding of the range of transportation alternatives beyond trucks that could occur during construction of the LDW cleanup; and
- Allow for more informed discussion of traffic impacts with affected community now and as we get closer to design and permitting

This study has helped us with both these interests. In addition, it is important to note the boundaries of the analysis and what it does not provide. This analysis does not assess the likelihood of, cost of, nor process for siting, permitting and development of transload facilities (direct-to-rail or barge-to-truck). This analysis also does not contemplate any additional traffic impacts that could be generated by addition and operation of transload facilities. Lastly, train and barge traffic increases and or impacts are not quantified or evaluated in this analysis. For example, increased barge traffic could generate more bridge openings/concurrent road closures; increased local rail traffic could generate local road crossing and temporary closures.

As a supplement to this analysis by Heffron Transportation, we have also partnered with the Lower Duwamish Waterway Group to secure consulting services from AECOM to analyze potential emissions reductions that could be generated by use of ultra-low sulfur fuels for the Lower Duwamish Waterway cleanup. I am sharing this report with you today as well along with the King County memo that summarizes the analysis.

We look forward to sharing both these studies with Duwamish River Cleanup Coalition and others. As this information is shared it may be important to note the following:

- King County is not proposing a particular transportation scenario.
- King County expects this information to be useful at the time of LDW project design and implementation.
- This study is not intended to override or replace the EPA Feasibility Study work.

King County is committed to working with the community to understand and minimize traffic impacts.
As design of the Lower Duwamish cleanup evolves, King County will be attentive to potential traffic impacts and opportunities for different transport alternatives.

If you have questions about this study, please contact Chris Townsend, Environmental and Community Services Section Manager at 206-477-5641.

Enclosures

Heffron Transportation, Inc. Technical Memorandum, *Lower Duwamish Waterway Cleanup Project,* DATE

King County DNRP Cover Memo to AECOM; *Emissions Assessment for Lower Duwamish Cleanup Alternatives*; Dec 11, 2013 Analysis, January 2, 2014

AECOM/LDWG Memorandum, *Estimated Emission Reduction from Reduced Truck Transportation in the Lower Duwamish Waterway Corridor and Use of Lower Sulfur Fuels,* DATE

TECHNICAL MEMORANDUM

To: Wastewater Treatment Division, King County

From: Jennifer Barnes, P.E. JAB
Tod McBryan, P.E.
Heffron Transportation, Inc.

Project: Lower Duwamish Waterway Cleanup Project

Subject: Truck Trip Analysis

Date: January 10, 2014

The Environmental Protection Agency's (EPA's) *Lower Duwamish Waterway Feasibility Study* evaluated cleanup alternative effects from construction in a way that allowed direct comparisons between alternatives. That analysis used one simplifying set of assumptions for construction-related transportation. King County wanted to look at a range of possible transportation alternatives to allow for a more informed discussion of potential project impacts with the affected community. This memorandum summarizes transportation estimates associated with that range of potential transportation options for the Lower Duwamish Waterway (LDW) Cleanup Project. It includes a description of three cleanup alternatives and three transport scenarios. For this analysis, we have developed estimates of average daily and hourly truck trips under three transport and transload facility scenarios, and identified the potential future truck haul routes to which those trips could be added. This analysis of potential transport impacts is intended for discussion only and does not constitute recommendations. It is anticipated that a much more detailed analysis of transport alternatives and impacts would be prepared as part of preliminary design and environmental review.

1. Description of Cleanup Alternatives and Transport Options

Cleanup alternatives analyzed comprise a combination of cleanup activities including enhanced natural recovery, capping, and dredging. Of these activities, dredging triggers the highest need for transport, as loads of excavated material would need to be hauled away from the site for disposal at a landfill. Three cleanup alternatives that would result in varying amounts of dredged sediment needing to be transported for disposal are summarized in Table 1. The three alternatives were chosen to help bracket and illustrate the range of potential transport impacts. The Key Elements Alternative has the lowest amount of dredging and transport, the EPA Proposed Alternative has a somewhat higher amount, and the Mostly Dredging (5R) Alternative has the highest amount.

The EPA's feasibility study analysis used the same daily rate of dredging (and number of trucks per day) for all cleanup alternatives. The difference in traffic impact between the cleanup alternatives is therefore the total number of days (and years) over which the dredging and hauling would take place. The cleanup alternatives considered in this transport analysis range in duration from approximately 5 years to 17 years. Therefore, while the differences in dredged volumes are not expected to significantly affect the number of truck trips generated on a single day, they would affect the number of years over which truck trips would be generated. This is described in more detail later in this memorandum.

Table 1. Summary of Cleanup Alternatives Used in Traffic Analysis

	Cleanup Actions Considered for Traffic Analysis		
	Key Elements	EPA Proposed	Mostly Dredging (5R)
Cleanup Action Components			
Enhanced Natural Recovery	48%	31%	0%
Capping	25%	28%	9%
Dredging	27%	41%	91%
Estimated Dredged Volume (cubic yards)	620,000	790,000	1,600,000
Estimated Dredged Truck Loads	33,000	42,000	86,000

Sources: EPA 2013; LDW FS 2012; LDWG 2012.

For each cleanup alternative, dredging and removal (transport) of the contaminated waste material can be accomplished in three different ways:

- **Nearshore** – For locations where dredging needs to be accessed from the land, contaminated sediment would be removed using equipment placed near the shore and loaded directly into containers that would be trucked to an offsite facility, where the containers would then be loaded onto a train that would carry the material to a landfill for disposal. Based on the topography and access characteristics of the LDW, the EPA feasibility analysis determined that 22% of the total dredged volume would be removed this way.

- **Transload (Barge-to-Truck)** – Contaminated sediment would be removed using equipment placed on a barge in the LDW. The excavated material would be transferred from barge to a container at a designated transload facility located at the LDW site. A truck would then carry the container to an offsite facility for transfer to rail.

- **Direct-to-Rail** – Contaminated sediment would be removed using equipment placed on a barge in the LDW, and the barge would then carry it directly to a shoreline facility where it would be transferred directly to containers on rail cars. With this option, no truck haul trips would be generated at the direct-to-rail LDW site. (Note, this is also a type of transload operation but for the purpose of this memorandum, in order to differentiate it from the barge-to-truck transload operation described above, it is referred to only as direct-to-rail.)

This analysis focuses on the degree to which each of these transport methods could be used. Note that for purposes of comparison between alternatives, EPA's feasibility analysis defined all dredged material as being trucked since a direct-to-rail facility would not necessarily be available at the time of the project. However, it acknowledged that trucking could be reduced if such facilities were used.

This analysis considers three transport scenarios for each cleanup alternative that would include varying proportions of the removal transportation methods described above. The three transport scenarios are summarized in Table 2. As shown, Transport Scenario A (100% by Trucks) would result in the highest number of truck trips because it would include no direct-to-rail operation and all dredged material would be hauled by truck from the site either as part of nearshore or transload operations. Transport Scenario C (22% by Trucks) represents the lowest percentage of truck usage available due to the use of nearshore operations. Under Scenario C, all other sediment placed onto barges would be direct-to-rail and therefore would not generate truck trips. The number of truck trips resulting from Transport Scenario B (60% by Trucks) was selected to be a middle scenario in-between the other transport scenarios with part of the sediment placed on barges transferred to trucks, and part carried direct-to-rail. This last scenario would occur if a direct–to-rail facility was available to handle part of the sediment dredged daily (based on a current facility's capacity). The resulting estimates of average daily and hourly truck trips are described in the following section.

Table 2. Dredging and Transportation Scenarios [1]

	Percentage of Operation		
Dredging and Transportation Operation	Transport Scenario A 100% by Trucks	Transport Scenario B 60% by Trucks	Transport Scenario C 22% by Trucks
Nearshore	22%	22%	22%
Transload	78%	38%	0%
Direct-to-Rail	0%	40%	78%
Total	100%	100%	100%

Source: King County 2013.
1. Applicable to any cleanup alternative.

2. Truck Trip Estimates

In order to estimate the average numbers of daily and hourly truck trips that could result from the three cleanup alternatives with the three dredging and transportation scenarios described above, the following additional parameters defined in EPA's feasibility analysis were assumed for this evaluation:

- **Number of operating days per year** – The expected annual work window for this operation would be October 1 to February 15. This reflects 138 calendar days. After accounting for weekends, holidays and equipment downtime, EPA's analysis used 88 dredging work days within this period. Therefore, depending on how many days per week the transportation would occur, the number of operating days per year is expected to range from 88 to 138. This analysis assumed the hauling would occur concurrently with the dredging over 88 operating days.

- **Number of operating hours per day** – Dredging operations could occur from 12 to 24 hours per day. However, the hours in which truck trips occur could also be constrained by the operating hours of the facility to which they are hauling the dredged loads. The posted service hours for both potential facilities are 7 A.M. to 6 P.M., which would provide an 11-hour transportation window. However, at least one facility indicates that it allows 24-hour access for contracted customers. Therefore, depending on the number of hours in which dredging would occur and the operating hours at the receiving facility, the number of operating hours per day is expected to range from 11 to 24. For purposes of comparison, this analysis assumed the hauling would occur during over the 11 facility operating hours. Actual hauling hours would be subject to permit conditions, receiving facility operations capacity, and other factors that would be determined at the time of construction.

When reviewing truck trip estimates, it is also important to note that hauling of one dredged load from the site would generate two truck trips. An unloaded truck would travel from the rail transfer facility to the transload site in the LDW area, and a truck with a full container would travel from the site to the rail transfer facility.

Table A-1 in Attachment A includes summary tables of trip estimates for the three cleanup alternatives, with each of the three transport scenarios. As shown, Transport Scenario A (100% trucks) is projected to average about 112 truck trips per day (about 11 truck trips per hour). Transport Scenario B (60% trucks) is projected to average about 66 truck trips per day (about 7 truck trips per hour), and Transport Scenario C (22% trucks) is projected to average about 24 truck trips per day (about 3 truck trips per hour).

While the number of trucks per day varies depending on the transport scenarios, the average daily and hourly truck trips for any particular transport scenario are similar for each cleanup alternative (Table A-1). Since the amount dredged each day would be constant, as the total volume dredged increases, the duration of the dredging would also increase. Therefore, the project's total number of truck trips is directly correlated to the dredging volume required to complete the cleanup alternative – regardless of the transport scenario (Table A-2). The shortest duration would occur with the Key Elements Alternative and the longest duration would occur with the Mostly Dredging (5R) Alternative.

Under all transport scenarios, about 24 daily trips (about 3 trips per hour) would be generated by nearshore operations. These trips would travel to and from various locations along the LDW where the localized nearshore dredging would occur. The remaining trips, if any, would be generated by the transload operations, so would travel to and from one or two transload facilities at specific locations.

The trip projections shown in Attachment A reflect the assumptions described above; operations over more days per year and/or hours per day would result in a lower number of trucks per day and per hour. For example, if transload operations stockpiled dredged material and had trucks continuously haul that dredged material more than 11 hours per day or over more than 88 days within the operating window, the average truck trips per hour or day would decrease for the three cleanup alternatives. Note that the total years in which truck trips occur would not change.

At the high end of the estimated range in Table A-1, 11 trips per hour would likely be noticeable to someone living or working adjacent to the transload facility (unless it were a site that already generates a high level of truck traffic), but may not be noticeable farther from the site on the major arterials used to access the site and the rail transfer facility. Traffic counts at key intersections along potential haul routes were conducted to provide additional information about the added increment of truck traffic and its likely impact on traffic operations, described later in this memorandum.

Table A-2 in Attachment A shows the total estimated truck trips projected for each cleanup alternative with each transport scenario over the duration of the project. As shown, the highest total truck trips would occur, about 172,000, with the Mostly Dredging (5R) Alternative under the "100% by Trucks" scenario. The lowest total trucks, about 14,500, would occur with the Key Elements Alternative under the "22% by Trucks" scenario. The other combinations of cleanup alternatives and transport scenarios would have total truck trips that range between those two estimates.

3. Potential Truck Haul Routes

Attachment B includes maps (Figures 1 through 5) showing potential truck routes that have been projected based upon potential locations for barge-to-truck transload facilities, the locations where nearshore operations are expected to occur as identified in EPA's feasibility study, and the locations of facilities where material can be transferred from truck to rail for ultimate disposal at a landfill.

