

Commercial Marine Vessels – 2014 EPA Estimates

The 2014v2 NEI includes emissions from commercial marine vessel (CMV) activity in the 50 states, Puerto Rico, and US Virgin Isles, out to 200 nautical miles from the US coastline.

1. Sector Description

The CMV sector includes boats and ships used either directly or indirectly in the conduct of commerce or military activity. The majority of vessels in this category are powered by diesel engines that are either fueled with distillate or residual fuel oil blends. For the purpose of this inventory, we assume that Category 3 (C3) vessels primarily use residual blends while Category 1 and 2 (C1 and C2) vessels typically used distillate fuels.

The C3 inventory includes vessels which use C3 engines for propulsion. C3 engines are defined as having displacement above 30 liters per cylinder. The resulting inventory includes emissions from both propulsion and auxiliary engines used on these vessels, as well as those on gas and steam turbine vessels. Geographically, the inventories include port and interport emissions that occur within the area that extends 200 nautical miles (nm) from the official U.S. shoreline, which is roughly equivalent to the border of the U.S. Exclusive Economic Zone. Only some of these emissions are allocated to states based on official state boundaries that typically extend 3 miles offshore.

The C1 and C2 vessels tend to be smaller ships that operate closer to shore, and along inland and intercoastal waterways. Naval vessels are not included in this inventory, though Coast Guard vessels are included as part of the C1 and C2 vessels.

The CMV source category does not include recreational marine vessels, which are generally less than 100 feet in length, most being less than 30 feet, and powered by either inboard or outboard. These emissions are included in those calculated by the MOVES model; they reside in the nonroad data category and EIS “Mobile - Non-Road Equipment” sectors of the 2011 NEI.

Each of the commercial marine SCCs requires an appropriate emissions type (M=maneuvering, H=hotelling, C=cruise, Z=reduced speed zone) because emission factors vary by emission type. Each SCC and emissions type combination was allocated to a shape file identifier in the nonpoint inventory. The allowed combinations are shown in Table 1. The default values are those assumed when the actual emission type may be unknown; for example, emissions that occur in shipping lanes are assumed to be ‘cruising’ and cannot be ‘hotelling’, which only occurs at ports.

Table 1: Commercial Marine SCCs and Emission Types in EPA Estimates

SCC	SCC Description	Allowed	Default
2280002100	Marine Vessels, Commercial Diesel Port	M	M
2280002200	Marine Vessels, Commercial Diesel Underway	C	C
2280003100	Marine Vessels, Commercial Residual Port	H	H
2280003100	Marine Vessels, Commercial Residual Port	M	H
2280003200	Marine Vessels, Commercial Residual Underway	C	C
2280003200	Marine Vessels, Commercial Residual Underway	Z	C

2. EPA-Developed commercial marine vessel activity and emissions data

This section summarizes the approach used to estimate emissions including compilation of 1) activity data (kilowatt hours or kW), 2) engine operating load factors, and 3) emission factors HAP speciation profiles.

Regarding vessel activities, the following data sources were used to develop vessel characteristics and quantify traffic patterns:

Entrance and Clearance (E&C) – This data set captures vessels involved in international trade, documenting where a vessel came from and its next port of call (U.S. Army Corps of Engineers, 2015a). These vessel-specific ship movements were linked to their individual engine characteristics (IHS, 2014) to calculate kilowatt hours. Most of the vessels in this data set are equipped with Category 3 propulsion engines, although some vessels were identified that are equipped with Category 1 and 2 propulsion engines.

Waterborne Commerce (WC) – The U.S. Army Corps of Engineers provided a data set of domestic vessel movements for tugs and barges, bulk carriers, tankers, and other vessels (U.S. Army Corps of Engineers 2015b). These data are provided as domestic trips along a defined route and mapped to the NEI ports and shipping lane segments. Typical vessel speeds by vessel type were used in conjunction with the distance associated with each trip to estimate the hours of operation which were applied to the vessels' propulsion power to get kilowatt hours.

Category 1 and 2 Study – For this inventory, the EPA's 2007 Category 1 and 2 vessels census was updated with more recent data, specifically for ferries, survey vessels, ships involved with offshore oil and gas activities, dredging, and U.S. Coast Guard operations. For these smaller vessels, less detailed information was available about their characteristics or traffic patterns, therefore, the kilowatt hours were estimated based on typical operations and applied to typical vessel power ratings.

Note all activity data were adjusted for typical engine loads for the modes of operation included in this study (i.e., cruising, reduced speed zone (RSZ), maneuvering, and hoteling). The adjusted kilowatt hours were applied to EPA emission factors by engine category as follows:

$$\text{Emissions} = \text{EF} \left(\frac{\text{g}}{\text{kWh}} \right) \times \frac{\text{D (NM)}}{\text{Vs} \frac{\text{NM}}{\text{hr}}} \times \text{LF} \times \text{Vp (kW)}$$

Where:

- EF = EPA Emission factor, in grams per kilowatt-hour (kWh)
- D = Distance along segment or RSZ (NM)
- Vs = 0.94 x maximum vessel speed = cruising speed or RSZ speed limit (NM/hr)

LF = Load Factor (fraction less than 1)
Vp = Vessel Power (kW)

D/Vs is used to estimate operating hours for E&C data and WC data. For C1/C2 study, typical operating hours are used instead. Also, if vessel speed is unknown, typical speed by vessel type was used (nautical miles/hr or knots). More detailed equations are available in Appendix A.

2.1 Activity Data

Entrance and Clearance

Vessel-specific routing data were available from the U.S. Army Corps of Engineers' 2012 E&C data (U.S. Army Corps of Engineers 2015a) for approximately 11,000 U.S. and foreign flagged vessels involved in international trade that complies with U.S. Customs and Clearance reporting requirements, as summarized in Table 2.

Table 2: Vessel-Specific Routing Data

Standard Type	Total Vessel Count	Domestic Flagged	Foreign Flagged
Barge	350	244	106
Bulk Carrier	3,294	11	3,283
Bulk Carrier, Laker	89	35	54
Buoy Tender	4	0	4
Container	1,319	51	1,268
Crude Oil Tanker	754	8	746
Dredger	2	1	1
Drilling	51	7	44
Fishing	248	142	106
FPSO	2	0	2
General Cargo	1,086	24	1,062
Icebreaker	2	0	2
Jackup	4	3	1
LNG Tanker	45	0	45
LPG Tanker	156	0	156
Misc.	47	17	30
Passenger	173	7	166
Pipelaying	14	0	14
Reefer	185	0	185
Research	61	31	30
RORO	92	7	85
Supply	255	197	58
Support	75	34	41
Tanker	1,428	14	1,414
Tug	679	533	146
Vehicle Carrier	465	20	445

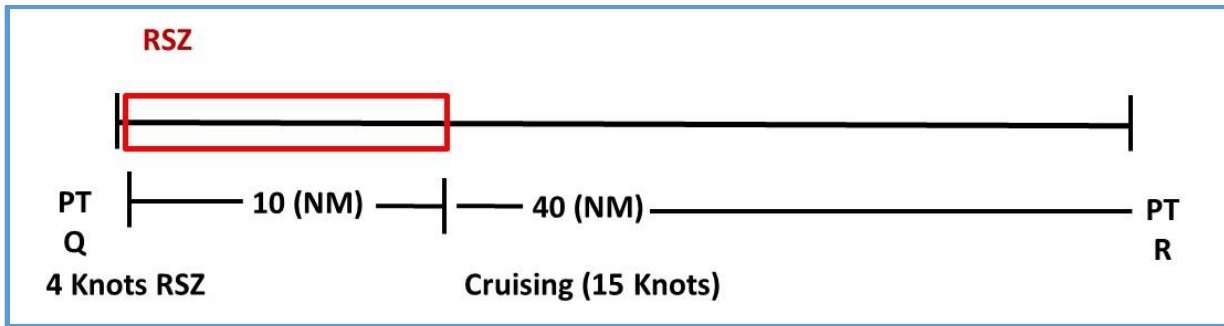
Table 2: Vessel-Specific Routing Data

Standard Type	Total Vessel Count	Domestic Flagged	Foreign Flagged
Well Stimulation	3	1	2
Total	10,883	1,387	9,496

These vessels were linked to their individual routes based on the originating port and the destination port. For the 2014 NEI, the E&C data were mapped to 7,176 routes comprising 410 unique ports, 174 of which are domestic U.S. ports. The waterway network was also edited to include 1,005 segments associated with RSZs based on the EPA's Regulatory Impact Assessment (US EPA 2003) for Category 3 vessels summarized Appendix B. Where the RSZ speed was unknown, a typical value of 10 knots was used.

To calculate hours of operation, the length of each route was divided by the vessel speed. Where a vessel travels through a RSZ, the vessel speed was reduced, thus increasing the hours of operation along that segment. Figure 1 provides an example of a vessel traveling from port Q to port R, moving through a 10 NM RSZ segment followed by a 40 NM normal cruising segment.

Figure 1: Example Route for Ship Movement from Port A to Port B via a RSZ



Hours to transit each segment were estimated for each vessel based on the distance traveled and the vessel cruising speed, which was assumed to be 94 percent of the vessel's maximum speed as obtained from Information Handling Services' (IHS 2015) Register of Ships. These cruising speeds were additionally reduced based on the latest International Maritime Organization (IMO) Greenhouse Gas emission inventory (IMO 2014) that quantifies actual vessel speeds and engine operating loads for select vessel types, accounting for recent practices to reduce fuel consumption known as slow steaming. The IMO data are presented in Table 3.

Table 3: IMO Vessel Speed Data

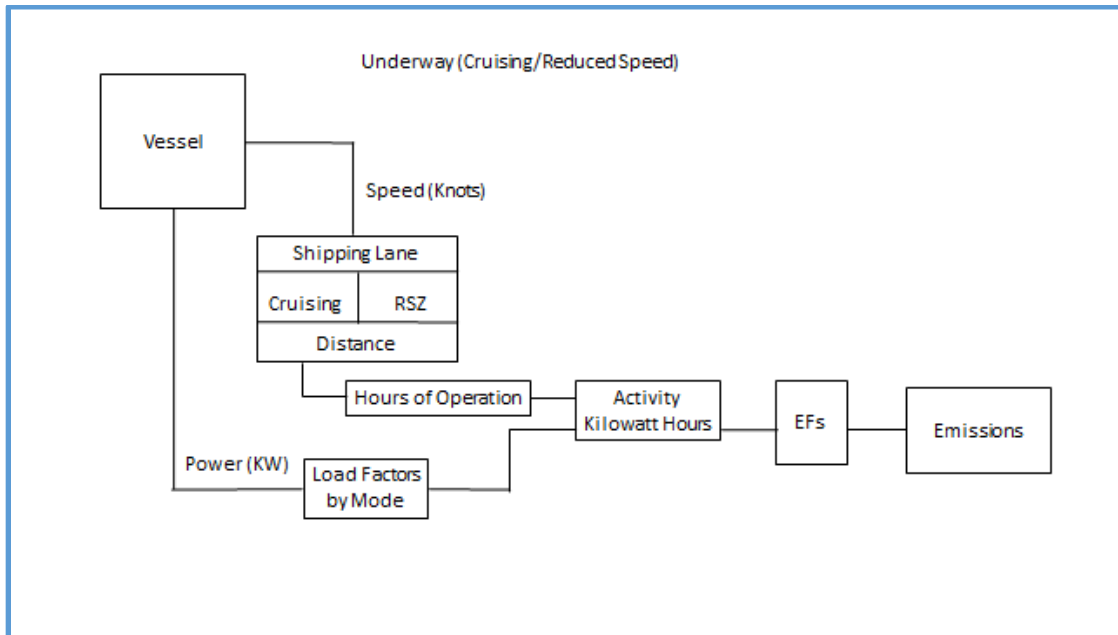
Ship Type	Size Category	Size Units	Ratio of average at-sea speed to design speed	Percent of total population	Weight amount	Weighted Cruising Speed Factor
Bulk Carrier	0-9999	dwt	0.84	0.9%	0.007403	0.822751023
	10000-34999		0.82	25.1%	0.20571	
	35000-59999		0.82	36.0%	0.295272	
	60000-99999		0.83	31.7%	0.263082	
	100000-199999		0.81	6.2%	0.050227	
	200000+		0.84	0.1%	0.001058	
Container	0-999	TEU	0.77	4.9%	0.038087	0.681508656
	1000-1999		0.73	11.8%	0.086059	
	2000-2999		0.7	12.5%	0.087716	
	3000-4999		0.68	32.8%	0.223116	
	5000-7999		0.65	28.6%	0.185944	
	8000-11999		0.65	9.0%	0.058409	
	12000-14500		0.66	0.3%	0.002176	
	14500+		0.6	0.0%	0	
Oil Tanker	0-4999	dwt	0.8	0.1%	0.001094	0.782982216
	5000-9999		0.75	0.3%	0.002052	
	10000-19999		0.76	0.0%	0	
	20000-59999		0.8	3.6%	0.028454	
	60000-79999		0.81	15.6%	0.12632	
	80000-11999		0.78	43.4%	0.338249	
	120000-199999		0.77	32.6%	0.250698	
	200000+		0.8	4.5%	0.036115	

dwt = dead weight tonnage; TEU = twenty foot equivalent units

For RSZs, a vessel's speed was assumed to be the zone's speed unless the vessel's cruising speed was lower. For example, a vessel with a cruising speed of 12 knots traveling through a waterway segment with a reduced speed of 14 knots was assumed to be operating at 12 knots.