Trucks hauling dredged material are expected to travel to and from one of two facilities that can accommodate truck-to-rail transfer of material, both located in south Seattle. These facilities are Republic Services (located at 2733 – 3rd Avenue S) and Waste Management (located at 70 Alaska Street S). Routes to and from each facility are shown on Figures 1 through 5 in Attachment B.

Truck trips generated by transload operation would travel to and from one or two transload facilities, where dredged material would be transferred from barge to containers and loaded onto trucks. The exact location of the transload facility (or facilities) is unknown at this time. Therefore, for the purpose of this analysis and to reflect the range of potential travel routes that could be used by trucks, the County identified four potential locations that could be used for transload activity. Two were identified on the west side of the LDW and two were identified on the east side. The potential west side locations are labeled as W-1 and W-2 on Figures 1 and 2, respectively, and the east side locations are labeled as E-1 and E-2 on Figures 3 and 4, respectively. Of the high-end estimated 11 truck trips per hour projected with Transport Scenario A (100% by trucks), 8 truck trips (4 inbound, 4 outbound) would be generated by transload operations; these trips would travel to and from one selected transload facility or could potentially be split between two transload facilities. The remaining 3 truck trips per hour with Transport Scenario A are projected to be generated by nearshore operations described in the EPA feasibility study. These trips could be generated at one of any of the locations where nearshore cleanup actions are expected to occur, labeled as NS-1 through NS-11 on Figure 5 in Attachment B.

The figures in Attachment B show that the majority of truck haul trips generated by LDW cleanup activities would be expected to occur on principal arterial routes: West Marginal Way, East Marginal Way, the West Seattle Bridge, 1st Avenue S and/or 4th Avenue S. Additionally, more than one viable route utilizing these major roadways exists between most points in the LDW project area and the potential rail transfer facilities. However, to access these major streets from the transload and nearshore loading locations adjacent to the LDW, some trips would likely occur on local streets. The local streets that provide access to the four potential transload sites (where the highest volume of truck trips would originate) are located in industrial areas (some with residences) that already have regular truck and heavy vehicle activity. Similarly, most of the local streets that provide access to the largest nearshore areas that could generate truck trips are in industrial areas (some with residences) with regular truck and heavy vehicle activity.

It should be noted that the analysis of potential routes assumed that the South Park Bridge would be reopened by the time truck trips begin occurring. However, based on the location of the likely transload sites and the areas where nearshore activity is likely to occur, no truck trips are expected to use the South Park Bridge as part of the access route to either of the rail transfer facilities. However, this assumption is dependent on the actual location of nearshore dredging operations.

It should also be noted that all the cleanup alternatives will generate an average of at least 2 trains of dredged material each day, resulting in 4 additional train trips through the area; passing of these trains through at-grade rail crossings would also affect vehicle traffic operations. These traffic effects were not evaluated as part of this study. Trains from the direct-to-rail facilities would need to access the main line and would have to cross more local roads than the trains originating from either of the two truck-to-rail transfer facilities located on the main lines.

4. Effect of Additional Truck Trips on Traffic Operations

To determine the potential level of traffic impact that could result from trucks generated by the project, operations at five intersections located along the potential haul routes were evaluated without and with the project-related truck trips. The five intersections, shown in the Attachment C figures and listed in Table 3 below, reflect representative locations along the potential truck haul routes through which truck trips would be expected to travel, depending on the location chosen for the transload facility, the location where a nearshore operation is taking place, and which truck-to-rail transfer facility is used. Conditions were evaluated for year 2018, which would be near the beginning of the construction period.

For the operational analysis, truck trips generated in Transport Scenario A (100% by trucks) were evaluated because they reflect the highest number of trucks that could potentially be generated by the project, and thus would have the highest level of potential impact of the three transport scenarios. Trucks generated with Transport Scenarios B or C would have an even lower effect than the results presented in the sections below. The weekday PM peak hour was evaluated because this is period in which the highest traffic volumes typically occur, so it reflects worst-case traffic operating conditions. It is typical in transportation analysis to evaluate the high end of the range of traffic volumes that could potentially occur without and with the project, in order to determine the worst-case traffic operating conditions that could result. However, it should be noted that at other non-peak times of day, background traffic volumes would be lower, and traffic operating conditions with or without the project would be expected to have lower average vehicle delay than what is presented below.

4.1. Intersection Traffic Volumes

Intersection traffic volumes are based upon new PM peak hour turning movement counts that were conducted on Tuesday, November 19, 2013. The count data include a breakdown of how many of the vehicles traveling through the intersection were heavy vehicles (including trucks and buses). Existing traffic volumes at the five study intersections are shown on Figure 6 in Attachment C.

Historical traffic counts conducted by the Seattle Department of Transportation (SDOT) [1] along the potential truck haul routes were reviewed to determine the traffic growth rates that have occurred in the area over the past 5 to 10 years. The data indicated that changes in traffic volumes have been variable. In some locations, traffic has grown with average increases of about 1% per year. In other locations, volumes have declined. Declines in volumes have been common over the past several years as a result of the economic recession. To provide a conservative estimate for future analyses, a 1% compound annual growth rate was applied to the existing counts to estimate 2018 volumes. This growth rate is intended to account for potential increases in traffic that may occur in the area as the economy continues to recover.

Projected PM peak hour traffic volumes are shown in the figures in Attachment C. Figure 7 shows projected 2018 PM peak hour intersection volumes without the proposed project-related truck traffic.

Figure 8 shows the highest average number of truck trips per hour expected to be added to each intersection by the project (with Transport Scenario A, 100% by Trucks). It should be noted that the

[1] Seattle Department of Transportation (SDOT), 2013, Annual Traffic Count Data, 2005 – 2012.

five intersections would not experience project-generated truck trips all at the same time. As described above, the actual truck trips would depend on the location chosen for the transload facility, the location where a nearshore operation is taking place, and which truck-to-rail transfer facility is used. The trips shown on Figure 8 represent the highest average trips per hour expected to potentially occur at any one of the intersections, if the relative locations of the transload operation, nearshore operation, and transfer facility (based upon the haul routes shown in Attachment B) were lined up for maximum usage of the intersection.

To estimate the 2018 "with project" intersection volumes, the project-generated truck trips were added to the "without project" traffic volumes. Figure 9 shows the projected 2018 "with project" PM peak hour intersection volumes.

4.2. Percent of Heavy Vehicles

Table 3 shows the percentages of heavy vehicles (trucks and buses) traveling through each intersection under existing conditions, and in 2018 without and with the trucks that would potentially be added by the LDW project. The "2018 without project" percentages are based upon the existing traffic counts that were conducted at the intersections. As shown, intersections along the expected truck haul routes already experience a fairly high level of truck traffic, ranging between 5% and 12% of total vehicles traveling through each intersection during the PM peak hour. This is not unexpected, due to the predominance of industrial development located along the potential truck haul routes. The largest increase in heavy vehicle percentage due to project-related truck trips among the five intersections is projected to occur at the East Marginal Way S/ Carleton Avenue S. At this location, the percentage is estimated to change from 12.0% to 12.7%. This and the other relatively small changes in the heavy-vehicle percentages resulting from the project would not likely be noticeable to drivers.

Table 3. Summary of Heavy Vehicle Percentages – PM Peak Hour

	Heavy Vehicle Percentage at Intersections [1]		
Intersection	Existing (2013)	2018 without Project	2018 with Project [2]
4th Avenue S / S Spokane Street	6.5%	6.5%	6.9%
East Marginal Way S / Diagonal Avenue S	5.3%	5.3%	5.6%
4th Avenue S / S Michigan Street	6.0%	6.0%	6.4%
East Marginal Way S / Carleton Avenue S	12.0%	12.0%	12.7%
West Marginal Way S / S Holden Street	8.5%	8.5%	8.8%

Source: Idax Data Solutions, November 2013; Heffron Transportation, Inc., December 2013.

1. Heavy vehicle percentages calculated as total number of trucks entering intersection divided by total entering volume at intersection.

2. With-project conditions reflect LDW Cleanup with Transport Scenario A, 100% by Trucks.

4.3. Level of Service

Level of service (LOS) analysis was performed at the study area intersections for the PM peak hour. Level of service is a qualitative measure used to characterize traffic operating conditions. Six letter designations, "A" through "F," are used to define level of service. LOS A and B represent conditions with the lowest amounts of delay, and LOS C and D represent intermediate traffic flow with some delay. LOS E indicates that traffic conditions are at or approaching congested conditions and LOS F indicates that traffic volumes are at a high level of congestion with unstable traffic flow. Level of service for intersections is defined in terms of average delay per vehicle in seconds. The thresholds applied to determine levels of service are described in Attachment D.

Levels of service for the study area intersections were analyzed using methodologies presented in the Highway Capacity Manual.[2] All level of service calculations were performed with Trafficware's *Synchro 8.0* analysis software. Table 4 summarizes the PM peak hour levels of service at the five analysis intersections, for existing conditions, 2018 conditions without the LDW project, and 2018 conditions with the LDW project. As shown, projected background traffic growth is expected to add some average delay at the intersections, but would not change the levels of service compared to existing conditions. Under existing conditions and in the future without the LDW project, the intersection of West Marginal Way/S Holden Street is projected to operate at LOS E, and the other four intersections are projected to operate at LOS B or C. The table shows that the potential addition of the LDW truck trips (average of 11 trucks per hour) would add less than 2 seconds of average delay to each intersection, and would not change the overall levels of service. As described previously, at other non-peak times of day background traffic volumes would be lower, and traffic operating conditions with or without the project would be expected to have lower average vehicle delay than what is presented below. Also, the lower number of truck trips generated with Transport Scenarios B or C would have an even lower effect on average delay than the increases shown in the table. Therefore, the impact of project-generated truck trips on roadway operations is considered to be negligible at all times of day with all three transport scenarios.

Table 4. Level of Service Summary – PM Peak Hour

	Existing (2013)		2018 without Project		2018 with Project [3]	
Intersection	LOS [1]	Delay [2]	LOS	Delay	LOS	Delay
4th Avenue S / S Spokane Street	B	10.5	B	10.9	B	10.9
East Marginal Way S / Diagonal Avenue S	B	11.9	B	13.8	B	13.9
4th Avenue S / S Michigan Street	C	31.4	C	32.6	C	32.8
East Marginal Way S / Carleton Avenue S	B	10.4	B	11.1	B	11.6
West Marginal Way S / S Holden Street	E	59.3	E	68.7	E	70.5

Source: Heffron Transportation, Inc., December 2013.
1. Level of service.
2. Average seconds of delay per vehicle.
3. With-project conditions reflect LDW Cleanup with Transport Scenario A, 100% by Trucks.

[2] Transportation Research Board, Highway Capacity Manual, 2010.

5. Potential Measures to Reduce Truck Trip Impacts

The addition of truck trips generated by LDW cleanup activities may be noticeable to businesses or residents located along the truck haul routes very close to the transload facility or nearshore operations. The additional truck traffic is not expected to be noticeable at the five analysis intersections and would not substantially affect the overall character of traffic or operations along the roadways or at major intersections. However, the following measures could be considered to further reduce potential truck trip impacts, though the measures would need to be considered in context with other factors such as actual facility locations, potential haul routes, and local train routes that will not be determined until immediately before construction:

- Designate truck haul routes on roadways that have minimal non-industrial development and require drivers to use those routes, to minimize potential impacts to residents or non-industrial businesses in the area. (Note, routes similar to those shown on the Attachment B figures could be designated, to make sure the potential impact to the Southpark and Georgetown neighborhoods is minimized.)

- Allow 24-hour transportation of loaded containers in non-residential areas, resulting in fewer truck trips per hour. (Note, this measure would result in a higher number of truck trips during nighttime and is dependent on the operating hours of the receiving facility.)

- If on-site storage is available, stockpile full containers at the nearshore or transload sites to allow trucks to haul containers on days when no dredging operation is underway, spreading truck trips out over a greater number of days. (Note, this would reduce trips per hour but increase the days over which truck trips occur.)

- Restrict trucks from traveling during weekday peak hours (typically 4:00 to 6:00 P.M.). (Note, this measure would result in a higher number of truck trips during off-peak hours.)

- If trucks would need to travel through unsignalized intersections near the nearshore or transload sites to access the arterial roadway system, resulting in operational impact at the intersections, install temporary signals or provide flaggers to direct traffic.

Attachments:
Attachment A – Truck Trip Calculation Worksheet
Attachment B – Potential Truck Haul Routes
Attachment C – Existing and Projected Future Traffic Volumes
Attachment D – Level of Service Description

JAB/tsm

ATTACHMENT A

TRUCK TRIP CALCULATION WORKSHEET

Dredging Assumptions

91,989 cubic yards dredged per year
1.5 tons per cubic yard
28 tons per load

Assumed Duration of Construction Activity

Nearshore Operation (direct to truck)
88 days of operation per year (October 1 through February 15)
11 hours/day nearshore truck operation

Transload Operation (barge to truck)
88 days of operation per year (October 1 through February 15)
11 hours/day barge-to-truck transload operation

Table A-1. Average Daily and Hourly Truck Trip Estimates - All Cleanup Alternatives

Scenario	Activity Type [1]	Activity (Percentage of Volume)	Truck Trips Per Day [2] Inbound	Truck Trips Per Day [2] Outbound	Truck Trips Per Day [2] Total	Truck Trips Per Hour [2] Inbound	Truck Trips Per Hour [2] Outbound	Truck Trips Per Hour [2] Total
A. 100% by Trucks	Nearshore	22%	12	12	24	2	1	3
	Transload	78%	44	44	88	4	4	8
	Direct-to-rail	0%	0	0	0	0	0	0
	Total Truck Trips	100%	56	56	112	6	5	11
B. 60% byTrucks	Nearshore	22%	12	12	24	2	1	3
	Transload	38%	21	21	42	2	2	4
	Direct-to-rail	40%	0	0	0	0	0	0
	Total Truck Trips	100%	33	33	66	4	3	7
C. 22% by Trucks	Nearshore	22%	12	12	24	2	1	3
	Transload	0%	0	0	0	0	0	0
	Direct-to-rail	78%	0	0	0	0	0	0
	Total Truck Trips	100%	12	12	24	2	1	3

1. Nearshore - contaminated sediment loaded directly to trucks.
   Transload - contaminated sediment loaded from barge to truck at on-site transload facility.
   Direct-to-rail - contaminated sediment loaded from barge directly to rail, no truck trips.
2. Average truck trips per day and per hour rounded to whole numbers.

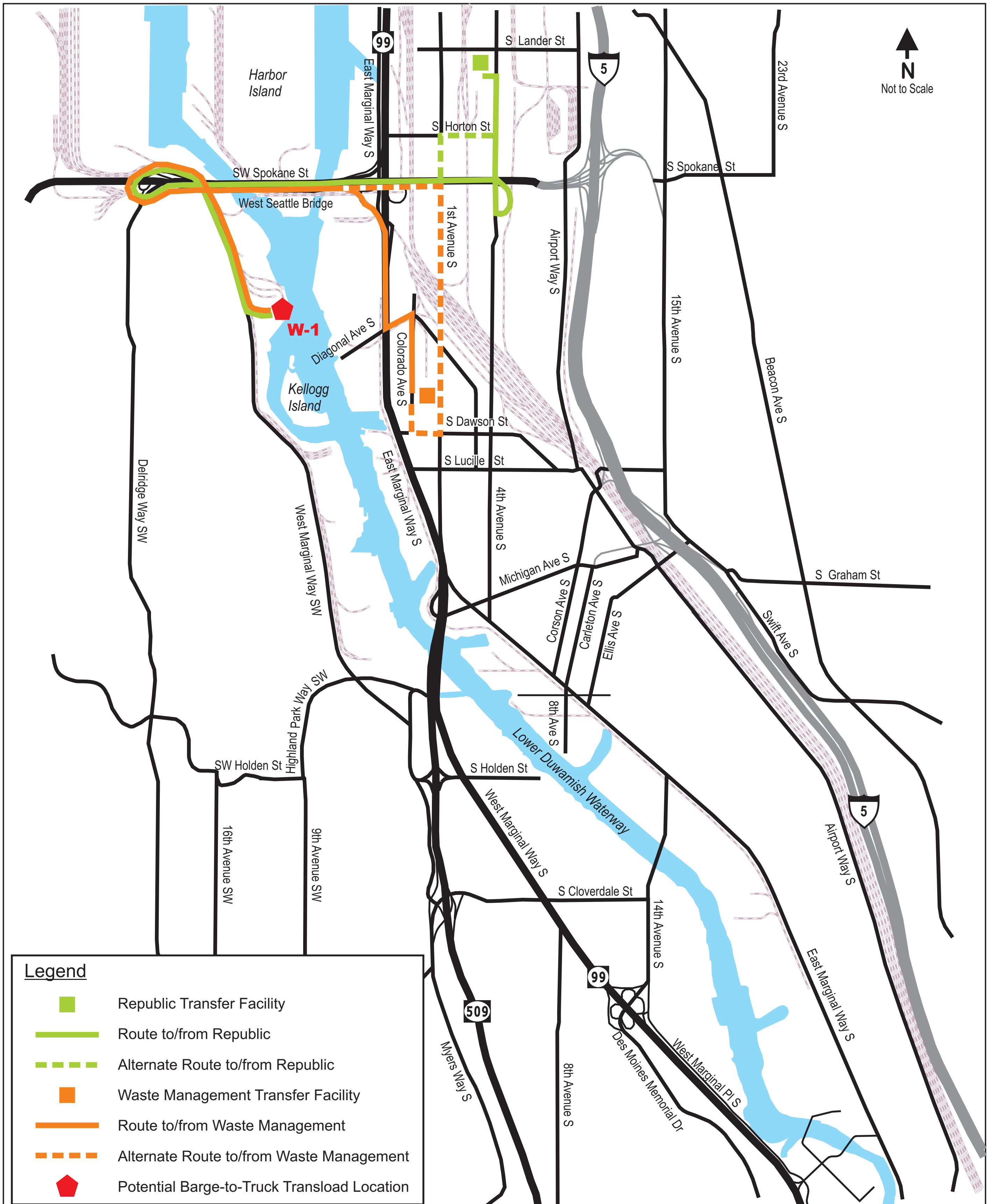
Table A-2. Total Truck Trips Over Duration of Construction - Per Cleanup Alternative

	Approximate Dredged Volume (cubic yards)	Approximate Number of Dredged Loads	Total Estimated Truck Trips [1] Scenario A 100% by Trucks	Scenario B 60% by Trucks	Scenario C 22% by Trucks
Alternative 1 - Key Elements	620,000	33,000	66,000	39,600	14,500
Alternative 2 - EPA Proposed	790,000	42,000	84,000	50,400	18,500
Alternative 3 - Most Dredging (5R)	1,600,000	86,000	172,000	103,200	37,800

1. Total truck trips rounded to the nearest hundred.

ATTACHMENT B

POTENTIAL TRUCK HAUL ROUTES

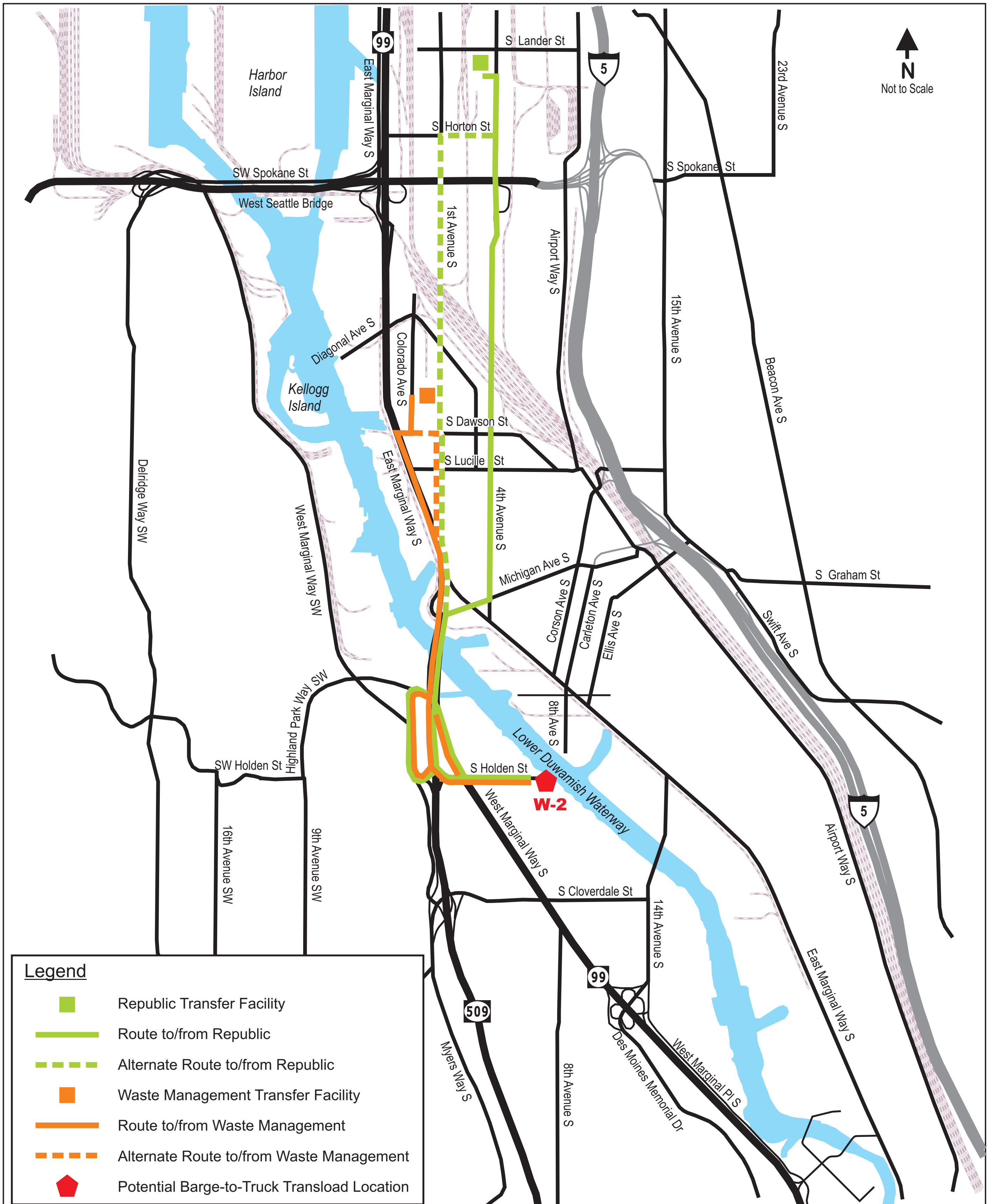


Lower Duwamish Waterway
Cleanup Project

Figure 1
Truck Haul Routes to/from Potential
Northern Transload Facility on West Side (W-1)

heffron transportation, inc.