The hours of operation were applied to the vessel's power, which was adjusted for typical engine operating loads to get kilowatt hours. In turn, the kilowatt hours were applied to the appropriate EPA emission factor based on the vessel engine's category to estimate criteria pollutant emissions. The flow of emissions calculations for underway vessels is illustrated in Figure 2.

Figure 2: Emission Calculations for Underway Operations



Vessel characteristics data were compiled from IHS Register of Ships (IHS 2014) and linked to vessels included in the 2012 E&C data. The vessel characteristics included the following data:

- Vessel identification codes
- Vessel name
- Country of registry
- Call sign
- Vessel type
- Gross/net tonnage
- Vessel power
- Auxiliary engine power
- Piston stroke length/cylinder diameter (to calculate vessel category)
- Maximum vessel speed.

Approximately 89 percent of the E&C vessels could be matched to their characteristics by cross referencing multiple attributes such as IMO identification code, country of registry, gross tonnage, net tonnage, vessel type, and vessel name. For the remaining vessels that could not be matched, vessel attributes were developed for each vessel type based on the matched vessel in the IHS data. If the vessel type was unknown, aggregate attributes derived from all matched vessels in the IHS data set were developed and used. Note that the auxiliary engine data in the IHS data set was poorly populated; therefore, vessel type surrogates were developed based on vessels that reported auxiliary engine power. The vessel power data used in this study are presented in Table 4.

Table 4: Vessel Power Attributes by Vessel Type

Standard Type	Count	Avg Main hrs	Avg Aux kW	Avg Max Speed	Default Vessel Category
Bulk Carrier	3,177	8,990	1,935	14.3	3
Bulk Carrier, Laker	80	7,069	2,216	13.7	3
Buoy Tender	4	4,266		12.6	2
Container	1,218	39,284	7,851	23.2	3
Crude Oil Tanker	731	15,070	2,888	15.1	3
Drilling	7	15,806	12,840	11.7	2
Fishing	123	1,262	272	2.3	1
FPSO	2	18,123		11.5	3
General Cargo	1,020	6,130	1,619	14.6	3
Icebreaker	2	21,844		12.0	2
Jackup	4	1,643	270	3.5	1
LNG Tanker	44	29,607	8,129	19.2	3
LPG Tanker	151	8,557	3,021	15.8	3
Misc.	35	2,805	631	10.0	1
Passenger	168	45,760	4,477	20.4	3
Pipelaying	14	11,355	5,037	12.6	2
Reefer	182	8,930	3,328	18.9	3
Research	55	5,395	1,905	11.2	2
RORO	72	9,479	4,006	16.7	3
Supply	255	3,201	662	10.1	1
Support	73	6,590	2,305	9.7	2
Tanker	1,423	8,474	2,730	14.5	3
Tug	396	3,440	348	7.7	2
Vehicle Carrier	441	13,829	3,729	19.8	3
Well Stimulation	3	7,697	340	8.2	3

Individual vessel movements were compiled as origination and destination pairs for each U.S. port included in the E&C data. The E&C data includes only vessels that enter or leave U.S. waters at some point in the trip. Over 49 percent of the records were for vessels that visit a single U.S. port during a single trip. Similarly, over 49 percent of the records were for vessels that visited multiple U.S. ports in one trip and less than one percent of the records were only between domestic U.S. ports.

Because the E&C data report the departure of a vessel from a U.S. port and the arrival of the same vessel in the destination port associated with the trip, it was necessary to adjust the

vessel movement data to avoid double counting of trips. To avoid the double counting only the entrance or clearance of the trip and not both are counted. Evaluating the duplicate trips was also an important quality check on the E&C data—ideally there should be a duplicate departure and arrival record for every trip, thus validating the completeness of the data. For example, for a vessel traveling from Long Beach to San Diego would typically have four E&C records:

- Arrival at Long Beach
- Departure from Long Beach (to San Diego)
- Arrival at San Diego (from Long Beach)
- Departure from San Diego.

Of the 23,008 unique ship movements for domestic origination and destination pairs, 85 percent of the vessel movements had corresponding arrivals and departures; 3,481 (15 percent) had an odd number of records, indicating that a vessel movement may be missing.

In many cases, the missing vessel movements were associated with an arrival in one port and a departure from an adjacent port, suggesting that the missing vessel movement was between the two adjacent ports. For example, the data may show only three records:

- Arrival at Long Beach
- Departure from Los Angeles (to San Diego)
- Arrival at San Diego (from Los Angeles)
- Departure from San Diego.

This dataset would thus suggest a missing Los Angeles to Long Beach trip.

To account for this type of error, adjacent ports were aggregated, reducing the unique vessel routes or movements to 19,883. Of the final 19,883 routes, only 4 percent of the vessel movements (attributed to 815 routes) had a missing arrival or departure. Many of the remaining missing ship movements were associated with the U.S. protectorates in the Caribbean Sea, where the arrival and departure information occasionally appeared to be switched.

The issue of duplicate trips was not a concern for foreign vessel movements because the E&C documents arrivals and departures for only U.S. ports, which means that a departure from a

U.S. port to a foreign port or an arrival from a foreign port to a U.S. port would always be a unique trip.

Adjustments were also made for Alaskan trips. The E&C data reported activity for 52 Alaskan ports, however, the vast majority of those are small ports and have very little traffic. To capture the majority of emissions, only the top 13 Alaska ports, which accounted for 94 percent of the Alaska traffic, were included. Table 5 lists the Alaska ports and associated vessel calls.

Table 5: Alaska Ports and Vessel Calls

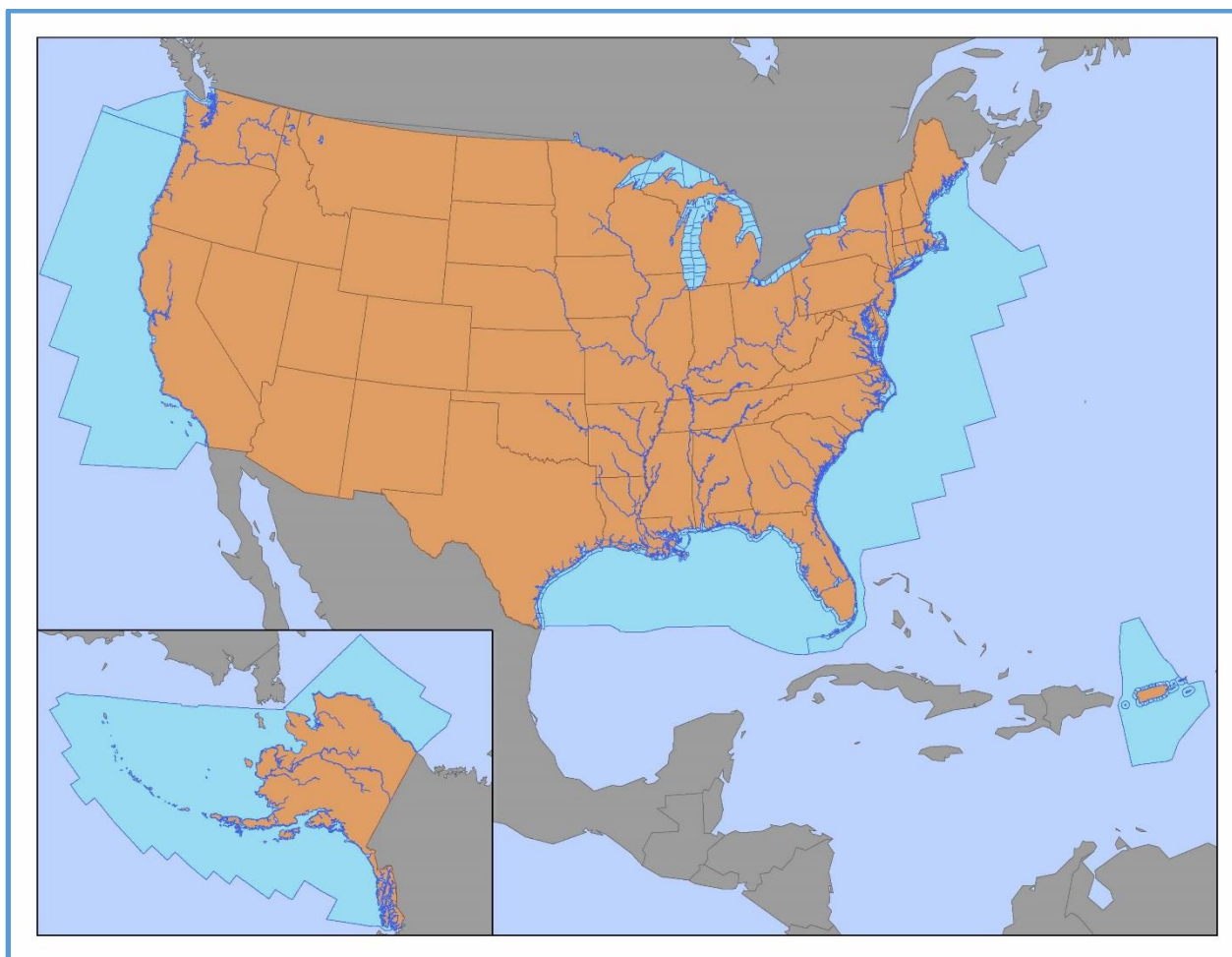
Ports	Total of Count	Domestic	Foreign	Fraction of Alaska Total
Juneau, AK	1,892	1,812	80	0.27
Ketchikan, AK	1,699	1,136	563	0.20
Skagway, AK	1,390	1,330	60	0.20
Anchorage, AK	563	526	37	0.08
Kivalina, AK	481		481	0.03
Sitka, AK	326	302	24	0.05
Iliuliuk Harbor, AK	212	76	136	0.02
Dutch Harbor, AK	196	84	112	0.02
Whittier, AK	182	65	117	0.02
Seward, AK	149	109	40	0.02
Icy Strait, AK	132	110	22	0.02
Wrangell, AK	88	15	73	0.01
Haines, AK	82	81	1	0.01

Once the E&C origination and destination port pairs were defined, trips were routed over a custom waterway network based on the U.S. Army Corps of Engineers' navigable waterway network using a Geographic Information System (GIS) and network analysis. The routes were then intersected with EPA's NEI shapefiles of ports and shipping lanes. Shipping lanes associated with RSZs were coded to allow for adjustment in vessel speed, time spent transiting the RSZ, and engine operating load.

Because U.S. territorial waters extend out 200 nautical miles from the coast (Figure 3)¹, international vessel routes were mapped only to the U.S. federal waters/international waters boundary. The distance traveled was calculated based on the route the vessel was assigned. Each waterway segment was coded to differentiate normal cruising versus RSZ operations.

¹ These are the official US territorial waters from NOAA, which are generally 200nm but do vary in some places due to foreign entities, etc. Spreading/condensing of emissions depends more on how the emissions were developed than the shapes we use here and is a frequent topic of conversation with modelers.

Figure 3: State and Federal Waters of the United States



Blue/Light Blue = state and federal water boundaries

Activity data for Entrance & Clearance time spent maneuvering/dockside

E&C data do not include details about time spent in each ship movement mode. Typical maneuvering times by vessel type were used to estimate time spent in this mode. Maneuvering durations for different vessel types were obtained from Entec's European emission inventory (Entec 2002) and are presented in Table 6. Note half of the maneuvering time presented in Table 6 was assumed to be approaching the terminal and half departing from the terminal.

Table 6: Estimated Maneuvering Time by Vessel Type

Vessel Type	Maneuvering Time (hours)
Bulk Carrier	1

Table 6: Estimated Maneuvering Time by Vessel Type

Vessel Type	Maneuvering Time (hours)
Bulk Carrier, Laker	1
Buoy Tender	1.7
Container	1
Crude Oil Tanker	1.5
General Cargo	1
LNG Tanker	1
LPG Tanker	1
Misc.	1
Passenger	0.8
Reefer	1
RORO	1
Tanker	1
Tug	1.7
Vehicle Carrier	1

To quantify the duration a vessel spends dockside, the E&C data were organized chronologically for individual vessels to determine when a vessel arrives at the dock and when it leaves. Some of the dockside durations seemed unreasonably high, indicating that either an arrival or departure was missing or out of sequence. These anomalies were identified and removed from the analysis. The data were then averaged by vessel type to develop port specific dockside duration times. It should be noted that the E&C data recorded the day the vessel arrived and the day the vessel departed. The daily periods were multiplied by 24 hours to get hourly values. If a vessel arrived and departed in the same day it was assumed that the dockside duration was 12 hours.