12.20.2013

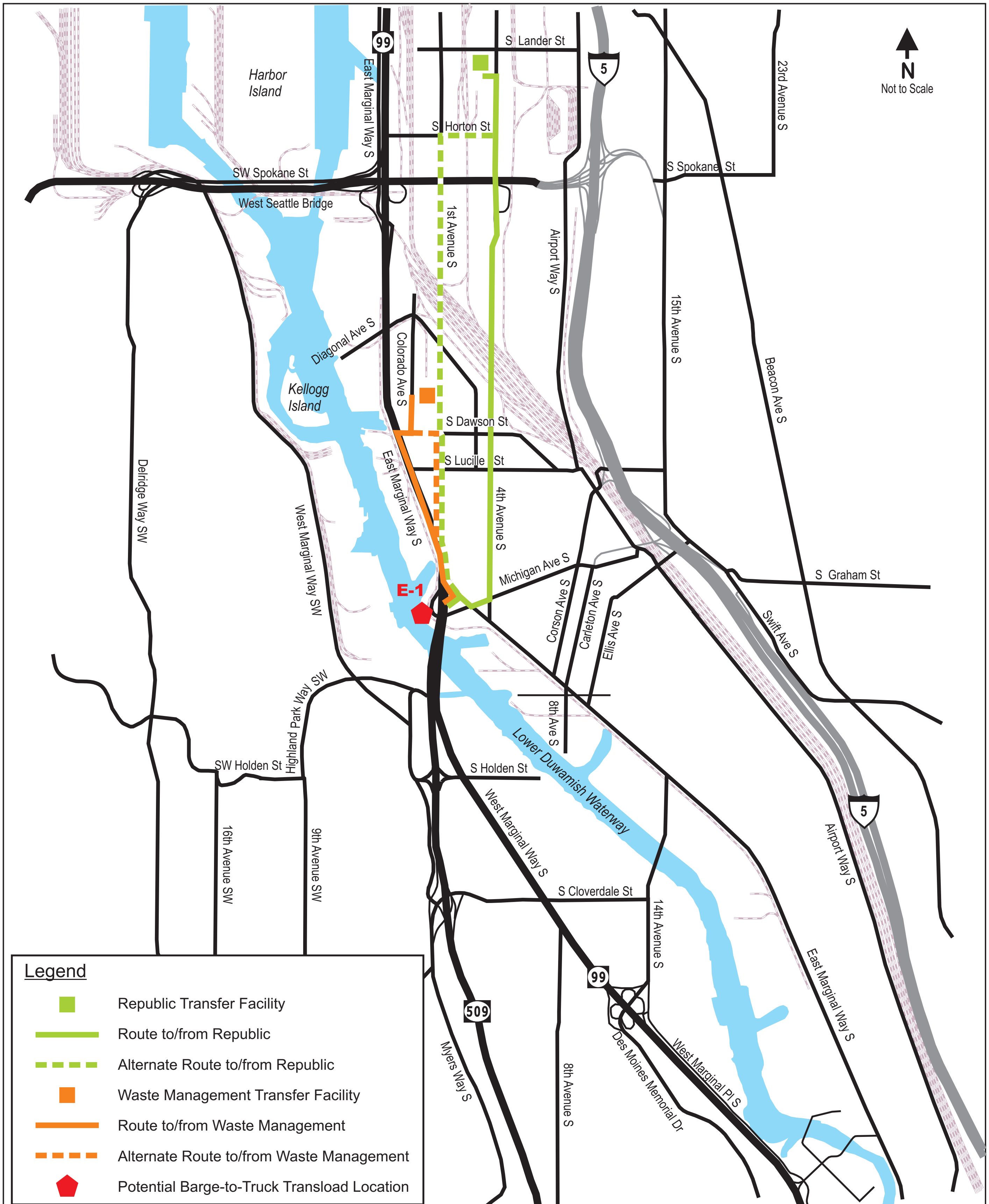


Lower Duwamish Waterway Cleanup Project

Figure 2
Truck Haul Routes to/from Potential Southern Transload Facility on West Side (W-2)

heffron transportation, inc.

12.20.2013



Lower Duwamish Waterway Cleanup Project

Figure 3
Truck Haul Routes to/from Potential Northern Transload Facility on East Side (E-1)

heffron transportation, inc.

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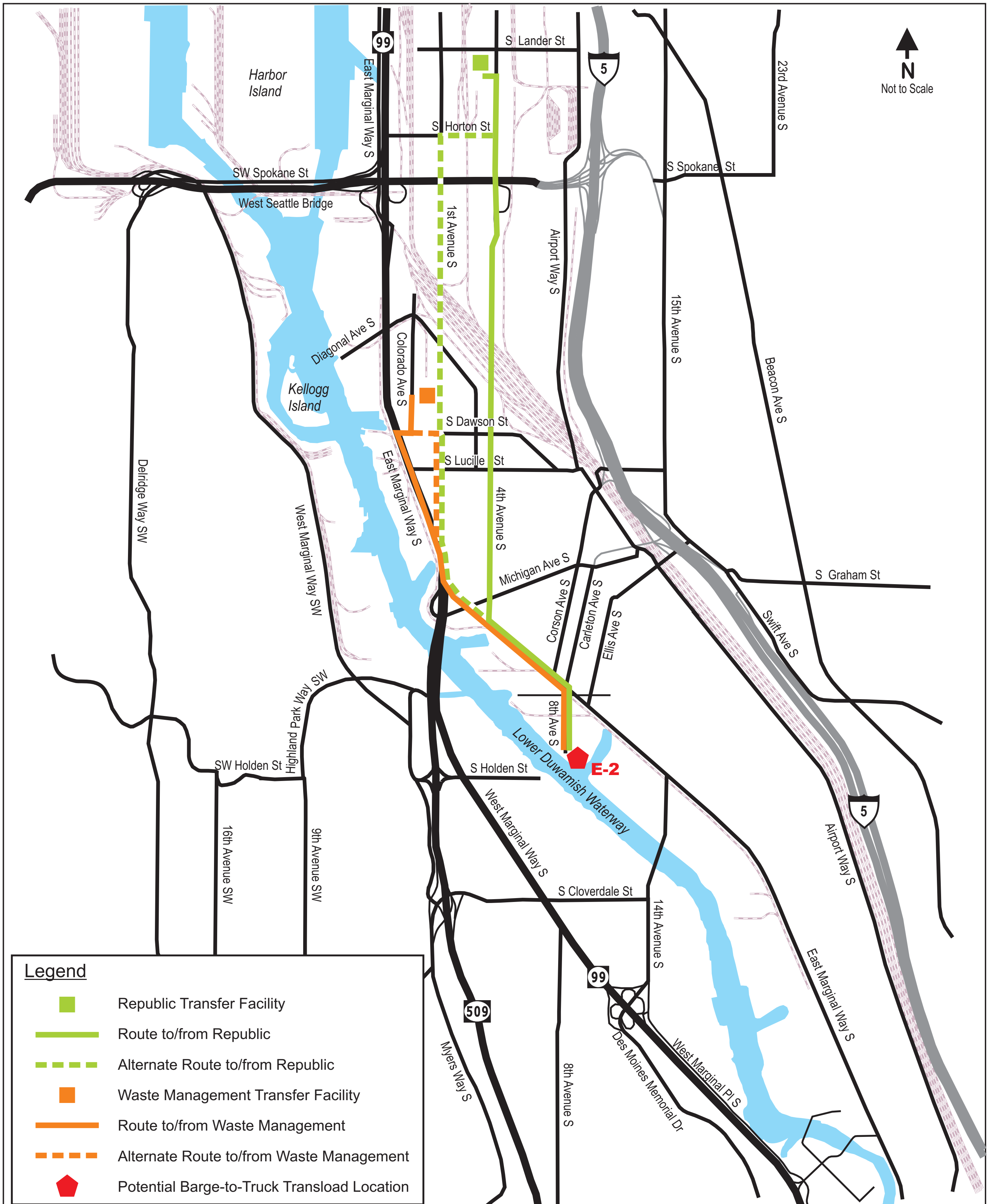
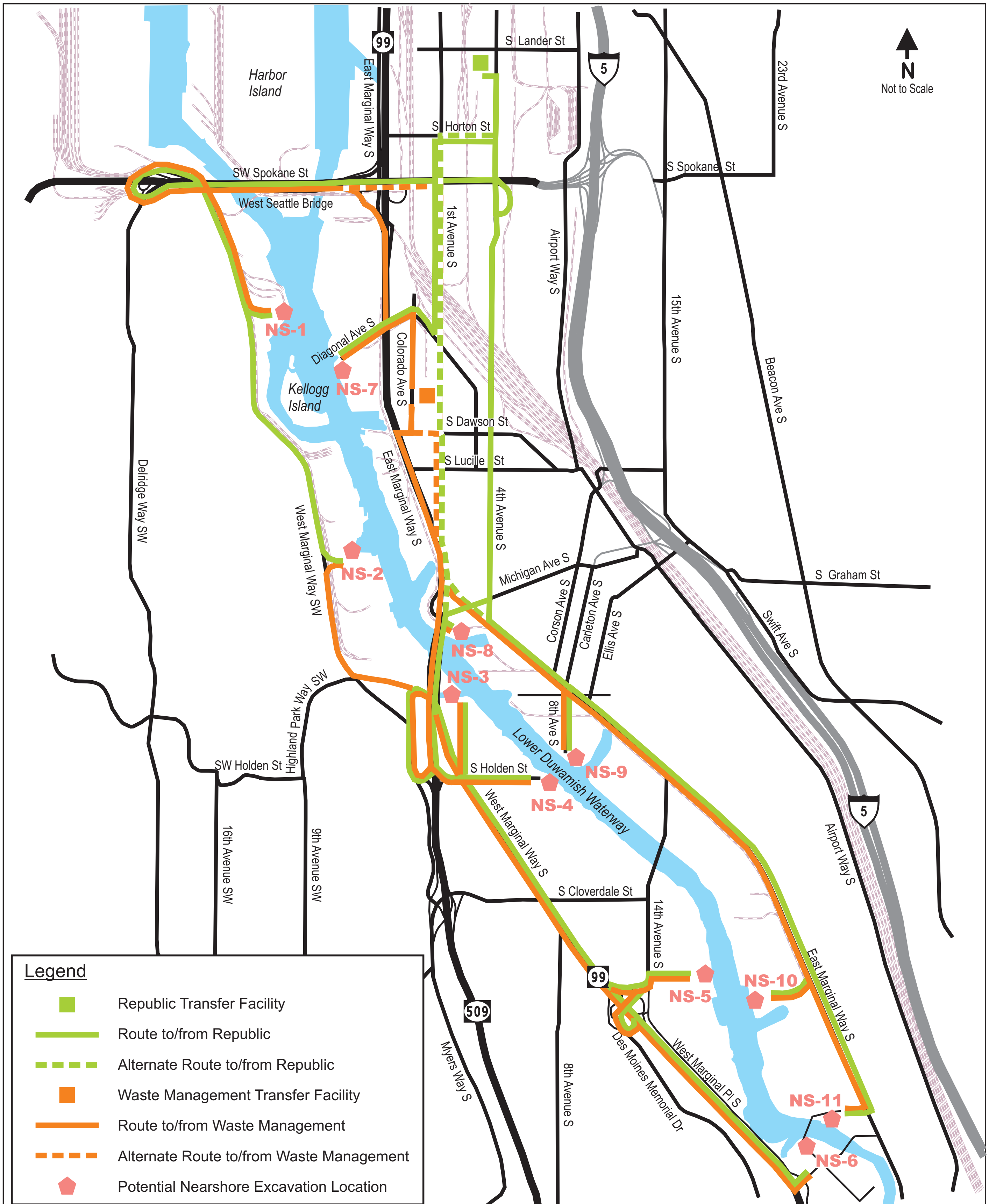


Lower Duwamish Waterway
Cleanup Project

Figure 4
Truck Haul Routes to/from Potential Southern Transload Facility on East Side (E-2)

heffron transportation, inc.

12.20.2013



Lower Duwamish Waterway Cleanup Project

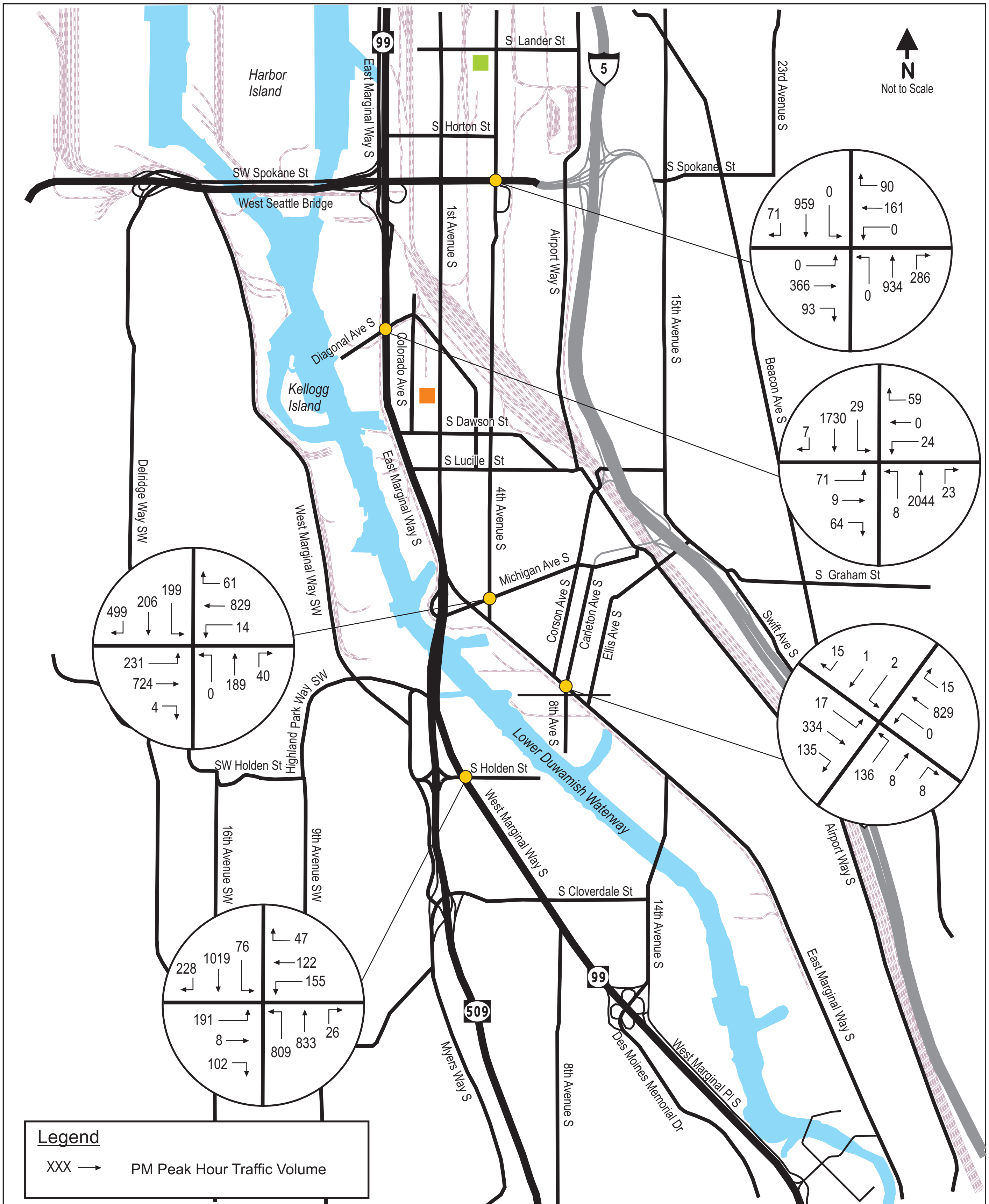
Figure 5
Truck Haul Routes to/from Potential Nearshore Locations

heffron transportation, inc.