The EPA provided hourly containership dockside data for 15 ports (US EPA 2015a). For the 2014 NEI, these containership data replaced containership E&C data for the following ports:

- Ports of Los Angeles and Long Beach
- Ports of New York and New Jersey
- Port of Seattle
- Port of Houston
- Port of Baltimore
- Port of Savannah
- Port of Norfolk
- Port of Charleston
- Port of New Orleans
- Port of Mobile
- Port of Miami
- Port of Philadelphia
- Port of Tampa
- Port of San Juan
- Port of Portland

Additionally, dockside duration data were identified for ports that developed their own inventories. These data were assumed to be the highest quality and replaced E&C and EPA containership data. 2014 Detailed port data were obtained from the following ports:

- Port of Los Angeles
- Ports of New York and New Jersey
- Port of San Francisco
- Port of San Diego

Activity data for waterborne commerce

As with the E&C data, the Army Corps of Engineers Waterborne Commerce Data (WCD) provides vessel trips for individual vessels operating over a specified route. The WCD also includes vessel power ratings and distance of each route. The distance data were evaluated using typical vessel speeds to calculate hours of operation to transit a specified route. Note, hours of operation were adjusted for slower speeds transiting RSZs. The cruising speeds for each vessel type were compiled from a variety of sources. The primary data source was the IHS data; vessels equipped with Category 1 and 2 propulsion engines were identified and grouped by vessel type and averages of the vessel's maximum speed were developed for each grouping. These values are shown in Table 7. The cruising speed was assumed to be 94% of the average maximum speed.

Table 7: Category 1 and 2 Average Maximum Speed by Vessel Type

Vessel Type	Vessel Count	Average Maximum Speed (knots)
Bulk Carrier	376.00	10.09
Bulk Carrier, Laker	27.00	13.74
Buoy Tender	197.00	6.90
Container	111.00	8.48

Table 7: Category 1 and 2 Average Maximum Speed by Vessel Type

Vessel Type	Vessel Count	Average Maximum Speed (knots)
Crude Oil Tanker	44.00	6.97
Drilling	39.00	11.74
Fishing	13,652.00	5.67
Floating Production and Storage Offloading	10.00	4.90
General Cargo	7,179.00	8.09
Icebreaker	27.00	10.52
Jackup	173.00	4.25
LNG Tanker	3.00	9.33
LPG Tanker	183	10.83
Miscellaneous	2,014	6.83
Passenger	3,017	15.67
Pipelaying	280	6.39
Reefer	183	9.62
Research	951	9.79
RORO	1,997	11.28
Supply	3,409	12.98
Support	1,036	10.42
Tanker	2,880	8.28
Tug	15,660	8.54
Vehicle Carrier	20	14.42
Well Stimulation	30	8.63

Because the WCD contain confidential business information not available to the general public, the activity data were aggregated to develop national total activities and reapportioned to appropriate NEI underway shapes. This approach provided reasonable national estimates while protecting the confidential business aspects of the WCD. The spatial allocation was developed in GIS using an approach similar to that used for the E&C data. The WCD were evaluated to identify consolidated routes using both the port and location names for the origins and destinations. For example, routes to and from “St. Thomas, VI” were combined with routes to and from “St. Thomas Harbor Virgin Islands.” We also removed routes where the origin and destination were the same, because these records were considered to be inter-terminal maneuvering and are likely to be included in the maneuvering assumptions. This consolidation process reduced the number of unique routes from 40,775 to 27,991. The remaining routes were mapped in GIS using a shortest-distance based network analysis, and the routes were again intersected with NEI shapes to identify which routes passed through each shape. This intersection process identified portions of some routes that passed outside of US waters, for

example, from Miami to Puerto Rico. For each route, the total length within US waters was divided by the total length of the route to obtain the percentage of the route activity that occurs in US waters. The activity data were adjusted accordingly to remove kilowatt hours that occurred in international waters.

Next, for each shipping lane segment shape, the number of vessel trips that passed through were totaled.

$$T_a = R_1 + R_2$$

Where:

- T_a = Total number of trips on segment a
- R_1 = Number of trips on route 1
- R_2 = Number of trips on route 2

The length of the waterway through each shape was calculated and multiplied by the number of trips that occur along the shape. This value was divided by the national total for trips multiplied by the length to determine the percentage of the national total activity to allocate to each shape.

$$P = (T * L) / (NT * NL)$$

Where:

- P = Percentage of national activity
- T = Total trips for the NEI underway shape
- L = Waterway segment length within underway shape
- NT = National trip total
- LN = National waterway network length total

Updating the Category 1 and 2 Vessel Census activity data

Since E&C includes only larger internationally-travelling vessels, additional data sources were needed to fill data gaps, particularly for smaller C1 and C2 vessel population involved in domestic traffic.

Dredging:

As part of the effort to update the EPA's C1 and C2 vessel data, dredging data were compiled as a new vessel category. To estimate dredging activities for different types of dredging vessels, operating days were obtained from the U.S. Army Corps of Engineers database of dredging

contracts for the entire country (U.S. Army Corps of Engineers 2014). This database included contracts from 2012 to 2014. For contracts active since 2012, only the portion of the contracts that were active during 2014 were used in this inventory. The 2014 dredging activities are presented in Appendix C by job name, dredging equipment, and actual operating days.

Operating hours were calculated from the number of days active in 2014, assuming a utilization rate documented in the Category 1/2 Vessel Census of 90% time spent dredging, excluding equipment positioning, maintenance, and refueling times. The U.S. Army Corps of Engineers data did not include horsepower or kW ratings for the engines on the dredging vessels but did include a dredging vessel type. A literature search of the dredging vessel types provided a kW rating for a typical vessel in each category, as summarized in Table 8.

Table 8: Power Rating by Dredging Type

Type	Contract Code	kW	Source
Bucket or mechanical	B	1,600	Anderson 2008
Hopper	H	7,272	TCEQ 2012
Non-conventional (Specialty) Type	N	2,093	Van Oord 2015
Pipeline (Cutterhead)	P	7,161	TCEQ 2012
Pipeline and Hopper Combination	Y	4080	Robinson et al. 2011
Undefined	U	5028	Average of compiled dredging data.

The typical kW ratings in Table 8 were matched by dredge type to each contracted vessel noted in Appendix C. The matched power rating was multiplied by the utilization rate and dredging duration to estimate kW-hrs which are summarized in Table 9.

Table 9: Summary of National Kilowatt Hours by Dredging Vessel Type

Type	Total kW-hr
Bucket or mechanical	63,659,520
Hopper	302,526,835
Non-conventional (specialty) type	15,280,574
Pipeline (cutterhead)	654,286,248
Undefined	5,973,264

Dredging activities were spatially apportioned to ship channels based on the job name. The job names indicated general location, such as a bay area or a waterway portion; however, they did not provide sufficient information to precisely locate the dredging activities or even geographic extent of the project. Best effort was given to identify the waterway segments in EPA's GIS shape files that most closely match the limited location information. It should be noted that these activities have been increasing over the past several years to accommodate larger vessels that will be able to transit the new Panama Canal.

Research Vessels:

A list of current US research vessels was obtained from the University of Delaware's International Research Ship Information and Schedule database (University of Delaware 2015). In the 2007 vessel census study (US EPA 2007), only 31 research vessels were included. Using the University of Delaware's research vessels website for this inventory, 251 vessels were identified. This gave a more accurate representation of C1 research vessels, which were undercounted in the original C1 and C2 census. Twenty-three of these vessels had detailed trip schedules for 2014, and activity in days was determined for these vessels. The list did not have vessel identification numbers or codes, so an online search was implemented to find vessel identification codes for the remaining vessels. Where identification codes could be found, the vessels were linked to research vessels in the IHS database, providing details on the engine power ratings and engine category. However, not all vessels were matched and another online search was implemented to obtain engine power ratings for the unmatched vessels. During this process, 35 vessels were removed from this analysis because information was found that indicated that the vessel was not in service in 2014 or not powered by a diesel combustion engine (e.g. electric powered remotely operated vehicle (ROV)). Detailed results are presented in Appendix D. Summary of research vessel matching activities are provided in Table 10.

Table 10: Research Vessel
Characteristics Matching
by Reference

Research Vessels Matching	
Original	251
IHS match	77
Online search	109
Annual schedule	23
Removed	35

For research vessels without engine power ratings, the matched vessel data were averaged to provide a default of 732 kW which was used to gap fill missing research vessel power data.

For the 2014 inventory, the duration of each research mission was used when available. For the vessels with no activity data, an average value (220 days converted to 5,280 hours) was obtained from the previous Category 1 and 2 Census report. This default duration data was used to when vessel schedule data were not available. The vessel power data were applied to the duration data to calculate kW-hrs for the research vessels.

Coast Guard:

A roster of U.S. Coast Guard vessels was provided by the US Coast Guard's (USCG) External Coordination Division (U.S. Coast Guard 2015a). Among the data given were vessel name, horsepower, and annual underway hours for 246 USCG cutters (Appendix E) and over 1,600 smaller boats. Fifty-eight percent of the smaller vessels were gas powered and excluded from this analysis. Also boats which were flagged as retired were also excluded from this analysis. This reduced the Coast Guard Boat list to 652 vessels.

All vessel power ratings were converted from horsepower to kW using the conversion factor 1 HP = 0.7457 kW. The vessel power ratings were multiplied by underway hours also provided by the U.S. Coast Guard to estimate kW-hrs per vessel. As Table 11 indicates, approximately 95 percent of activity is related to cutter operations and 5 percent is associated with the smaller boats. The Coast Guard data also included general information about where the vessels operated; for the 2014 NEI inventory, each vessel's kW-hrs were associated with the area of operation and summarized in Table 12.

Table 11: Summary of Coast Guard Underway Activity

Vessel Type	Number of Vessels	Total kW-hrs
Cutter	267	2,125,794,310
Boats	652	117,895,003
Total	384	2,243,689,313

Table 12 General Location of Coast Guard Underway Activities

Area	Total kW-hrs
Arkansas River	1,025,173
Atlantic	643,954,356
Elizabeth River	92,689,163
Great Lakes	53,675,432
Gulf	129,482,530
Illinois River	343,721
Lower Atchafalaya River	625,932

Table 12 General Location of Coast Guard
Underway Activities

Area	Total kW-hrs
Mississippi River	3,349,678
Ohio River	1,276,438
Pacific	1,311,967,588
Puget Sound	3,793,450
Tennessee River	1,115,487
Willamette River	354,849
Lake Champlain	35,515
Total	2,243,689,312

As the vessel fleet roster quantified at sea hours of operation, an inquiry was sent to the Coast Guard to ask specifically about in-port activities for the cutters. The Coast Guard staff indicated that cutters generally use shore power whenever it is available. There are some instances where maintenance, testing, or training could necessitate the need to run on ship's power. Because of these exceptions, it is estimated that the time on ship's power is no more than 10 hours per 30 days of in-port time. This means that while in-port, a Coast Guard cutter is estimated to be on shore power "99% of the time" (U.S. Coast Guard 2015b). As this response indicates, in-port ship activity is relatively small, so it was not included in this version of the NEI.

Note, currently the NEI does not include emission estimates from U.S. Naval exercises in U.S. waters. It is anticipated that data may be available in 2016 that will allow inclusion of these vessels.

Commercial Fishing:

To obtain the most accurate survey of commercial fishing vessels operating in the United States, regional offices of the National Oceanic and Atmosphere Administration (NOAA) were contacted. Of the offices contacted, only Northeast, Southeast (including the Gulf of Mexico), West Coast, and Alaska provided data. Data for the Great Lakes, Puerto Rico, and the U.S. Virgin Islands were not obtained. Upon further research, it was found that fishing vessels in Puerto Rico and the Virgin Islands are almost all powered by small single engines, diesels too small to be considered C1 vessels or gasoline powered vessels not included in this inventory effort.

Due to confidentiality concerns, the responding NOAA regions were not able to provide specific vessel information. The Northeast (NOAA 2015b) and Southeast (NOAA 2015d) region provided the data on annual number of trips, vessel count, and days absent by port or county, which were used to estimate and spatially allocate annual hours of operation.