12.20.2013

ATTACHMENT C

EXISTING AND PROJECTED FUTURE TRAFFIC VOLUMES

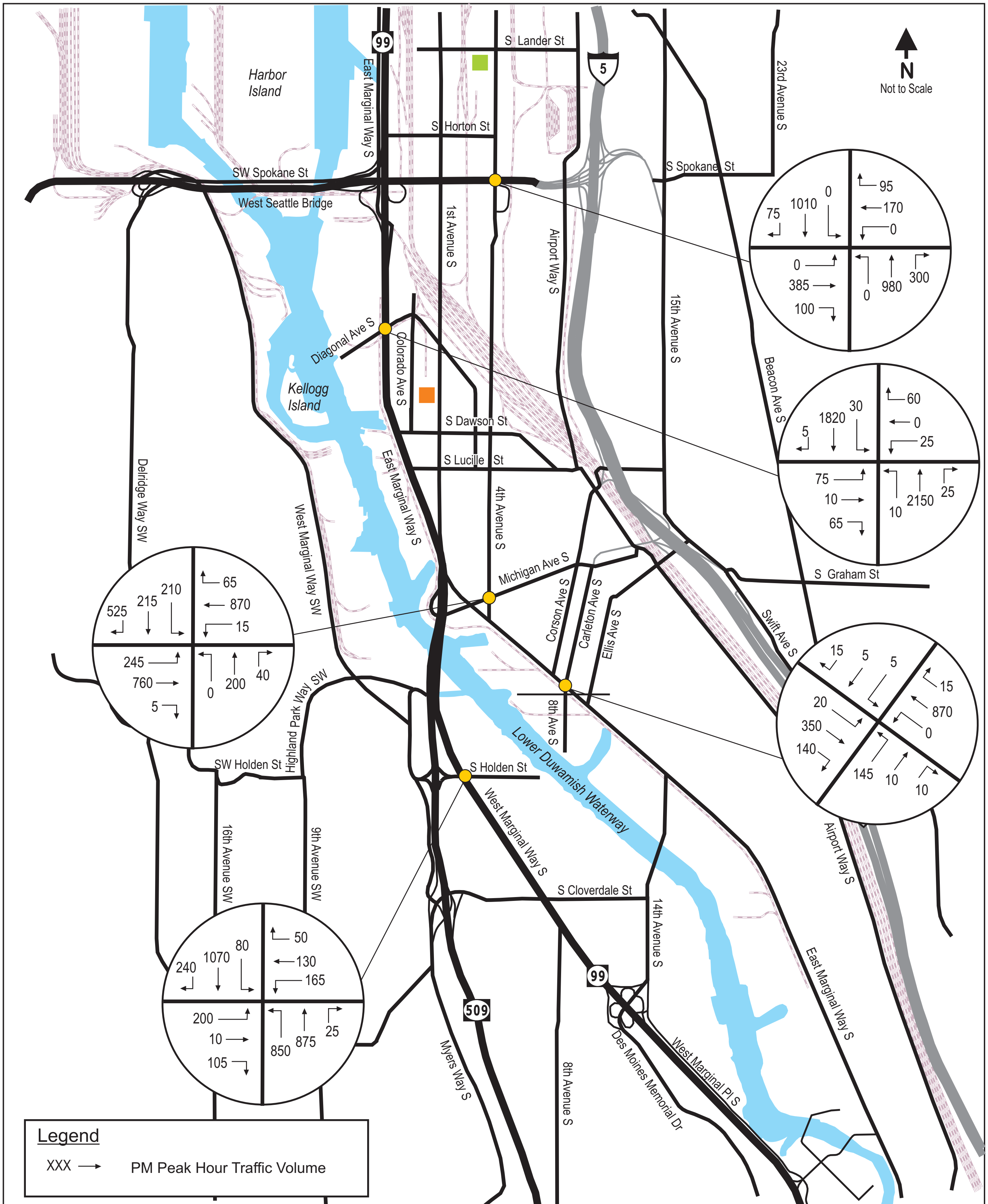


Lower Duwamish Waterway
Cleanup Project

Figure 6
Existing (2013) Traffic Volumes
PM Peak Hour

heffron transportation, inc.

12.20.2013

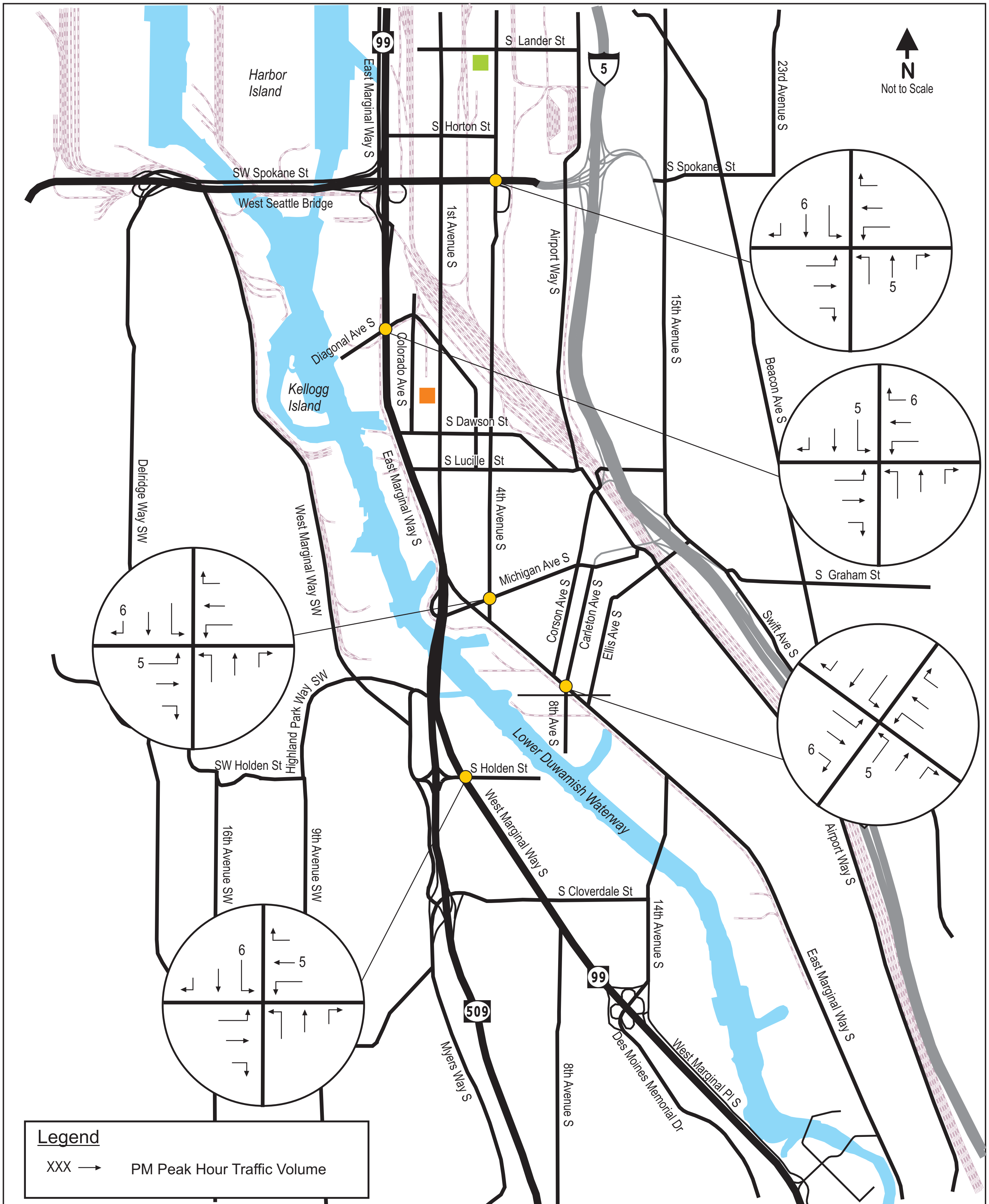


Lower Duwamish Waterway Cleanup Project

Figure 7
Future (2018) Traffic Volumes
Without Project - PM Peak Hour

heffron transportation, inc.

12.20.2013



Lower Duwamish Waterway
Cleanup Project

Figure 8
Average Truck Trips per Hour
Generated by Project

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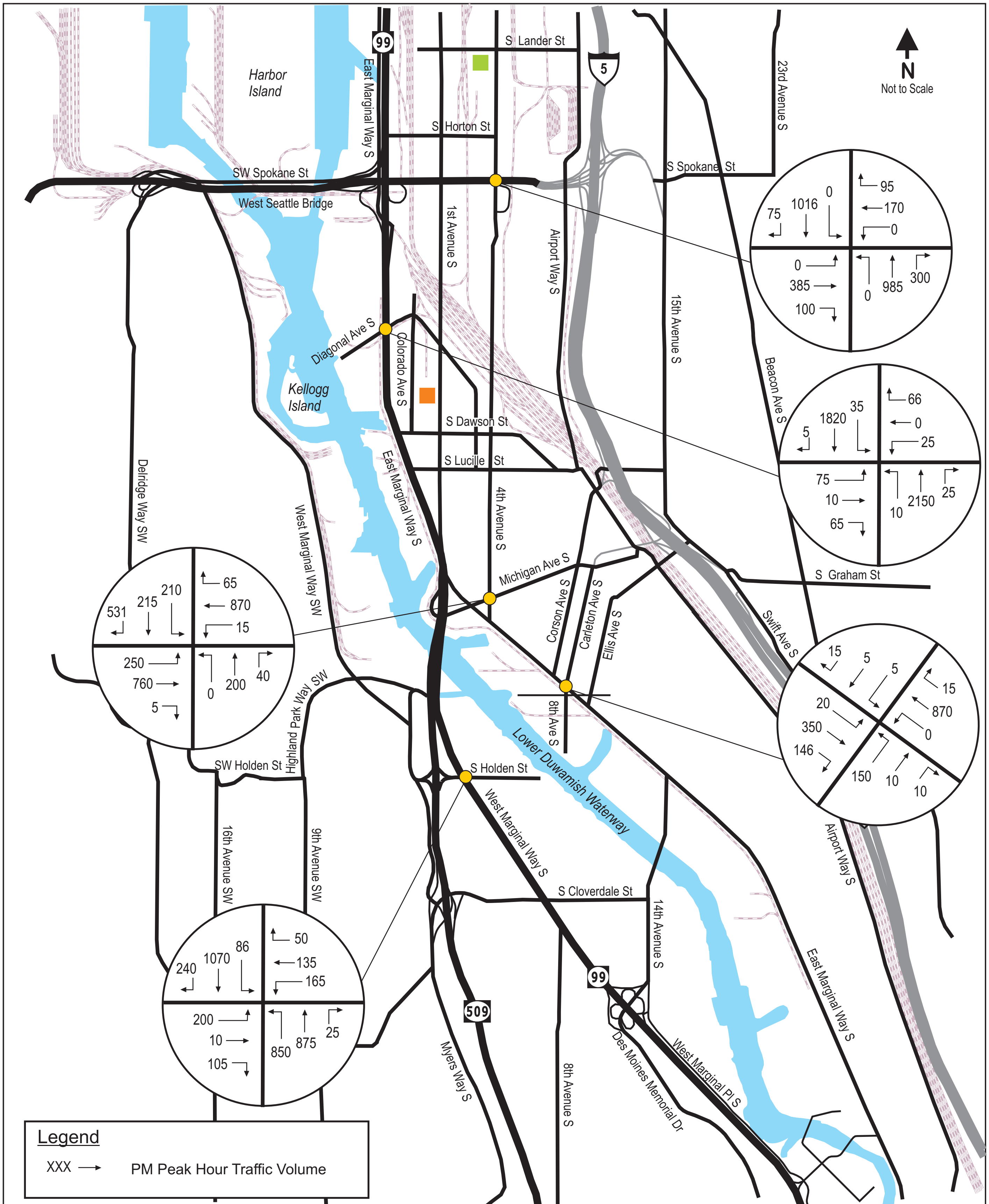

Lower Duwamish Waterway Cleanup Project

Figure 9
Future (2018) Traffic Volumes With Project - PM Peak Hour

heffron transportation, inc.

12.20.2013

ATTACHMENT D

LEVEL OF SERVICE DESCRIPTION

Levels of service (LOS) are qualitative descriptions of traffic operating conditions. These levels of service are designated with letters ranging from LOS A, which is indicative of good operating conditions with little or no delay, to LOS F, which is indicative of stop-and-go conditions with frequent and lengthy delays. Levels of service for this analysis were developed using procedures presented in the *Highway Capacity Manual* (Transportation Research Board, 2010).

Level of service for signalized intersections is defined in terms of delay. Delay can be a cause of driver discomfort, frustration, inefficient fuel consumption, and lost travel time. Specifically, level of service criteria are stated in terms of the average delay per vehicle in seconds. Delay is a complex measure and is dependent on a number of variables including: the quality of progression, cycle length, green ratio, and a volume-to-capacity ratio for the lane group or approach in question. Table D-1 shows the level of service criteria for signalized intersections from the *Highway Capacity Manual*.

Table D-1. Level of Service Criteria for Signalized Intersections

Level of Service	Average Delay Per Vehicle	General Description
A	Less than 10.0 Seconds	Free flow
B	10.1 to 20.0 seconds	Intermediate flow
C	20.1 to 35.0 seconds	Intermediate flow
D	35.1 to 55.0 seconds	Intermediate flow
E	55.1 to 80.0 seconds	Approaching forced flow
F	Greater than 80.0 seconds	Forced flow

Source: Transportation Research Board, Highway Capacity Manual, 2010.

Emissions Assessment for Lower Duwamish Cleanup Alternatives

King County DNRP Cover Memo to AECOM Dec 11, 2013 Analysis

January 2, 2014

The Lower Duwamish Waterway Feasibility Study (FS) was produced when new heavy vehicle and equipment emissions requirements were being phased in by the Environmental Protection Agency. These requirements are being phased in over the next 15 years, with several deadlines and incentives for early implementation. Because the timing of implementation could not be predicted, the FS (AECOM 2013) did not assume if or when the phasing would occur and used the existing emissions calculation methodology to produce emission estimates used in the FS.

AECOM was asked to recalculate the emissions assuming early compliance with the new requirements including exhaust filters and use of ultra-low sulfur fuel (ULSF). These new estimates (Appendix) were made for three cleanup alternatives (Key Elements, EPA's proposed plan and FS Alternative 5R) that cover the range of cleanup alternatives being discussed. The new estimates presented in the Appendix include emissions of CO_2, CO, NO_x, SO_x and PM_{10} (particulates greater than 10 microns). A summary of the results is provided in Table 1. CO_2 provides the majority of the greenhouse gas emissions and PM_{10} exacerbates asthma and other respiratory problems. While CO, NO_x and SO_x are also air pollutants of concern that effect health and contribute to the formation of particulates through chemical reactions, this discussion will focus on CO_2 and PM_{10}. As Table 1 shows, project CO_2 emissions are slightly reduced from the FS estimates, while PM10 emissions declined by almost 60% from the FS estimates. The reduction in particulates is primarily due to the use of the ULSF.

Table 1. Updated Emissions Estimates (Metric Tons) Due to Compliance with Required ULSF Use and Emission Filters

Emission	Key Elements			EPA Proposed			Alt. 5R		
	FS	Up-dated	Percent Reduction	FS	Up-dated	Percent Reduction	FS	Up-dated	Percent Reduction
CO_2	24,400	23,200	5%	31,500	27,300	13%	59,000	54,000	8%
CO	66	61	6%	85	72	15%	160	142	11%
NO_x	496	278	44%	641	327	49%	1,200	646	46%
SO_x	12	3	75%	15	3	80%	28	6	78%
PM_{10}	21	9	57%	26	11	58%	50	21	58%

Note: Requirements are phased in over next 15 years but assumed from start of cleanup

Since emissions are proportional to the use of heavy vehicles, a range of the material transport alternatives identified and discussed in the FS were assessed by AECOM to describe the range of possible scenarios that could occur. Depending on the availability of direct-to-rail sediment transfer facilities, the use of trucks will vary. While trucks represent only a portion of the emissions-generating equipment used during construction, they are the only factor that changes significantly under the different material transport scenarios. The 100% truck scenario assumes no direct-to-rail facilities would be available and the 22% truck scenario predicts that most of the sediment will be offloaded to direct-to-rail facilities. There is no 0% truck scenario because some material will be removed from banks and intertidal areas that are not accessible by barge. This material will need to be trucked to a facility that transfers that material to rail.

Table 2 presents the differences in project CO_2 emissions depending on the sediment transport methods being used. Note that the CO_2 emissions decline with the reduction in the amount of sediment transported by truck by less than 2 %. This result reflects the relatively small percentage of total emissions that are generated by the trucks when the full use of ULSF has been implemented.

Table 2. CO_2 (Metric Tons) reductions by changing from barge-to-trucks-to-rail to barge-to-rail

Scenario	Key Elements	EPA Proposed	Alt. 5D
100% trucks	23,200	27,300	54,000
60% trucks	23,000	27,100	53,600
22% trucks	22,800	26,900	53,200

Note: PM_{10} does not change appreciably with change in truck use. Reduction in PM_{10} emissions from earlier FS estimates in Table 1 are due to the change to ULSF in all diesel equipment.

In order to gain some context for the amount of emissions the cleanup project will generate in the Lower Duwamish Valley, existing emission inventories were researched. Unfortunately there were no existing estimates of emissions within the Lower Duwamish valley that can be directly compared to the LDW cleanup project estimates. The existing inventories are at the city- or county-wide scale or look at one particular type of source. The most relevant data to provide some context would be the 2011 Puget Sound Maritime Air Emissions Inventory (PSMAF 2012). This inventory included an estimate of all heavy equipment used by the Port of Seattle, including short haul trucks. The majority of the Port's operations are in the Lower Duwamish Valley so this provides some context to other, but certainly not all, heavy equipment emissions in the local area. Since all the cleanup alternatives conduct the same amount of work each year (the alternatives vary by the number of years they take to complete), any cleanup plan will emit roughly the same yearly emissions[1].

Table 3 presents the yearly emissions for the cleanup project compared to the yearly emissions form Port-associated heavy equipment. Not considering other emission sources in the valley (either point source or transportation), the project emits 2 orders of magnitude less emissions than Port-related equipment and depending on type would represent approximately1% to 3% increase in emissions over existing Port activities. It should be noted that over half of the

[1] Note that the yearly emissions vary among alternatives in Appendix Table 3 but that is due to rounding the final partial year of work (which varies among the alternatives) into an annual emissions estimate.

cleanup project emissions occur outside of the Lower Duwamish valley due to dredged material transport and disposal at the regional landfill.

Table 3. Yearly Emissions (Metric Tons) Comparison to 2011 Port Heavy Equipment Emissions Inventory (mainly from trucks)

Emission (MT/yr)	LDW Cleanup		Port Heavy Equipment	Cleanup as a Percent of Port Emissions
	FS	Updated		
CO_2	4,400	4,000	340,000	<1.2%
PM_{10}	3.7	1.6	50	<3.2%

References:

AECOM 2012. Lower Duwamish Waterway Feasibility Study. Prepared for the U.S. Environmental Protection Agency, Region 10, Seattle, WA.

PSMAF 2012. 2011 Puget Sound Maritime Air Emissions Inventory. Prepared by Starcrest Consulting Group. LLC. For the Puget Sound Maritime Air Forum.

Appendix: Estimated Emission Reduction from Reduced Truck Transportation in the Lower Duwamish Waterway Corridor and Use of Lower Sulfur Fuels

Memorandum

To: Lower Duwamish Waterway Group (LDWG)

From: Matt Salmon, Anne Fitzpatrick, Chuck Vita, John Ryan - AECOM

Subject: Estimated Emission Reduction from Reduced Truck Transportation in the Lower Duwamish Waterway Corridor and Use of Lower Sulfur Fuels

Date: January 14, 2014

Introduction

As requested by LDWG to address a question from King County, this memorandum summarizes the analysis completed to estimate the changes in gas and particulate emissions in the Lower Duwamish Waterway (LDW) Corridor due to reduced truck transportation and the now required use of ultra-low sulfur diesel (ULSD) fuel.

Over the last decade, EPA has focused on reducing CO_2, NO_X, SO_X, and PM_{10} emissions under the Diesel Emissions Reduction Act (DERA). CO_2 emissions are known to contribute to the green house gas effect. Emissions from SO_X and PM_{10} are known to contribute to health problems, while NO_X also "contributes to the formation of ozone and PM through chemical reactions." New national emission requirements are intended to reduce CO_2 by up to 20%, NO_X by up to 90%, and PM by up to 95% by the year 2030. SO_X emissions are reduced by the switch from low sulfur diesel to ULSD. Two major steps taken by the EPA to reduce emissions involve updating engines in equipment fleets and mandatory use of ULSD fuel (EPA 2010).

For this analysis, the LDW Corridor is defined as the neighborhoods between the LDW and the Burlington Northern Santa Fe (BNSF) Railroad transfer stations in Georgetown and SODO. Neighborhoods in the LDW Corridor that could be affected by local truck transportation of contaminated sediment include Georgetown, Harbor Island, SODO, and South Park. [1]

Method Assumptions

The analysis uses the same AECOM Sustainability Tool developed for the LDW Feasibility Study (FS), to compare three remedial cleanup alternatives, each with three different truck transportation options (see assumptions) for a total of nine scenarios. The three LDW remedial

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[1] Local truck transportation from the LDW to the BNSF transfer stations.

alternatives being compared are the LDWG Key Elements (LDWG 2011), EPA Preferred Alternative (Alternative 5CPlus) as presented in the Proposed Plan (EPA 2013a), and FS Alternative 5R (AECOM 2012). The first two alternatives use a combination of active technologies (dredging, capping, and ENR) to achieve remedial goals. LDW FS Alternative 5R is a removal-focused alternative that relies on dredging technology to achieve remedial goals. Table 1 shows the acreage addressed by each technology under each cleanup alternative.

Truck Transportation Options. Project-generated truck transportation through the LDW Corridor is varied by reducing the volume of contaminated sediment transported by trucks to the transfer station(s). The truck transportation options are:

- Truck option 1 – 100% of sediment is trucked to transfer station (assumes no direct-to-rail facilities are available);
- Truck option 2 – 60% of sediment is trucked to transfer station (assumes 1 direct-to-rail facility is available); and
- Truck option 3 – 22% of sediment is trucked to transfer station (assumes 2 direct-to-rail facilities are available).

This analysis assumes that the portion of contaminated dredge material not being trucked to a transfer station will be directly loaded onto rail cars at a local transloading facility (e.g., similar to operations currently used at the facility operated by LaFarge).