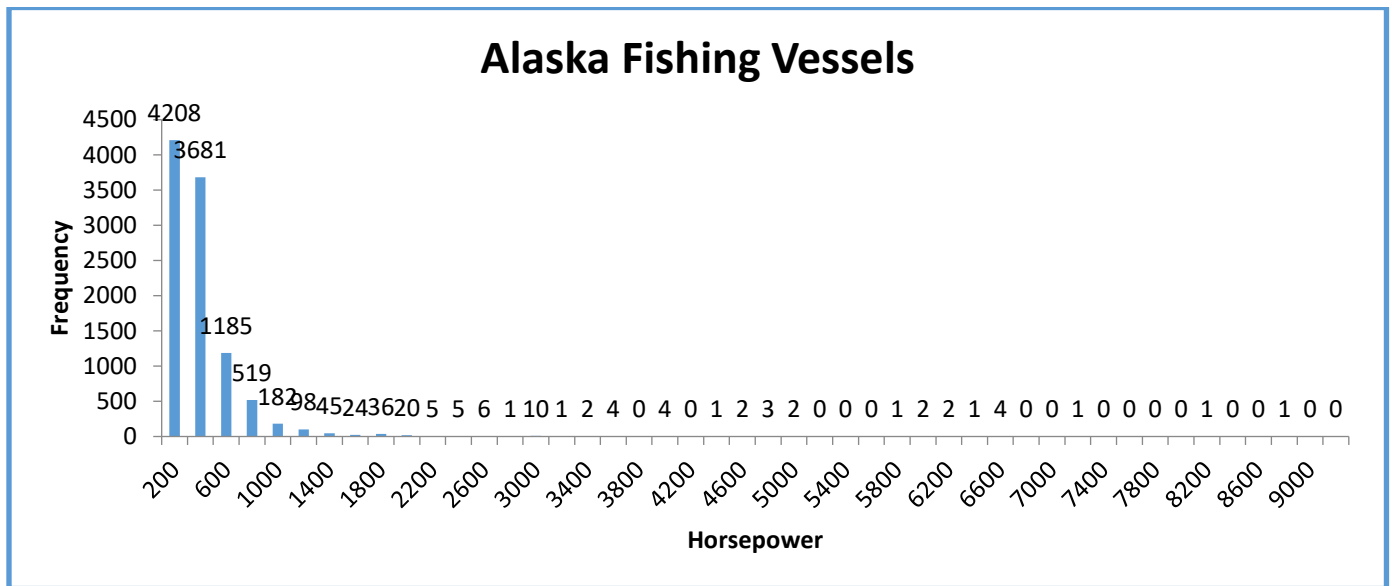
Data obtained from the West Coast regional office (NOAA 2015c) were not used in this inventory because the data provided only quantified the number of vessels operating and amount of fish caught by port. Data to quantify hours of operation were not provided. To gap fill the West Coast and the Great Lakes hours of operation, the NOAA website's commercial fishery landings by state (NOAA 2015a) were used to calculate a percent change between 2006 and 2013 commercial fish landings in pounds. It should be noted that data for 2014 was not available at the time, so 2013 data were used. Fishing vessel activity values in terms of kW-hrs developed in the original Category 1 and 2 Census Study (US EPA 2007) for the West Coast and Great Lakes were extrapolated using the percent change summarized in Table 13.

Table 13: State Fish Landing Data for Great Lakes and Pacific States

	Great Lakes					Pacific				
Year	Michigan	Minnesota	Ohio	Wisconsin	Total	California	Hawaii	Oregon	Washington	Total
2006 Pounds	9,350,764	308,409	4,241,973	4,449,476	18,350,622	341,660,769	26,020,904	282,846,344	241,606,439	892,134,456
2013 Pounds	9,487,700	457,374	4,812,541	3,850,262	18,607,877	363,798,075	32,447,284	339,589,404	273,796,328	1,009,631,091
Percent Change	1.5%	48.3%	13.5%	-13.5%	1.4%	6.5%	24.7%	20.1%	13.3%	13.2%

It is expected that the Alaska fishing vessel activity data would be significant as it represents about half of the U.S. fish landings. But the NOAA data (NOAA 2015e) obtained from the Alaska region was problematic as it documented the fleet size to be 2,267 vessels, noting the average duration at-sea per trip was 3 days, but could not provide an estimate of the number of trips these vessels made. Data from the Alaska Commercial Fisheries Entry Commission (CFEC) website which tracked Alaskan fishing vessels for the year 2014 (State of Alaska 2015) was used to evaluate the state's fishing fleet. The database included build date, horsepower rating, and duration at sea for 10,058 individual vessels. Assessing the horsepower of the vessels included in the database revealed that many of the vessels had very small or had no kW ratings (Figure 4). It was uncertain whether these smaller vessels were powered by recreational gasoline marine engines.

Figure 4: Horsepower for Alaskan Fishing Vessels



For this version of the NEI, vessels in the CFEC with a rating of 400 horsepower or less were omitted, leaving 2,169 vessels with horsepower ratings between 402 and 8,800. A study of active commercial Alaskan fishing vessels implemented by the North Pacific Fishery Management Council estimated the commercial fishing vessel fleet operating in state and federal waters around Alaska to be 1,646 unique vessels (North Pacific Fishery Management Council 2012). Unfortunately vessel characteristics of the fleet were not included in the report. Therefore the 2,169 larger vessels identified in the CFEC database were evaluated selecting the largest 1,646 vessels for inclusion into the 2014 NEI.

The days of operation for the vessels in the CFEC database seemed inflated and may indicate potential periods for operation, but not actual periods of operation. For example, many vessels were shown to operate year round, while most of the regulated fishing seasons in Alaska are restricted to the period from May to September (Alaska Department of Fish and Game 2014), which is about 150 days. The value of 3,600 hours per year (150 days/year x 24 hours = 3,600 hours) was used for Alaska vessels, which may over estimate emissions as it is assumed to be a maximum value for the fishing season. Future versions of the NEI marine vessel inventory should review available AIS data to better quantify Alaskan fishing vessel operations.

For the Northeast and Southeast regions where vessel power was not provided, an average fishing vessel kW power rating (1,000 kW) was obtained from the Category 1 and Category 2 Census (US EPA 2007) to estimate kW-hrs.

For the Alaska regions, horsepower ratings were converted to kW ratings, and applied to the hours of operation to estimate kW-hrs.

Where fishing vessel in-port and underway activities were not distinguished, activity was split to 95% underway and 5% in-port based on the Category 1 and Category 2 Census (US EPA 2007). Underway activity was also divided between state and federal waters using percentages derived from data on commercial landings of fish and shellfish in the Pacific Ocean for 2013 (NOAA 2015a); landings less than 3 miles from the coast were assumed to be in state waters and landings greater than 3 miles were assumed to be in federal waters. This approach will underestimate some states' activities such as Texas, Florida's Gulf coast, and Puerto Rico where the federal/state water boundary is 9 nautical miles.

It should be noted that additional study of fishing vessel activities is necessary to get a more accurate estimate of the fleet and its vessel characteristics and activity levels in Alaska, Pacific, and Great Lake Areas.

Ferries:

The U.S. Department of Transportation's Bureau of Transportation Statistics maintains a database of ferry vessels and activity (U.S. Department of Transportation 2014). This database includes ferry vessels characteristics by operator, trip segment, and terminal information. Individual vessels were linked to operators to develop operator fleet profiles which could be matched to trip segments. The operator fleet profiles included average vessel power and speed. The trip segments did not include travel distance or time information, so GIS tools were used to determine the distance between originating and destination terminals for each segment. During the process, duplicate trip segments were consolidated. Segment travel time was calculated using the segment distances and typical vessel speeds. Each segment had a season start date, as well as a count of trips. Total kW-hrs for each segment that an operator used were calculated using the following equation.

$$\text{kW-hrs} = (D_S / S_V) \times (SL \times [WT_V / 7]) \times kW_V$$

Where:

- D_S = distance of segment S in nautical miles between the start and end ports
- S_V = typical speed of vessel V in knots
- SL = length of the ferry season in days
- WT_V = number of trips made in a week for vessel V
- kW_V = kW rating of main engines for vessel V

Offshore oil and gas support vessels:

For the purpose of this inventory, 2011 estimates for the offshore oil and gas support vessels operating in the Gulf of Mexico were obtained from the Bureau of Ocean Energy Management (BOEM 2013). These vessels include:

- Seismic survey vessels
- Crew boats
- Supply boats
- Drilling rigs
- Anchor handling tugs
- Offshore tugs
- Pipelaying vessels

The 2011 estimates were adjusted to 2014 based on changes in the Gulf of Mexico's annual crude oil production. BOEM anticipates that the 2014 Gulf of Mexico emission inventory will be available in later 2016.

2.2 Engine Operating Loads

Because the activity data used to develop the 2014 NEI did not include engine operating load data or actual vessel speeds, typical operating loads were compiled for each vessel type based on published reports. Initially engine operating load assumptions were taken from the EPA's Current Methodologies in Preparing Port Emission Inventories (US EPA 2009). This guidance document provided a typical cruising load factor of 0.83. Engine load data from the most recent IMO GHG study (IMO 2014) were also evaluated. The data in the IMO study included an assessment of bulk carriers, containerships, and tanker speed and engine loads, which accounted for the practice of slow steaming. The IMO data were weighed based on the fleet composition of the E&C data linked up to the IHS vessel characteristics, as provided in Table 14.

Table 14: IMO Underway Cruising Vessel Speed and Engine Load Factors for Bulk Carriers, Containerships, and Tankers

Ship Type	Size Category	Size Units	Average at-sea Main Engine Load Factor (% MCR)	Percent of Total Pop.	Engine Load Weight Fraction	Weighted Load Factor
Bulk Carrier	0-9999	dwt	70%	0.9%	0.0062	0.5893
	10000-34999		59%	25.1%	0.1480	
	35000-59999		58%	36.0%	0.2089	
	60000-99999		60%	31.7%	0.1902	
	100000-199999		57%	6.2%	0.0353	
	200000+		62%	0.1%	0.0008	
Container	0-999	TEU	52%	4.9%	0.0257	0.3672
	1000-1999		45%	11.8%	0.0531	
	2000-2999		39%	12.5%	0.0489	
	3000-4999		36%	32.8%	0.1181	
	5000-7999		32%	28.6%	0.0915	
	8000-11999		32%	9.0%	0.0288	
	12000-14500		34%	0.3%	0.0011	
	14500+		28%	0.0%	0.0000	

Table 14: IMO Underway Cruising Vessel Speed and Engine Load Factors for Bulk Carriers, Containerships, and Tankers

Ship Type	Size Category	Size Units	Average at-sea Main Engine Load Factor (% MCR)	Percent of Total Pop.	Engine Load Weight Fraction	Weighted Load Factor
Oil Tanker	0-4999	dwt	67%	0.1%	0.0009	0.5158
	5000-9999		49%	0.3%	0.0013	
	10000-19999		49%	0.0%	0.0000	
	20000-59999		55%	3.6%	0.0196	
	60000-79999		57%	15.6%	0.0889	
	80000-11999		51%	43.4%	0.2212	
	120000-199999		49%	32.6%	0.1595	
	200000+		54%	4.5%	0.0244	

dwt = dead weight tonnage; TEU = twenty foot equivalent units

Load factors for RSZ were developed based on vessel speed which was either the maximum speed of the RSZ or the cruising speed of the vessel, whichever value was the smaller. The vessel speed was used in conjunction with the vessel's maximum speed and the propeller rule to estimate the propulsion engine operating load while in the RSZ.

$$LF = (AS/MS)^3$$

Where:

- LF = Load Factor (percent)
- AS = Actual Speed (knots)
- MS = Maximum Speed (knots)

Propulsion engine load factor for maneuvering was assumed to be 0.2, based on Entec's European emission inventory (Entec 2002). It is recommended that future versions of this inventory consider reviewing AIS in port data to more accurately quantify maneuvering loads. It was also assumed that the auxiliary engines would be operating during maneuvering based on EPA port guidance (US EPA 2009) as summarized in Table 15.

Table 15: Auxiliary Operating Loads

Vessel Types	Maneuver	Hotel
Bulk Carrier	0.45	0.1
Bulk Carrier, Laker	0.45	0.1
Buoy Tender	0.45	0.22
Container	0.48	0.19
Crude Oil Tanker	0.33	0.26
Drilling	0.45	0.22
Fishing	0.45	0.22
FPSO	0.45	0.22
General Cargo	0.45	0.22
Icebreaker	0.45	0.22

Table 15: Auxiliary Operating Loads

Vessel Types	Maneuver	Hotel
Jackup	0.45	0.22
LNG Tanker	0.33	0.26
LPG Tanker	0.33	0.26
Misc.	0.45	0.22
Passenger	0.8	0.64
Pipelaying	0.45	0.22
Reefer	0.67	0.32
Research	0.45	0.22
RORO	0.45	0.26
Supply	0.45	0.22
Support	0.45	0.22
Tanker	0.33	0.26
Tug	0.45	0.22
Vehicle Carrier	0.45	0.22
Well Stimulation	0.45	0.22

While the vessel is dockside, it was assumed that propulsion engines would not be operating and the auxiliary engines were operating at the loads noted in Table 15. For vessels equipped with C 1 and C2 propulsion engines it was assumed that neither the propulsion nor the auxiliary engines would be operating while dockside to conserve fuel. This version of the NEI also did not include activity or emissions associated with boilers used to generate steam or to run cargo handling equipment and pumps.

2.3 Emission Factors/ HAP Speciation Profiles

Vessels equipped with Category 3 propulsion engines

As the dominant propulsion engine configuration for large Category 3 vessels is the slow speed diesel (SSD) engine, the following SSD emission factors were used for Category 3 propulsion engines. Medium speed diesel (MSD) emission factors were used for auxiliary engines associated with these larger vessels. For the 2014 inventory, it was assumed that Emission Control Area (ECA) compliant fuels were used while transiting U.S. waters. Emission factors for vessels equipped with Category 3 propulsion engines are presented in Table 16.

Table 16: Category 3 Emission Factors (g/kW-hrs)

Type	Engine	Fuel	NO _x	VOC _a	HC	CO	SO ₂	CO ₂	PM ₁₀	PM _{2.5} ^b
SSD	Main	1% Sulfur	14.7	0.6318	0.6	1.4	3.62	588.86	0.45	0.42
MSD	Aux	1% Sulfur	12.1	0.4212	0.4	1.1	3.91	636.6	0.47	0.43

From: U.S. EPA/OTAQ, Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder, March 2008.

^a Hydrocarbon (HC) was converted to VOC using a conversion factor of 1.053 as provided in the above reference

^b PM_{2.5} was assumed to be 97 percent of PM₁₀ using the above reference

Note that this approach assumes that all large vessels will implement fuel switching before 2014 to comply with the 1% fuel sulfur standard, and use of controls such as scrubbing of high sulfur fuels, which is also an option to meet regulations, will be minimal.

If an engine load factor is less than 20 percent of the engine operating load, the emission factors were adjusted to account for operations outside the engines typical optimal load. For this 2014 inventory, these low load periods tend to occur during vessel movements in the RSZ. The low load adjustment factors used in this inventory were obtained from the EPA port guidance (US EPA 2009) and are provided in Table 17.

Table 17: Calculated Low Load Multiplicative Adjustment Factors

Load	NO _x	HC	CO	PM	SO ₂	CO ₂
1%	11.47	59.28	19.32	19.17	5.99	5.82
2%	4.63	21.18	9.68	7.29	3.36	3.28
3%	2.92	11.68	6.46	4.33	2.49	2.44
4%	2.21	7.71	4.86	3.09	2.05	2.01
5%	1.83	5.61	3.89	2.44	1.79	1.76
6%	1.60	4.35	3.25	2.04	1.61	1.59
7%	1.45	3.52	2.79	1.79	1.49	1.47
8%	1.35	2.95	2.45	1.61	1.39	1.38
9%	1.27	2.52	2.18	1.48	1.32	1.31
10%	1.22	2.20	1.96	1.38	1.26	1.25
11%	1.17	1.96	1.79	1.30	1.21	1.21
12%	1.14	1.76	1.64	1.24	1.18	1.17
13%	1.11	1.60	1.52	1.19	1.14	1.14
14%	1.08	1.47	1.41	1.15	1.11	1.11
15%	1.06	1.36	1.32	1.11	1.09	1.08
16%	1.05	1.26	1.24	1.08	1.07	1.06
17%	1.03	1.18	1.17	1.06	1.05	1.04
18%	1.02	1.11	1.11	1.04	1.03	1.03
19%	1.01	1.05	1.05	1.02	1.01	1.01
20%	1.00	1.00	1.00	1.00	1.00	1.00

Vessels equipped with Category 1 / Category 2 propulsion engine

Activity data for smaller vessels equipped with C1 and C2 engines are aggregated together, therefore Category 2 emission factors (Table 18) were used for these vessels as these factors tended to provide more conservative emission estimates.

Table 18: Tier Emission Factors for Vessels Equipped With Category 2 Propulsion Engines (g/kW-hrs)

Tier	PM ₁₀	NO _x	HC	CO	VOC ^a	PM _{2.5} ^b	SO ₂	CO ₂
0	0.32	13.36	0.134	2.48	0.141102	0.3104	0.006	648.16
1	0.32	10.55	0.134	2.48	0.141102	0.3104	0.006	648.16
2	0.32	8.33	0.134	2.00	0.141102	0.3104	0.006	648.16
3	0.11	5.97	0.07	2.00	0.073710	0.1067	0.006	648.16

From: U.S. EPA/OTAAQ, Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder, March 2008.

^a HC was converted to VOC using a conversion factor of 1.053 as provided in the above reference.

^b PM_{2.5} was assumed to be 97 percent of PM₁₀ using the above reference.

The Tier emission factors noted in Table 18 were weighted relative to the vessel type based on the year the vessel was manufactured. 19 shows the vessel age distribution by Tier.

Table 19: Vessel Tier Population By Type For Vessels Equipped With C1 or C2 Propulsion Engines

Trip Count	Vessel Count	Vessel Type	Total*	Tier Level				Percent Tier			
				0	1	2	3	0	1	2	3
5330	51	Bulk Carrier	51	46		5		90.2%	0.0%	9.8%	0.0%
932	23	Bulk Carrier, Laker	23	23				100.0%	0.0%	0.0%	0.0%
5	3	Buoy Tender	3	3				100.0%	0.0%	0.0%	0.0%
200	2	Container	2	2				100.0%	0.0%	0.0%	0.0%
2421	25	Containership	25	22	3			88.0%	12.0%	0.0%	0.0%
140767	426	Crewboat / Supply / Utility Vessel	425	298	37	87	3	70.1%	8.7%	20.5%	0.7%
7	5	Drilling	5	2		3		40.0%	0.0%	60.0%	0.0%
19026	13	Excursion / Sightseeing Vessel	13	12		1		92.3%	0.0%	7.7%	0.0%
276	45	Fishing	45	43	2			95.6%	4.4%	0.0%	0.0%
29660	153	General Cargo	152	93	11	48		61.2%	7.2%	31.6%	0.0%
8	2	Icebreaker	2	2				100.0%	0.0%	0.0%	0.0%
10	3	Jackup	3	2		1		66.7%	0.0%	33.3%	0.0%
8	2	LPG Tanker	2			2		0.0%	0.0%	100.0%	0.0%
247369	35	Misc.	33	28	2	3		84.8%	6.1%	9.1%	0.0%
749	26	Passenger	26	24	1	1		92.3%	3.8%	3.8%	0.0%
4666	18	Passenger Carrier	18	15	3			83.3%	16.7%	0.0%	0.0%
61	10	Pipelaying	10	10				100.0%	0.0%	0.0%	0.0%
344540	1626	Pushboat	1,625	1,348	43	214	20	83.0%	2.6%	13.2%	1.2%
63	12	Reefer	12	12				100.0%	0.0%	0.0%	0.0%
346	42	Research	42	35	1	6		83.3%	2.4%	14.3%	0.0%
1771	19	RORO	19	17	1	1		89.5%	5.3%	5.3%	0.0%
230	3	RO-RO Vessel	3	3				100.0%	0.0%	0.0%	0.0%
4778	243	Supply	243	126	31	86		51.9%	12.8%	35.4%	0.0%
808	66	Support	66	28	7	31		42.4%	10.6%	47.0%	0.0%

Table 19: Vessel Tier Population By Type For Vessels Equipped With C1 or C2 Propulsion Engines

Trip Count	Vessel Count	Vessel Type	Total*	Tier Level				Percent Tier			
				0	1	2	3	0	1	2	3
5553	102	Tanker	101	47	11	43		46.5%	10.9%	42.6%	0.0%
3962	336	Tug	336	286	13	35	2	85.1%	3.9%	10.4%	0.6%
142519	867	Tugboat	867	630	48	172	17	72.7%	5.5%	19.8%	2.0%
2	1	Well Stimulation	1	1				100.0%	0.0%	0.0%	0.0%
956067	4159	Total / Average Percent Tier	4,153	3158	214	739	42	76.0%	5.2%	17.8%	1.0%

Note this approach does not account for early introduction of controls by vessel operators, compliance with more stringent local standards, or participation in voluntary emission reduction programs such as California's Carl Moyer Program or the Texas Emission Reduction Plan (TERP).

Hazardous air pollutant emissions were estimated by applying speciation profiles (Appendix F) to the VOC estimates for organic HAPs and PM estimates for metal HAPs using the following equation:

$$E = A \times SF$$

Where:

- E = Annual emissions for HAP (tons)
- A = Annual emissions for speciation base (tons)
- SF = Speciation factor (unit less fraction)

Emission Summaries

Based on the approach documented above, Table 20 summarizes activity and emissions by vessel propulsion engine category and mode.

Table 20: 2014 Vessel Activity (kW-hrs) and Emissions (tons) by Propulsion Engine and Mode

Category	Source	SCC	Mode	Total Activity (kW-hr)	CO	CO ₂	NO _x	PM ₁₀ -PRI	PM ₂₅ -PRI	SO ₂	VOC
Cat1/2	E&C	2280002100	Maneuvering	742,228,543	125	61,923	1,179	44	40	333	39
Cat1/2	E&C	2280002200	Cruising	945,222,365	1,896	516,687	9,648	255	247	5	113
Cat1/2	Misc-C1/C2	2280002100	Maneuvering	4,086,763,051	2,178	583,975	11,316	285	276	5	126
Cat1/2	Misc-C1/C2	2280002200	Cruising	13,348,660,561	66,114	21,066,882	336,909	10,409	10,097	2,258	5,785
Cat1/2	WBD	2280002100	Maneuvering	2,090,680,129	1,112	298,746	5,754	147	143	3	65
Cat1/2	WBD	2280002200	Cruising	19,795,947,087	38,038	10,250,302	196,657	5,049	4,898	94	2,228

Table 20: 2014 Vessel Activity (kW-hrs) and Emissions (tons) by Propulsion Engine and Mode

Category	Source	SCC	Mode	Total Activity (kW-hr)	CO	CO ₂	NO _x	PM ₁₀ -PRI	PM ₂₅ -PRI	SO ₂	VOC
Cat3	E&C	2280003100	Dock	27,735,673,393	3,775	2,060,823	39,098	1,540	1,409	12,665	1,503
Cat3	E&C	2280003100	Maneuvering	7,217,499,394	618	286,003	6,568	216	200	1,758	267
Cat3	E&C	2280003200	Cruising	64,474,040,733	55,862	23,496,513	586,555	17,956	16,759	144,444	25,210
Cat3	E&C	2280003200	Reduced Speed Zone	7,055,981,077	2,629	891,303	22,034	713	666	5,492	1,319
Total				147,492,696,332	172,348	59,513,157	1,215,718	36,614	34,735	167,058	36,654

Note: Misc C1/C2 includes: Coast Guard, dredging, ferries, fishing, offshore oil & gas support, and research.

Table 21 also summaries emissions by vessel type.

Table 21: 2014 Vessel Activity (kW-hrs) and Emissions (tons) by Vessel Type

Vessel Type	Total Activity (kW-hr)	CO	CO ₂	NO _x	PM ₁₀ -PRI	PM ₂₅ -PRI	SO ₂	VOC
Bulk Carrier	16,502,188,704	11,855	4,539,374	108,528	3,278	3,070	23,396	4,264
Bulk Carrier, Laker	591,085,436	502	183,897	4,349	129	121	865	161
Buoy Tender	2,647,731	6	1,548	32	1	1	0	0
Coast Guard	2,150,964,635	4,881	1,275,547	26,292	630	611	12	278
Containership	53,193,329,151	23,199	9,236,172	220,943	6,808	6,359	50,912	9,048
Dredging	1,041,726,442	2,278	595,427	12,273	294	285	5	130
Excursion / Sightseeing Vessel	4,319,972	10	2,562	50	1	1	0	1
Ferries	5,641,357,376	6,307	1,694,863	32,678	825	800	16	365
Fishing	6,585,566,278	14,354	3,751,598	76,606	1,852	1,797	34	817
General Cargo	4,462,901,347	3,729	1,527,286	36,436	1,126	1,052	8,522	1,472
Misc	1,101,196,066	794	214,600	4,247	108	105	53	53
Offshore Oil & Gas*	669,380,168	37,117	13,443,080	182,540	6,653	6,454	2,188	4,128
Passenger	11,886,827,285	11,964	5,053,464	123,561	3,835	3,576	30,586	5,254
Reefer	1,082,375,467	930	400,149	9,645	303	282	2,425	406
Research	2,015,808,882	4,316	1,160,121	22,507	573	556	11	253
RO-RO	2,369,916,464	3,245	987,219	20,995	574	547	1,998	469
Tanker, Crude Oil	7,192,697,038	4,061	1,742,324	42,670	1,329	1,238	10,710	1,819
Tanker, LNG/LPG	1,461,972,434	1,268	540,689	13,291	412	384	3,314	567
Tanker, Misc	14,088,889,926	15,197	5,558,738	121,580	3,725	3,508	22,470	4,221
Tug	11,197,514,271	22,763	6,093,037	119,306	3,005	2,913	250	1,343
Vehicle Carrier	4,250,031,261	3,571	1,511,461	37,187	1,154	1,076	9,291	1,608
Total	147,492,696,332	172,348	59,513,157	1,215,718	36,614	34,735	167,058	36,654

* Note: Some Offshore Oil & Gas emissions were derived from the BOEM Emission Inventory which did not include activity data.