Truck options were selected based on the availability of direct-to-rail facilities. 100% truck transportation assumes no direct-to-rail facility will be available. 60% truck transportation assumes one direct-to-rail facility will be available, reducing trucked material by 40%. The 22% truck transportation assumes that two direct-to-rail facilities will be available and only the material within the intertidal area (~22%) would be loaded directly to trucks using land-based equipment.

Transportation of dredged contaminated sediment from the LDW to the Roosevelt Landfill[2] assumes three steps in the transport process:

1. Transport of contaminated sediment from the LDW barge to the rail cars:
   a. Trucking contaminated sediment over a 6-mile round-trip through the LDW Corridor from a transloading facility on the LDW to a BNSF transfer station located either in Georgetown or SODO. Contaminated sediment volumes transported through the LDW Corridor by truck will be either: 100% (Option 1), 60% (Option 2), or 22% (Option 3) of the total dredge volume.

[2] The Roosevelt Landfill in Washington State was identified in the FS as the most likely site for receiving excavated sediments from the LDW.

b. The remaining portion will be loaded directly from the barge, docked alongside the transloading facility, to rail (eliminates the 6-mile truck trip through the LDW Corridor).

2. Rail transport of contaminated sediment comprising a 569-mile round-trip from the transfer station or transloading facility (i.e., LaFarge) to Roosevelt Landfill.[3]

3. Trucking contaminated sediment over a 6-mile round-trip from the BNSF transfer station to Roosevelt Landfill for final disposal.

Table 2 presents the volumes used in the analyses by technology and remedial alternative. The inputs to the sustainability tool are provided in Attachment 1. Only Step 1 is varied in this analysis; Steps 2 and 3 are held constant.

AECOM Sustainability Tool Update - Use of ULSD Fuel. Since submittal of the final LDW FS in October 2012, EPA has mandated ULSD in all on-road (e.g., trucks) and non-road equipment (e.g., railroad locomotives, tug boats, and construction equipment)[4]. Since the timing of the compliance was uncertain, the FS did not assume these requirements in its emissions analysis, and instead assumed the use of low sulfur diesel (LSD) fuel. The most recent version of the Sustainability Tool has been updated to take this requirement into account (i.e., maximum sulfur content of 15 parts per million [ppm] sulfur). For this analysis, all engines are also assumed to meet all new EPA emission standards (i.e., use newer Tier 4 engines or retrofit older ones to accept clean diesel technology) regardless of age. Besides adjusting for ULSD and assuming that all equipment will meet new emission standards, no other structural changes have been made to the tool and its calculations since finalization of the LDW FS. For reference, emission factors for all of the technologies are provided in Attachment 2.

Equipment Emission Factors. For a limited time, EPA is providing financial benefits/compensation under DERA to owners who upgrade equipment with clean diesel

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[3] The 6-mile truck trip described in Step 1 does not vary. The distance is small compared to the entire 569-mile trip to the landfill, which is mostly by train. Because the BNSF transfer stations are located in close proximity to the LDW, it was assumed that any additional rail distance would be negligible. Therefore, rail transportation distance does not significantly increase as truck transport decreases. The transfer stations in Georgetown and SODO are approximately the same distance from the landfill as the potential LDW transloading facility sites.

[4] EPA instituted use of low sulfur diesel fuel in two phases. The first phase was instituted in 2007 and required low sulfur diesel (i.e., maximum sulfur content of 500 ppm) to be used in all on-road and non-road diesel equipment (except ocean going vessels). The second phase was instituted in 2010 and required use of ULSD with a maximum sulfur content of 15 ppm (EPA 2004).

emission reduction technology[5], including particulate filters, crankcase ventilators, etc. to reduce NOx and PM_{10} emissions (EPA 2010).

EPA has mandated engine manufacturers to reduce emissions over the past decade through a tiered system, tier 1 to 4, with each tier requiring lower emissions. Final requirements (i.e., tier 4) take effect at 2014 year end for heavy duty truck, non-road, locomotive, and marine diesel engines (ARB and EPA 2013).

EPA is requiring almost all refineries and importers to produce only diesel fuel with a sulfur content not to exceed 15 ppm by 2013 year end. This requirement does not yet apply to the small class of transmix fuel, which is fuel formed by mixing during pipeline transport. The transmix fuel can only be used in approved older model locomotives and marine engines (EPA 2013b). However, older engines using transmix fuel are not used in this analysis for transportation of LDW sediments.

Emission factors used in this analysis assume that all engines use ULSD and meet all EPA emission requirements by the year 2015 (e.g., low emission vehicles, Tier 4 engines, clean diesel technology upgrades, etc.). In reality, not all engines may be able to meet this new requirement when construction begins and some older engines may be used for sediment remediation in the LDW. Therefore, this analysis represents a best-case estimate of reduced emissions.

Results

The switch from LSD fuel (assumed in the FS) to ULSD fuel using the new EPA engine and clean diesel technology requirements to calculate emissions, results in a slight decrease in CO_2 emission estimates, and a larger decrease in NO_X, SO_X and PM_{10} emissions as shown in Table 3. For example, CO_2 emissions were reduced from 59,000 to 54,000 metric tons (an approximately 8% reduction from the FS) while NO_X, SO_X, and PM_{10} emissions were reduced by 46%, 78%, and 58%, respectively compared to the FS calculations.

The estimated total and annual gas and particulate emissions for all nine scenarios (three remedial alternatives, three transport options for each) are shown in Table 4. A detailed breakdown of emission calculations by technology is provided in Attachment 3.

All five emissions calculated (i.e., CO_2, CO, NO_X, SO_X, and PM_{10}) slightly decreased as the percentage of sediment traveling by truck through the LDW Corridor changed, as shown in Attachment 3 in the row labeled "transportation." Reduced truck transportation (for the 6-mile local trip) results in only a small decrease in total emissions for CO_2 and SO_X, because of the contributions from the dredging equipment and rail transport. Thus, the reduction in emissions

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5 According to newsletters, tug boat companies in Seattle, WA, including Harley Marine, Foss, and Crowley, have already begun to take advantage of upgrade incentives for converting their fleets to use ULSD.

from decreased truck use is insignificant (i.e., 1% or less) when compared to total emissions, and falls within the expected error of the emissions model.

The other emissions, CO, NO_X, and PM_{10}, did not see a noticeable reduction in their total emissions as the percentage of dredged sediment traveling by truck changed. This is because these emissions are driven by rail transportation and not by truck transportation. This is illustrated in Table 5 by the high emission factors for rail transport and the low emission factors for truck transport.

In conclusion, use of ULSD by cleanup project equipment and trucks operating in the LDW would reduce total project emissions as compared to project delivery with LSD. Reductions range from approximately 5% for CO_2 to almost 80% for SO_X. By comparison, reductions in local truck transport if more direct-to-rail transloading facilities were available would reduce emissions by less than 2% of the total emissions for CO_2 and SO_X.

References

AECOM 2012. *Lower Duwamish Waterway Final Feasibility Study.* Submitted to the U.S. Environmental Protection Agency and the Washington State Department of Ecology. Prepared for the Lower Duwamish Waterway Group. October 31, 2012.

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EPA 2004. *Regulatory Announcement – Clean Air Nonroad Diesel Rule*. EPA420-F-04-032. Office of Transportation and Air Quality. May 2004.

EPA 2010. *Second Report to Congress: Highlights of the Diesel Emissions Reduction Program.* Energy Policy Act of 2005 Title VII, Subtitle G, Sections 791-797. Prepared by U.S. EPA's Office of Transportation and Air Quality. 2010.

EPA 2013a. *Proposed Plan for the Lower Duwamish Waterway Superfund Site*. Environmental Protection Agency. February 28, 2013.

EPA 2013b. *Electronic Code of Federal Regulations, Subpart I – Motor Vehicle Diesel Fuel; Nonroad, Locomotive, and Marine Diesel Fuel; and ECA Marine Fuel.* Environmental Protection Agency. Accessed November 30, 2013.

GREET 2012. Center for Transportation Research, Energy Systems Division. Argonne National Laboratory. 2012

LDWG 2011. *Key Elements for Optimizing the Cleanup of the LDW – Technical Memorandum.* Prepared by AECOM for the Lower Duwamish Waterway Group. August 1, 2011.

Table 1 Active Technology Assignment Areas - for Each Alternative

Technology	Remedial Alternative		
	LDWG Key Elements (Acres)	EPA Preferred Alternative (Acres)	LDW FS Alternative 5R (Acres)
Dredge	38	64	143
Partial Dredge and Cap	17	20	14
Capping	17	24	—
Enhanced Natural Recovery (ENR)	65	48	—
Total Active Area	137	156	157

Table 2 Volumes by Technology Used in the Sustainability Analysis

Technology		Remedial Alternative		
		LDWG Key Elements (CY)	EPA Preferred Alternative (CY)	LDW FS Alternative 5R (CY)
Dredge Volume[a]		620,000	790,000	1,600,000
Total Material Placement Volume[b]		480,000	360,000	590,000
Volume of sediment transported by truck through LDW corridor to BNSF transfer station(s)[c]	Option 1 – 100%	620,000	790,000	1,600,000
	Options 2 – 60%	372,000	474,000	960,000
	Option 3 – 22%	136,400	173,800	352, 000
Volume of sediment transported by train to landfill[c]		620,000	790,000	1,600,000
Final Truck Transportation Volume at Roosevelt Landfill from Rail[c]		620,000	790,000	1,600,000
Construction Period (Years)		5	7	17

Notes:

a Includes sediment removed by dredging, including areas of partial dredging and capping. Assumes dredge cut prism volume, with performance contingency volumes.

b Material placement includes sand and amendments placed as capping, ENR, stone armor material, dredge residuals management, and/or dredge footprint habitat restoration. Placement material is assumed to be transported to the LDW via barge.

c Transportation to Roosevelt Landfill for disposal assumes a round trip of 581 miles. The trip includes 6 miles of truck transport to a BNSF transfer station from the LDW, 569 miles of rail transport between Seattle and Roosevelt BNSF transfer stations, and 6 miles of truck transport from a BNSF transfer station to Roosevelt Landfill.

Table 3 Comparison of Emissions between Low Sulfur and Ultra Low Sulfur Diesel Fuels

Emission	LDW FS Alternative 5R		Percent Reduction in Emissions
	Low Sulfur Diesel (metric tons)	Ultra Low Sulfur Diesel (metric tons)	
CO_2	59,000	54,000	8%
CO	160	142	11%
NO_X	1,200	646	46%
SO_X	28	6	78%
PM_{10}	50	21	58%

Table 4 Emission Results in Metric Tons

		Alternative:	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
		Truck Transportation Option:	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Total Emissions	CO_2	metric tons	23,200	23,000	22,800	27,300	27,100	26,900	54,000	53,600	53,200
	CO	metric tons	61	61	61	72	72	72	142	142	142
	NO_x	metric tons	279	279	279	327	327	327	646	646	645
	SO_x	metric tons	2	2	2	3	3	3	6	6	5
	PM_{10}	metric tons	9	9	9	11	11	11	21	21	21
Annual Emissions	CO_2	metric tons	4,630	4,600	4,570	3,890	3,870	3,840	3,180	3,150	3,130
	CO	metric tons	12.3	12.3	12.3	10.3	10.3	10.3	8.4	8.4	8.3
	NO_x	metric tons	55.8	55.8	55.8	46.7	46.7	46.6	38.0	38.0	38.0
	SO_x	metric tons	0.48	0.47	0.47	0.40	0.40	0.39	0.33	0.32	0.32
	PM_{10}	metric tons	1.89	1.89	1.88	1.55	1.55	1.55	1.26	1.26	1.26

Notes:

1. Option 1 assumes 100% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes no direct-to-rail facilities are available)
2. Option 2 assumes 60% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes 1 direct-to-rail facilities are available)
3. Option 3 assumes 22% of dredged sediment is trucked from the LDW to a Seattle based BNSF Transfer Station. (assumes 2 direct-to-rail facilities are available)
4. Annual emission calculations are based on construction periods of 5, 7, and 17 years for the LDWG Key Elements, EPA Preferred Alternative, and LDW FS Alternative 5R, respectively.

Table 5 Ultra Low Sulfur Diesel Emission Factors Used for Transportation

Source	Emission	ULSD Factor (lb/gal)
Truck Transportation (GREET 2012)	CO_2	23.701
	CO	0.004
	NO_x	0.013
	SO_x	0.003
	PM_{10}	0.001
Train Transportation (GREET 2012)	CO_2	23.567
	CO	0.062
	NO_x	0.318
	SO_x	0.002
	PM_{10}	0.008

1. These emission factors account for 100% use of ULSD in equipment that meets meet all EPA emission requirements by the year 2015 (e.g., Tier 4 engines, clean diesel technology upgrades, etc.).

Last revised by MLS an AGF 1/13/14 and checked by KAP 1/13/14
Saved: P:\ENV\PROJECTSW\LowerDuwamish\Research & Guidance\Short term effectiveness\LDWG Truck GSR Comparison

Attachments

Attachment 1 – AECOM Sustainability Tool Inputs

Attachment 2 – Technology Emission Factors Applicable for Year 2015

Attachment 3 – Emissions by Technology, Remedial Alternative, and Truck Miles

Attachment 1 – AECOM Sustainability Tool Inputs

1 DREDGING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume removed below -10 ft	Barge-mounted derrick crane	cy	465,000	465,000	465,000	592,500	592,500	592,500	1,200,000	1,200,000	1,200,000
Volume removed above -10 ft	Barge-mounted backhoe	cy	155,000	155,000	155,000	197,500	197,500	197,500	400,000	400,000	400,000
Fuel consumption	Barge-mounted derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
	Barge-mounted backhoe	gal/hr	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
	Survey boat	gal/hr	8	8	8	8	8	8	8	8	8
Dredging rate	Barge-mounted derrick crane	cy/hr	55	55	55	55	55	55	55	55	55
	Barge-mounted backhoe	cy/hr	39	39	39	39	39	39	39	39	39
Total time required for survey operation	Survey boat	hr	596	596	596	760	760	760	1,588	1,588	1,588

2 TRANSLOADING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume transloaded	Tug	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
Offloading volume material to lined containers	Derrick crane	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
Fuel consumption	Tug full engine	gal/hr	85	85	85	85	85	85	85	85	85
	Derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
Distance from the site to the offloading area	Tugs	miles	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Speed	Tugs	miles/hr	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Barge capacity	Barge	cy	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Offloading rate by derrick crane	Derrick crane	cy/hr	110	110	110	110	110	110	110	110	110
Number of water equipment operators	—	worker	3	3	3	3	3	3	3	3	3
Number of construction equipment operators	—	worker	3	3	3	3	3	3	3	3	3

3 TRANSPORTATION											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume transported	Truck in LDW	cy	620,000	372,000	136,400	790,000	474,000	173,800	1,600,000	960,000	352,000
	Truck at landfill	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Railcar to landfill	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Tug clean capping material to the site	cy	480,000	480,000	480,000	360,000	360,000	360,000	590,000	590,000	590,000
	Truck in LDW (one way)	miles	3	3	3	3	3	3	3	3	3
Distance	Truck at landfill (one way)	miles	3	3	3	3	3	3	3	3	3
	Train (total distance)	miles	568.6	568.6	568.6	568.6	568.6	568.6	568.6	568.6	568.6
Fuel consumption	Truck	gal/miles	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Train	gal/miles	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
	Tug	gal/hr	85	85	85	85	85	85	85	85	85
Load capacity	Truck	cy	20	20	20	20	20	20	20	20	20
	Railcar	cy	67	67	67	67	67	67	67	67	67
Transportation rate	Tug	cy/hr	122.7	122.7	122.7	122.7	122.7	122.7	122.7	122.7	122.7
Speed	Truck	miles/hr	40	40	40	40	40	40	40	40	40
	Train	miles/hr	50	50	50	50	50	50	50	50	50

4 SEDIMENT CAPPING											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume placed below - 10 ft	Barge-mounted derrick crane	cy	336,000	336,000	336,000	252,000	252,000	252,000	413,000	413,000	413,000
	Precision excavator	cy	72,000	72,000	72,000	54,000	54,000	54,000	88,500	88,500	88,500
Volume placed above - 10 ft	Precision excavator	cy	72,000	72,000	72,000	54,000	54,000	54,000	88,500	88,500	88,500
Fuel consumption	Barge-mounted derrick crane	gal/hr	25	25	25	25	25	25	25	25	25
	Precision excavator	gal/hr	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
	Survey boat	gal/hr	8	8	8	8	8	8	8	8	8
C = Capping placement rate (>0)	Barge-mounted derrick crane	cy/hr	163	163	163	163	163	163	163	163	163
	Precision excavator	cy/hr	128	128	128	128	128	128	128	128	128
Total time required for survey operation	Survey boat	hr	350	350	350	262	262	262	429	429	429

5 MISCELLANEOUS											
Description	Equipment	Units	LDWG Key Elements - Option 1	LDWG Key Elements - Option 2	LDWG Key Elements - Option 3	EPA Preferred Alternative - Option 1	EPA Preferred Alternative - Option 2	EPA Preferred Alternative - Option 3	LDW FS Alternative 5R - Option 1	LDW FS Alternative 5R - Option 2	LDW FS Alternative 5R - Option 3
Volume	Loader	cy	620,000	620,000	620,000	790,000	790,000	790,000	1,600,000	1,600,000	1,600,000
	Dozer	cy	0	0	0	0	0	0	0	0	0
Fuel consumption	Loader	gal/hr	7	7	7	7	7	7	7	7	7
	Dozer	gal/hr	0	0	0	0	0	0	0	0	0
Excavation rate	Loader	cy/hr	200	200	200	200	200	200	200	200	200
	Dozer	cy/hr	70	70	70	70	7	70	70	70	70

NOTES

Distance: Average distance is the total distance travelled; one way is the distance of the landfill from the site (will be doubled for calculations).

Attachment 2 – Technology Emission Factors[6] Applicable for Year 2015

1 DREDGING			
References	Description	Units	Value
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NOx	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

2 TRANSLOADING			
References	Description	Units	Value
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NO_x	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

6 Emission factors assume that all engines use ULSD and meet all EPA emission requirements by the year 2015 (e.g., Tier 4 engines, clean diesel technology upgrades, etc.)

3 TRANSPORTATION			
References	Description	Units	Value
GREET – Truck Transportation, Diesel *- Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.701
	Emission factor for CO	lb/gal	0.004
	Emission factor for NO_x	lb/gal	0.013
	Emission factor for SOx	lb/gal	0.003
	Emission factor for PM_{10}	lb/gal	0.001
GREET – Train Transportation, Diesel *- Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.567
	Emission factor for CO	lb/gal	0.062
	Emission factor for NO_x	lb/gal	0.318
	Emission factor for SOx	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.008
GREET – Barge Transportation, Diesel *- Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NOx	lb/gal	0.334
	Emission factor for SOx	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

4 SEDIMENT CAPPING			
References	Description	Units	Value
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012
*GREET – **Barge Transportation, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.586
	Emission factor for CO	lb/gal	0.067
	Emission factor for NO_x	lb/gal	0.334
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

5 MISCELLANEOUS			
References	Description	Units	Value
*GREET – **Stationary Engine, Diesel** - Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2012*	Emission factor for CO_2	lb/gal	23.557
	Emission factor for CO	lb/gal	0.070
	Emission factor for NO_x	lb/gal	0.140
	Emission factor for SO_x	lb/gal	0.002
	Emission factor for PM_{10}	lb/gal	0.012

Attachment 3 – Emissions by Technology, Remedial Alternative, and Truck Miles

Technology	Technology Description	Emissions (in metric tons)	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
			Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Dredging	Dredging Equipment	CO_2	2,708	2,708	2,708	3,452	3,452	3,452	6,985	6,985	6,985
		CO	8	8	8	10	10	10	21	21	21
		NO_x	16	16	16	21	21	21	42	42	42
		SO_x	0.28	0.28	0.28	0.36	0.36	0.36	0.72	0.72	0.72
		PM_{10}	1	1	1	2	2	2	4	4	4
	Bathymetric Survey of Dredging Footprint	CO_2	51	51	51	65	65	65	136	136	136
		CO	0.14	0.14	0.14	0.18	0.18	0.18	0.38	0.38	0.38
		NOx	0.72	0.72	0.72	0.92	0.92	0.92	1.92	1.92	1.92
		SO_x	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		PM_{10}	0.03	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07
Transloading	Transloading Tug transport of Dredge Sediment	CO_2	1,411	1,411	1,411	1,796	1,796	1,796	3,638	3,638	3,638
		CO	4	4	4	5	5	5	10	10	10
		NO_x	20	20	20	25	25	25	52	52	52
		SO_x	0	0	0	0	0	0	0	0	0
		PM_{10}	1	1	1	1	1	1	2	2	2
	Offloading barge with derrick crane	CO_2	1,506	1,506	1,506	1,919	1,919	1,919	3,892	3,892	3,892
		CO	4.26	4.26	4.26	5.44	5.44	5.44	11.02	11.02	11.02
		NO_x	21	21	21	27	27	27	55	55	55
		SO_x	0.15	0.15	0.15	0.20	0.20	0.20	0.40	0.40	0.40
		PM_{10}	0.77	0.77	0.77	0.98	0.98	0.98	1.98	1.98	1.98
Transportation	Truck Transport in LDW Corridor to transfer facility	CO_2	400	240	88	508	306	112	1,034	621	227
		CO	0.08	0.05	0.02	0.10	0.06	0.02	0.20	0.12	0.04
		NO_x	0.22	0.13	0.05	0.29	0.17	0.06	0.58	0.35	0.13
		SO_x	0.05	0.03	0.01	0.06	0.04	0.01	0.13	0.08	0.03
		PM_{10}	0.02	0.01	0.00	0.02	0.01	0.00	0.04	0.03	0.01

Technology	Technology Description	Emissions (in metric tons)	LDWG Key Elements			EPA Preferred Alternative			LDW FS Alternative 5R		
			Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Transportation *(continued)*	Rail Transport to Roosevelt	CO_2	12,156	12,156	12,156	15,513	15,513	15,513	31,434	31,434	31,434
		CO	32	32	32	41	41	41	83	83	83
		NO_x	164	164	164	209	209	209	424	424	424
		SO_x	1.24	1.24	1.24	1.58	1.58	1.58	3.20	3.20	3.20
		PM_{10}	4.24	4.24	4.24	5.40	5.40	5.40	10.93	10.93	10.93
	Truck Transport at Roosevelt Landfill	CO_2	400	400	400	508	508	508	1,034	1,034	1,034
		CO	0.08	0.08	0.08	0.10	0.10	0.10	0.20	0.20	0.20
		NO_x	0.22	0.22	0.22	0.29	0.29	0.29	0.58	0.58	0.58
		SO_x	0.05	0.05	0.05	0.06	0.06	0.06	0.13	0.13	0.13
		PM_{10}	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04
	Tug Transport of Clean Aggregate to the Site	CO_2	3,556	3,556	3,556	2,667	2,667	2,667	4,373	4,373	4,373
		CO	10	10	10	8	8	8	12	12	12
		NO_x	50	50	50	38	38	38	62	62	62
		SO_x	0.36	0.36	0.36	0.27	0.27	0.27	0.44	0.44	0.44
		PM_{10}	2	2	2	1	1	1	2	2	2
Capping	Placing Capping Material	CO_2	676	676	676	508	508	508	835	835	835
		CO	2.00	2.00	2.00	1.50	1.50	1.50	2.46	2.46	2.46
		NO_x	4.04	4.04	4.04	3.03	3.03	3.03	4.94	4.94	4.94
		SO_x	0.07	0.07	0.07	0.05	0.05	0.05	0.09	0.09	0.09
		PM_{10}	0.34	0.34	0.34	0.26	0.26	0.26	0.42	0.42	0.42
	Bathymetric Survey of Material Placement Footprint	CO_2	30	30	30	22	22	22	37	37	37
		CO	0.08	0.08	0.08	0.06	0.06	0.06	0.10	0.10	0.10
		NO_x	0.42	0.42	0.42	0.32	0.32	0.32	0.52	0.52	0.52
		SO_x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		PM_{10}	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02
Miscellaneous	Front-End Loader Used at Transloading Facility to Load Containers.	CO_2	232	232	232	295	295	295	599	599	599
		CO	0.68	0.68	0.68	0.87	0.87	0.87	1.77	1.77	1.77
		NO_x	1.38	1.38	1.38	1.76	1.76	1.76	3.57	3.57	3.57
		SO_x	0.02	0.02	0.02	0.03	0.03	0.03	0.06	0.06	0.06
		PM_{10}	0.12	0.12	0.12	0.15	0.15	0.15	0.30	0.30	0.30