2.4 Allocation of Port and Underway Emissions

Ports and underway activity and emissions are summarized in Table 22. Note that in this version of the marine vessel component of the NEI, auxiliary emissions for underway operations were considered less significant than other modes and were not included in this version of the NEI marine vessel inventory, such that actual underway emissions may be slightly higher than the values presented in Table 22.

Table 22: 2014 Vessel Activity (kW-hrs) and Emissions (tons) by Propulsion Engine and in Port and Underway Modes

SCC Description	SCC	Total Activity (kW-hr)	CO	CO ₂	NO _x	PM ₁₀ -PRI	PM ₂₅ -PRI	SO ₂	VOC
Diesel Port Emissions	2280002100	6,919,671,722	3,416	944,645	18,250	476	459	341	230
Diesel Underway Emissions	2280002200	34,089,830,013	106,048	31,833,871	543,214	15,713	15,242	2,357	8,125
Residual Port Emissions	2280003100	34,953,172,787	4,393	2,346,825	45,666	1,756	1,609	14,423	1,770
Residual Underway Emissions	2280003200	71,530,021,810	58,491	24,387,816	608,589	18,669	17,425	149,936	26,529
Total		147,492,696,332	172,348	59,513,157	1,215,718	36,614	34,735	167,058	36,654

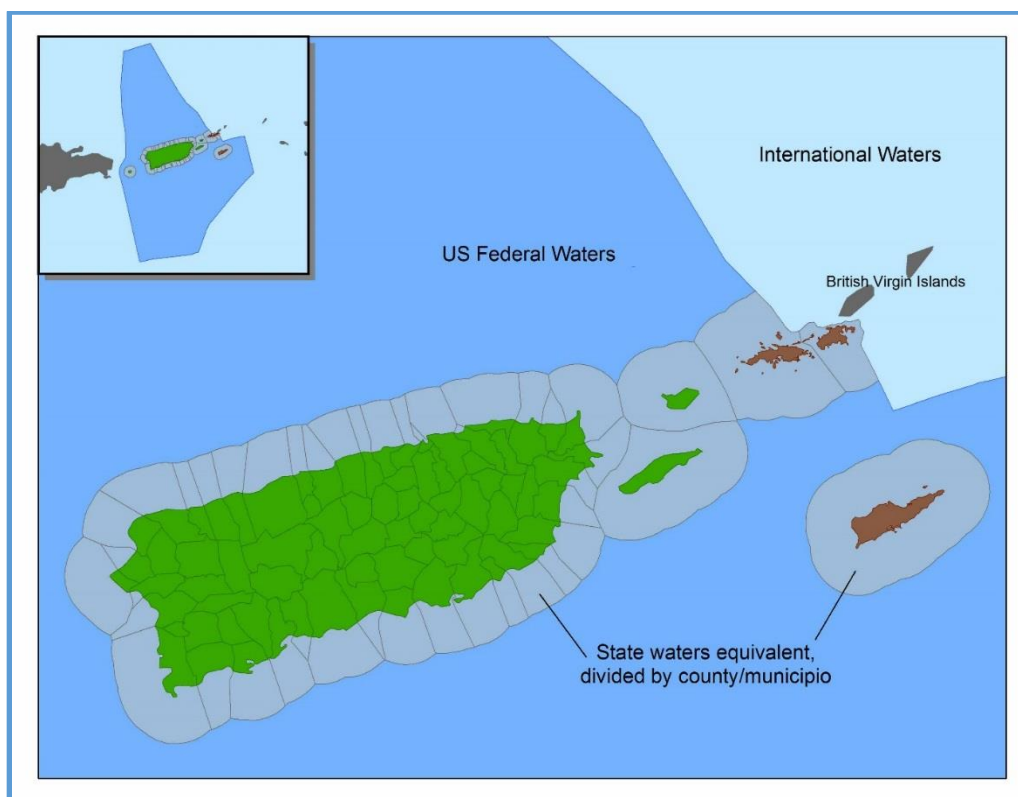
EPA has continued to develop and improve port shapes using a variety of resources. First, GIS data or maps provided directly from the ports were used to delineate port boundaries. Next, maps or port descriptions from local port authorities and port districts were used in combination with existing GIS data to identify port boundaries. Finally, satellite imagery from tools such as Google Earth and street layers from StreetMap USA were used to delineate port areas. Originally, primary emphasis was placed on mapping the 117 ports with C3 vessel activity using available shapefiles of the port area. As the availability of C1 and C2 activity improved, additional port shapes were required to represent their emissions. The NEI port shapefiles were revised to include 114 additional ports from the 2014 inventory. Further revisions over the years have increased the count of the current 5,649 port shapes for the 2014v1 inventory. 2014v2 revisions reduced the number of port shapes dramatically, to 915.

In all cases, port shapes were split by county boundary, such that no shape crosses county lines, to facilitate totaling of emissions to the state or county level. Each port shape was identified by the port name and state and county FIPS in addition to a unique Shape ID. For 2014v1, in most cases, port shapes were created on land bordering waterways and coastal areas. However, the additional port shapes created in this effort were generated as small circles with a radius of 0.25 miles that cover both land and water. Additionally, activity data such as Automatic Identification System (AIS) indicated that vessels frequently have maneuvering/hoteling activities further offshore than previously anticipated. As such, the underway shapes were

duplicated, given new IDs, and added to the port shapefile to provide a place to put these activities if state or local agencies wish to include them. For 2014, the port shapes were revised to remove shapes from on land and more accurately represent hoteling and maneuvering activities in the water near port terminals. The new port shapes were simplified and formatted to improve suitability for modeling. The duplicates of underway shapes were removed and those emissions placed in port shapes.

Underway shapes remain unchanged from 2011NEI, with the exception of new shapes added to represent state and federal waters around Puerto Rico and the U.S. Virgin Islands as shown in Figure 5.

Figure 5: New Underway Shapes for Puerto Rico and the U.S. Virgin Islands



Spatial allocation of the activity data varied by data source. Port activity was allocated to the origin and destination port shapes. E&C data and the WCD were routed along a waterway network, then the routes were intersected with EPA's shapefiles shipping lanes for NEI. For the E&C data, underway activity for each vessel trip was divided among the NEI shapes based on the portion of the route that passed through each shape. The length of the waterway segment passing through each shape was divided by the total trip length to calculate the percentage of the trip's activity to assign to each shape.

$$V = (L/T) * A$$

Where:

- V = Activity for shape V
- L = Length of waterway segment within shape V
- T = Total trip length
- A = Total trip activity

For WCD, hoteling and maneuvering activity was allocated to the nearest water-based port shapes for each origin and destination. For underway activity, the length of the waterway through each shape was calculated and multiplied by the number of trips in that shape. This value was divided by the national total for trips multiplied by length to determine the percentage of the national total activity to allocate to each shape.

$$P = (T * L)/(NT*NL)$$

Where:

- P = Percentage of national activity
- T = Total trips for the NEI underway shape
- L = Waterway segment length within underway shape
- NT = National trip total
- LN = National waterway network length total

Offshore oil and gas support vessel data derived from AIS data used by BOEM was limited to federal waters and was assigned to the associated shape, though the more refined activity can be seen in Figure 6. Research vessel activity was allocated to shapes based on the spatial allocation from the Category 1 and Category 2 Census (US EPA 2007). Dredging activities were spatially apportioned to ship channels based on the job name. The job names indicated general location, such as a bay area or a waterway portion; however, they did not provide sufficient information to precisely locate the dredging activities or even extent of the project. Best effort was given to identify the waterway segments in GIS that most closely match the limited location information. Ferry activity was split to 65% port and 35% underway, and all terminals were mapped using the coordinates available in the National Census of Ferry Operators (DOT 2014). Activity was then allocated to the port or underway shape nearest each ferry terminal. The underway spatial allocation can be seen in Figure 7. U.S. Coast Guard activity was provided by region, NEI shapes in each region were identified, and underway activity was allocated to individual shapes as a fraction of the total region's area as shown in Figure 8.

Figure 6: Spatial Allocation of 2014 Support Vessel Activity

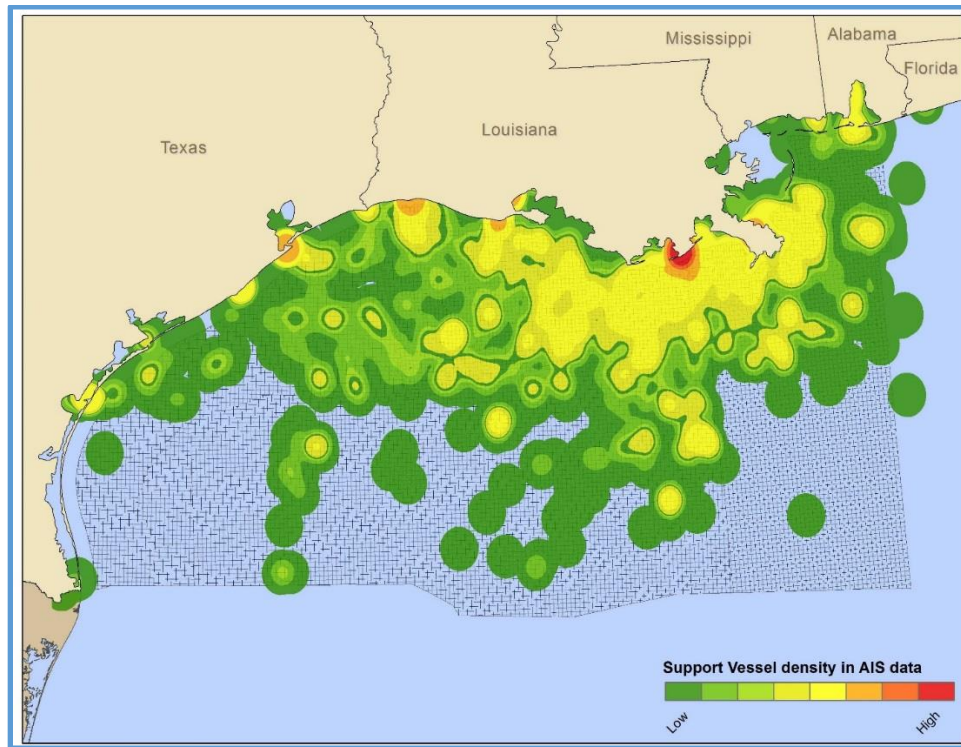


Figure 7: Spatial Allocation of 2014 Ferry Activity

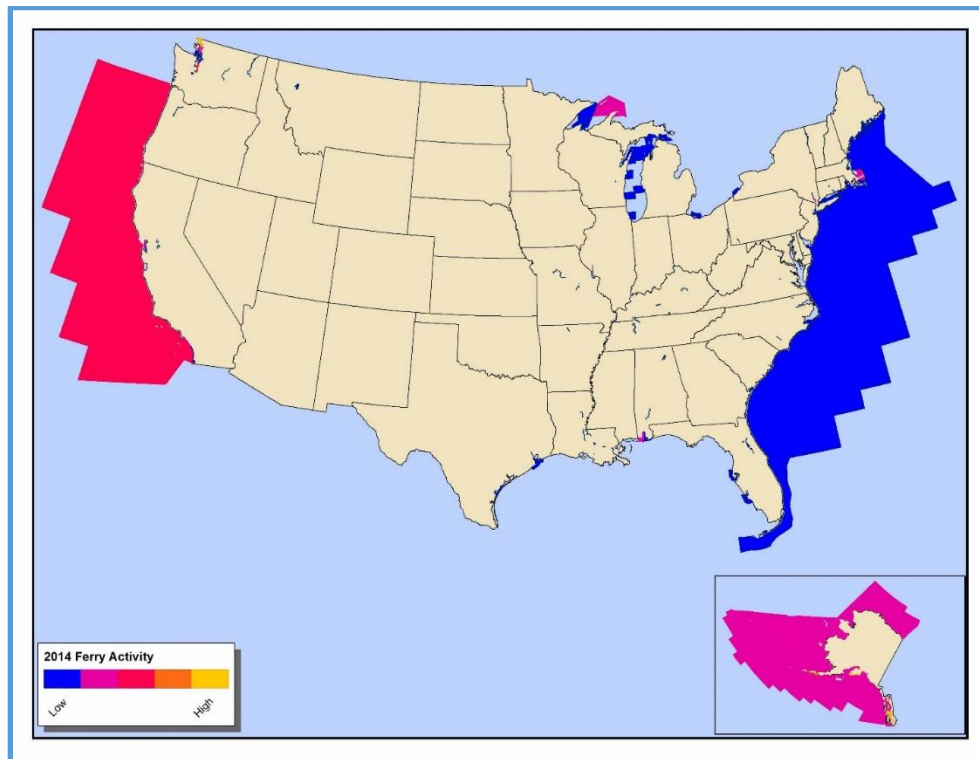
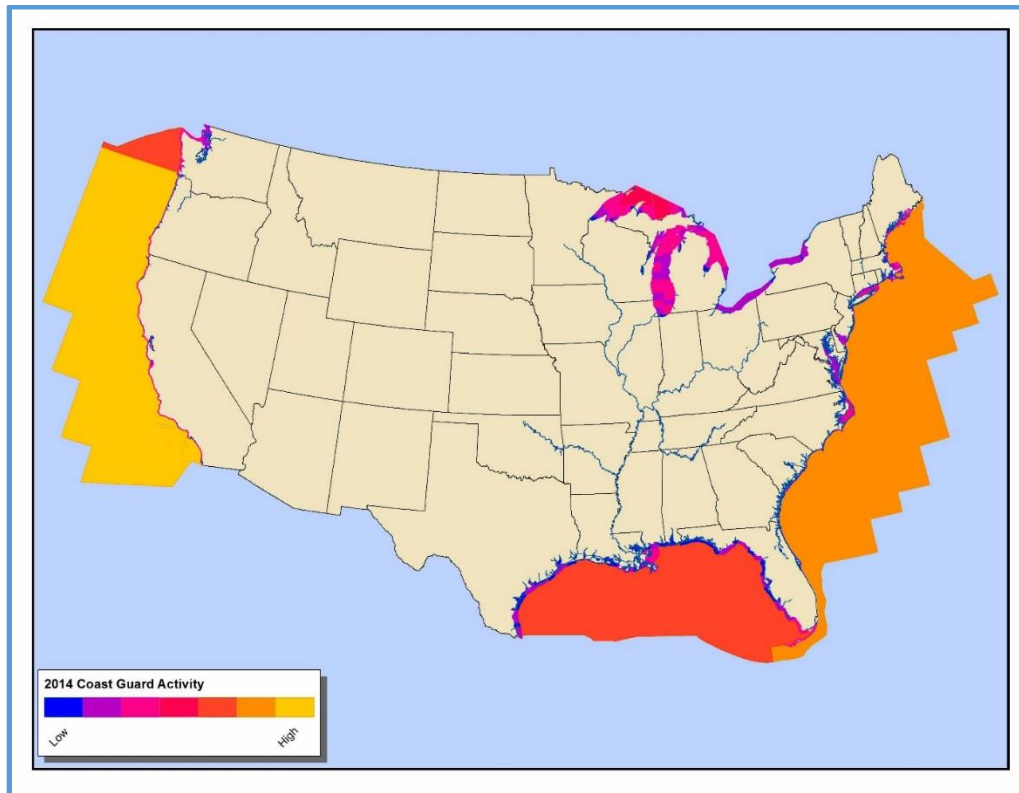


Figure 8: Spatial Allocation of 2014 Coast Guard Activity



Fishing vessel activity was spatially allocated using different methods based on available regional data. Alaska fishing activity was spatially apportioned based on NOAA data that listed the number of catcher vessels by region for the Aleutian Islands, Western Alaska, Central Gulf of Alaska, and Eastern Gulf of Alaska as shown in Table 23. The NEI shapes were assigned to these regions in GIS, and then emissions were spatially allocated by region based on shape area.

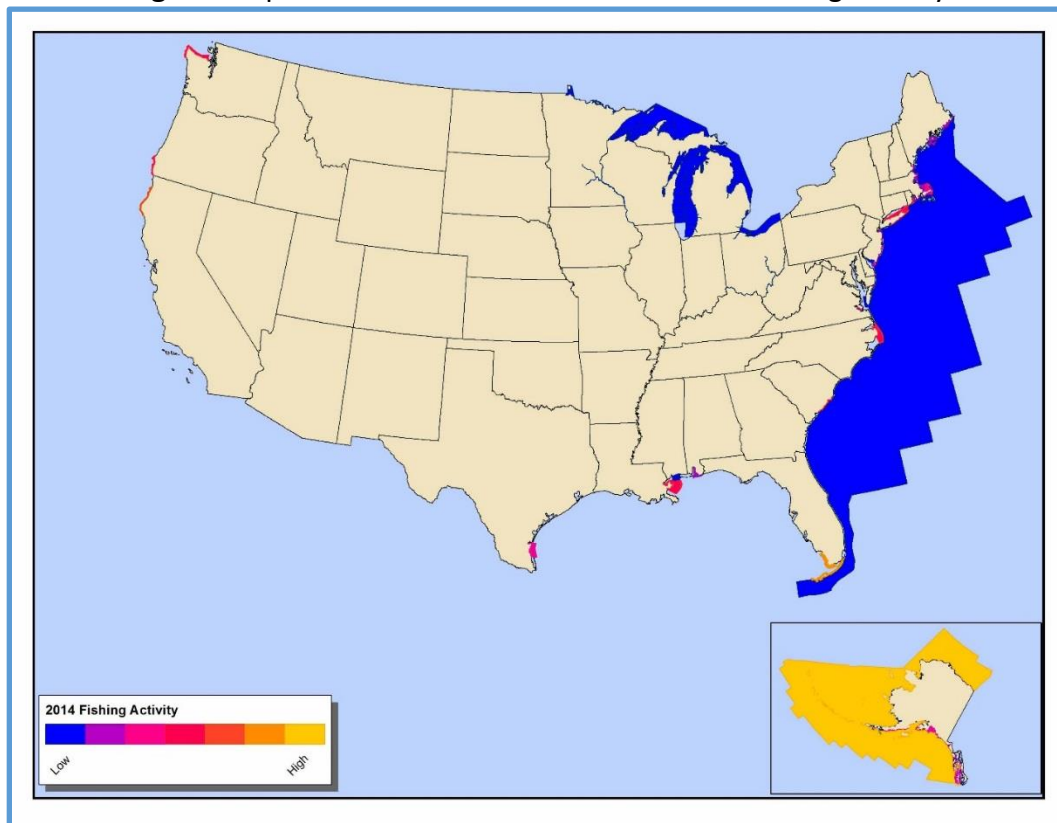
Table 23: Alaska Commercial Fishing Catcher Vessel Count

Area	Catcher Vessels	Percent
Aleutian Islands	494	0.23
Western Alaska	64	0.03
Central Gulf of Alaska	728	0.34
Eastern Gulf of Alaska	854	0.40

The Northeast NOAA data provided fishing activity by city or by state (NOAA 2015b). Cities were mapped, and activity values were assigned to the nearest port and underway shape ID. In some cases, the city name was unknown, so the activity was divided between other known ports

within that state proportionate to their activity values. For the southeast and the west coast, total activity was provided by state. Statewide activity was divided as 95% underway and 5% in-port and then allocated to shapes based on the previous fishing allocation in the Category 1 and Category 2 Census (US EPA 2007). The final fishing allocation can be seen in Figure 9.

Figure 9: Spatial Allocation of 2014 Commercial Fishing Activity



2.5 Summary of quality assurance methods

- While developing the EPA 2014 marine vessel inventory, data quality checks were implemented at critical points; this included comparison with earlier data sets used to develop the C1 and C2 inventory, published emission factors, and previous NEI emission estimates for all engine categories.
- All calculations were checked by experience staff members of the team.
- During data transfers into the project database, quality assurance checks were implemented and data summary tables generated to ensure that no corrupted data were transferred and the record count was consistent with the transfer.
- All assumptions were documented and discussed with team members to ensure that the assumptions were reasonable and consistent with other known data points.

- Microsoft Access data queries were documented and reviewed by experience staff who were not directly involved in developing the current databases.
- GIS imagery were reviewed to identify any spatial anomalies in the data.
- Where anomalies were found during these checks, additional research was implemented to determine whether the identified issue was correct or whether there was an error in developing the estimate.

EPA compared shape-, state-, and county-level sums in (1) EPA default data, (2) state/local/tribal (S/L/T) agency submittals, and (3) the resultant 2011 NEI selection by:

- Pollutants, SCCs, and SCC-emission types
- Emissions summed to agency and SCC level.

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Appendix A. Detailed Equations

As mentioned in the text the general equation for estimating emissions is noted in the following equation:

$$EF \left(\frac{g}{kWh} \right) \times \frac{D (NM)}{Vs \frac{NM}{hr}} \times LF \times Vp (kW) = \text{Emissions}$$

Where:

D = Distance along Segment, NM / C or RSZ Knots

Vs = 0.94 x maximum vessel speed = cruising speed or RSZ speed.

If vessel speed is unknown used typical speed by vessel type.

(D/Vs is used to estimate operating hours for E&C data and WC data – for C1/C2 study typical operating hours are used instead)

LF = Load Factor (fraction less than 1)

Vp = Vessel Power

Below are more detailed equations based on the actual data and their field names for the various transportation modes (cruising, RSZ, maneuvering, and hoteling).

Entrance and Clearance Emission Estimation:

Routes in the E&C were subdivided into cruising portions and RSZ portions. The data fields for cruising and RSZ are the same and the field names and descriptions are listed below in Table A-1.

Table A-1: Data Fields in Entrance and Clearance Data

Data Field	Description
RecordIDRaw	Internal tracking number
ECDATE	E&C dates
WHERE_IND	"D" or "F" for Domestic or Foreign trips
ERGVesselID	Internal vessel tracking number
ShipType	Standardized Vessel Type to link to Emission Factors
FromPortv2	Standardized Origin Port Name (Domestic) or Country (Foreign)
ToPortv2	Standardized Destination Port Name (Domestic) or Country (Foreign)
MainkW	Total kW for main engines
AuxkW	Total kW for auxiliary engines
CruiseSpeed(94%Max)Revised	Cruising Speed (knots), 94% of the max rated speed.*
CatLookup	Vessel Category to link to Emission Factors

Table A-1: Data Fields in Entrance and Clearance Data

Data Field	Description
RSZName	Reduced Speed Zone Name or "Cruising" if not in a RSZ
RSZ_Speed_kn	RSZ limit
SumOfLength_nm	Distance of route within U.S. water (nautical miles)

* Note: Cruise speed (CruiseSpeed(94%Max)Revised) was further adjusted for slow steaming (Bulk Carrier, Container, and Tankers). This information is listed below.

Bulk Carriers, containerships, and tankers slow steam (travel at slower speeds) to be more efficient. Therefore the cruising speed, which is 94% of the rated max speed) is further reduced multiplying the speed by the reduction factors in Appendix B.

The emission factor data field names and descriptions are summarized in Table A-2 below.

Table A-2: Emission Factor Data Fields

EF Data Field	Description
ShipType	Standardized Vessel Type to link to E&C data
RSZ_Speed_nm	Links to E&C data
Engine Type	Main or Auxiliary
Mode	RSZ or Cruising
CatLookup	Vessel Category to link to E&C data
Pollutant	Pollutant name
EF-g/kwhr	Emission Factor in g/kW-hr

Entrance and Clearance Cruising:

Emissions are calculated for main engines only for cruising. Using the detailed equation and the data field names from the E&C data and the emission factor table, the following criteria and equation are used.

Cruising Criteria

- E&C RSZName = "Cruising"
- EF Mode = "RSZ"
- EF Engine Type = "Main"

Cruising Linkage

- ShipType
- CatLookup
- RSZ_Speed_nm

Cruising Emission Equation

$$EM = \text{SumofLength_nm} / \text{CruiseSpeed}(94\%\text{Max})\text{Revised} * \text{MainkW} * \text{EF-g/kWhr}$$

Entrance and Clearance RSZ:

Emissions are calculated for main engines only for RSZ. Using the detailed equation and the data field names from the E&C data and the emission factor table, the following criteria, linkages, and equation are used. It should be noted that there is an IF statement for the speed based on the fact that if the vessel's cruising speed is already lower than the RSZ speed limit the vessel would not accelerate to the speed limit but stay at the already lower speed.

RSZ Criteria

- E&C RSZName <> "Cruising"
- EF Mode = "Cruising"
- EF Engine Type = "Main"
- IF (CruiseSpeed(94%Max)Revised < RSZ_Speed_kn,
 - then CruiseSpeed(94%Max)Revised
 - otherwise RSZ_Speed_kn

RSZ Linkage

- ShipType
- CatLookup
- RSZ

RSZ Emission Equation

$$EM = \text{SumofLength_nm} / \text{IF}(\text{CruiseSpeed}(94\%\text{Max})\text{Revised} < \text{RSZ_Speed_kn}, \text{then CruiseSpeed}(94\%\text{Max})\text{Revised}, \text{otherwise RSZ_Speed_kn}) * \text{MainkW} * \text{EF-g/kWhr}$$

Entrance and Clearance Maneuvering:

Emissions are calculated for both main and auxiliary engines for maneuvering. Using the detailed equation and the data field names from the Port E&C data and the emission factor table, the following criteria, linkages, and equation are used. The data fields in the Port E&C for maneuvering are summarized in Table A-3.

Table A-3: Port Entrance and Clearance Data Fields for Maneuvering

Port E and C Data Field	Description
Port	Standardized US Ports
ERGVesselType	Standardized Vessel Type to link to Emission Factors

Table A-3: Port Entrance and Clearance Data Fields for Maneuvering

Port E and C Data Field	Description
Count	Trip Count to Port
ERGVesselID	Internal vessel tracking number
MainkW	Total kW for main engines
AuxkW	Total kW for auxiliary engines
CatLookup	Vessel Category to link to Emission Factors
Maneuvering Time (hours)	Maneuvering Time by Port and Type Divided by 2 to correct for the change from routes (lines) to ports (points)
TotalMainkW-hrs	Main kW * maneuvering time * Count
TotalAuxkW-hrs	AuxkW*maneuvering time * Count

Maneuvering Criteria

- EF Mode = “Man”
- EF Engine Type = IF(Engine Type = “Main”
 - Then, kW-hrs = MainkW* Maneuvering Time,
 - Otherwise, kW-hrs = AuxkW*Maneuvering Time (where Engine Type = “Aux”)

Maneuvering Linkage

- ShipType
- CatLookup
- Engine Type

Maneuvering Emission Equation

EM = If Engine Type = “Main”

- Then, MainkW-hrs* EF-g/kW hr,
- Otherwise AuxkW-hrs * EF-g/kW hr (where Engine Type = “Aux”)

Entrance and Clearance Hoteling:

Emissions are calculated for auxiliary engines only for maneuvering and Hoteling, which is when their operations are assumed to be the most significant. Using the detailed equation and the data field names from the Port E&C data and the emission factor table, the following criteria, linkages, and equation are used. The data fields in the Port E&C for hoteling are summarized in Table A-4.

Table A-4: Port Entrance and Clearance Data Fields for Hoteling

Port E and C Data Field	Description
Port	Standardized US Ports
ERGVesselType	Standardized Vessel Type to link to Emission Factors
Count	Trip Count to Port
ERGVesselID	Internal vessel tracking number
AuxkW	Total kW for auxiliary engines
CatLookup	Vessel Category to link to Emission Factors
Hours Time (hours)	Hoteling Time by Port and Type Divided by 2 to correct for the change from routes (lines) to ports (points)
TotalAuxkW-hrs	AuxkW*maneuvering time * Count

Hoteling Criteria

- EF Mode = “Man”
- EF Engine Type = “Aux”

Hoteling Linkage

- ShipType
- CatLookup
- Engine Type

Hoteling Emission Equation

$$EM = \text{AuxkW-hrs} * EF\text{-g/kWwhr}$$

Waterborne Commerce Cruising:

Emissions are calculated for main engines only for cruising. Using the detailed equation and the data field names from the E&C data and the emission factor table, the following criteria and equation are used. The data fields in the U.S. WCD for cruising are summarized in Table A-5.

Table A-5: U.S. WCD for Cruising Data Fields

U.S. ACE Data Field	Description
VESSEL	Internal tracking number
ERGVesselType	Pushboat
StandardVesselType	Standardized Vessel Type to link to Emission Factors
HORSEPOWER	Main Horsepower
UniqueRouteID	Internal Route ID for tracking purposes
Origin	Standardized Origin Port

Table A-5: U.S. WCD for Cruising Data Fields

U.S. ACE Data Field	Description
Destination	Standardized Destination Port
TRIP_MILES	Total Distance of Trip (nm)
SumOfTRIPS	Total Sum of Trip Counts
Speed(knots)	94% of Average Max speed (knots)
Time(hr)	Total time (TRIP_MILES/ Speed(knots))
Percent	Percent of distance in US Waters

Cruising Criteria

- EF Mode = “Cruising”
- EF Category = “Cat1/2”

Cruising Linkage

- StandardVesselType

Cruising Emission Equation

$EM = TRIP_MILES / Speed(knots) * SUMOfTRIPS * Percent * HORSEPOWER * HP\ to\ kW\ conversion\ factor * EF-g/kWhr$

Waterborne Commerce Maneuvering:

Emissions are calculated for main engines only for cruising. Using the detailed equation and the data field names from the E&C data and the emission factor table, the following criteria and equation are used. The data fields in the WCD for cruising are summarized in Table A-6.

Table A-6: U.S. WCD for Maneuvering Data Fields

WCD Data Field	Description
VESSEL	Internal tracking number
ERGVesselType	Pushboat
StandardVesselType	Standardized Vessel Type to link to Emission Factors
HORSEPOWER	Main Horsepower
MaxOfUniqueRouteID	Internal Route ID for tracking purposes
Port	Standardized Port Name
Source	“Origin” or “Destination” Port
SumOfTRIPS	Total Sum of Trip Counts
Time(hr)	0.5 default for maneuvering

Maneuvering Criteria

- EF Mode = "Man"
- EF Category = "Cat1/2"

Maneuvering Linkage

- StandardVesselType

Maneuvering Emission Equation

$$EM = 0.5 \text{ hours} * \text{SumofTRIPS} * \text{HORSEPOWER} * \text{HP to kW conversion factor} * \text{EF-g/kWhr}$$

Misc. C1 and C2 Vessels:

For all other C1 and C2 vessels not included in the E&C data or the Waterborne Commerce were calculated together. Vessel data were aggregated by type. The kW-hrs were summed together and the emission factors were applied to the kW-hrs. Emission factors were linked by vessel category and StandardVesselType.

$$EM = \text{kW-hrs} * \text{EF (g/kW-hrs)}$$

Appendix B. Reduced Speed Zone

Table B-1: Segments and RSZs Based on Summary of EPA
Regulatory Impact Assessment for Category 3 Vessels

Port Name	RSZ Distance (NM)	RSZ Speed (knots)
Palm Beach, FL	3.1	3
Lake Charles, LA	38	6
Coos Bay, OR	13	6.5
Beaumont, TX	53.5	7
Port Arthur, TX	21	7
Matagorda Ship	24	7.3
Everglades, FL	2.1	7.5
Brownsville, TX	18.7	8.8
Manatee, FL	27.4	9
Tampa, FL	30	9
Fall River, MA	22.7	9
Providence, RI	24.9	9
Searsport, ME	22.2	9
New Bedford/Fairhaven, MA	22.4	9
Kalama, WA	68.2	9.25
Longview, WA	67.3	9.25
Vancouver, WA	95.7	9.25
Portland, OR	105.1	9.25
Barbers Point, HI	5.1	10
Honolulu, HI	10	10
Valdez, AK	27.2	10
Hilo, HI	7.1	10
Kahului, HI	7.5	10
Nawiliwili, HI	7.3	10
Gulfport, MS	17.4	10
Panama City, FL	10	10
Pascagoula, MS	17.5	10
New Orleans, LA	104.2	10
Baton Rouge, LA	219.8	10
South Louisiana, LA	142.8	10
Plaquemines, LA	52.4	10
Portland, ME	11.4	10
Hopewell, VA	91.8	10
Morehead City, NC	2.2	10

**Table B-1: Segments and RSZs Based on Summary of EPA
Regulatory Impact Assessment for Category 3 Vessels**

Port Name	RSZ Distance (NM)	RSZ Speed (knots)
Canaveral, FL	4.4	10
New Haven, CT	2.1	10
Bridgeport, CT	2	10
Wilmington, NC	27.6	10
Richmond, VA	106.4	10
Jacksonville, FL	18.6	10
Boston, MA	14.3	10
Mobile, AL	36.1	11
Pensacola, FL	12.7	12
Georgetown, SC	17.6	12
Charleston, SC	17.3	12
Miami, FL	3.8	12
Catalina, CA	11.9	12
Carquinez, CA	39	12
El Segundo, CA	23.3	12
Eureka, CA	9	12
Hueneme, CA	2.8	12
Long Beach, CA	18.1	12
Los Angeles, CA	20.6	12
Oakland, CA	18.4	12
Redwood City, CA	36	12
Richmond, CA	22.6	12
Sacramento, CA	90.5	12
San Diego, CA	11.7	12
San Francisco, CA	14.4	12
Stockton, CA	86.9	12
Brunswick, GA	38.8	13
Savannah, GA	45.5	13
Newport News, VA	24.3	14
Anchorage, AK	143.6	14.5
Nikishka, AK	90.7	14.5
Anacortes, WA	108.3	unknown
Everett, WA	123.3	unknown
Grays Harbor, WA	4.9	unknown
Olympia, WA	185.9	unknown
Port Angeles, WA	65	unknown
Seattle, WA	133.3	unknown

**Table B-1: Segments and RSZs Based on Summary of EPA
Regulatory Impact Assessment for Category 3 Vessels**

Port Name	RSZ Distance (NM)	RSZ Speed (knots)
Tacoma, WA	150.5	unknown
Other Puget Sound	106	unknown
Freeport, TX	2.6	unknown
Galveston, TX	9.3	unknown
Houston, TX	49.6	unknown
Texas City, TX	15.1	unknown
Albany, NY	142.5	unknown
New York/New Jersey	15.7	unknown
Marcus Hook, PA	94.7	unknown
Paulsboro, NJ	83.5	unknown
Chester, PA	78.2	unknown
New Castle, DE	60.5	unknown
Penn Manor, PA	114.5	unknown
Camden, NJ	94	unknown
Philadelphia, PA	88.1	unknown
Wilmington, DE	65.3	unknown
Baltimore, MD	157.1	unknown
Corpus Christi, TX	30.1	unknown

Appendix C. Dredging Activities

Table C-1: 2014 Dredging Activities

Job Name	Dredge Type	Operating Days
La Pointe, WI	bucket or mechanical	13
Raritan River-Arthur Kill	bucket or mechanical	39
Raritan River, NJ	bucket or mechanical	55
NYNJ Chan-Perth Amboy	bucket or mechanical	70
Matoc Ybor Channel/Sparkman	bucket or mechanical	61
Great Kills Harbor, NY	bucket or mechanical	94
Bayridge & Redhook Channel	bucket or mechanical	89
Baltimore Harbor and Channel	bucket or mechanical	87
MOTSU/WH/Mid-river	bucket or mechanical	33
S-SR-2	bucket or mechanical	245
Wethersfield Cove	bucket or mechanical	59
Buttermilk Bay, MA	bucket or mechanical	31
Manitowoc, WI (W/ Kewaunee)	bucket or mechanical	36
WIN / RCB Lower Approaches	bucket or mechanical	9
Big Sandy Harbor	bucket or mechanical	55
St Lucie Inlet O&M	bucket or mechanical	51
Kewaunee, WI (w/ Manitowoc)	bucket or mechanical	36
The Dalles Shoal Removal	bucket or mechanical	2
Oakland Harbor (Inner & Outer)	bucket or mechanical	9
FY14 Swinomish Channel	bucket or mechanical	35
Lower Col River Clamshell	bucket or mechanical	97
Seattle Harbor	bucket or mechanical	32
South Coast Clamshell Maint.	bucket or mechanical	81
Waukegan Harbor	bucket or mechanical	263
Point Lookout, MI - SOM	bucket or mechanical	107
Oakland Harbor (Inner & Outer)	bucket or mechanical	153
Matoc Kings Bay EC O&M	hopper	20
Calcasieu Bar HDR 1-13	hopper	255
Wilm Hbr Outer Ocean Bar	hopper	37
SNWW Outer Bar and Bank	hopper	69
Anchorage 2012-2014	hopper	184
Hudson River, NY (Germantown)	hopper	324
Asbury Park-Avon, NJ (3b)	hopper	97
Matoc Ft Pierce O&M TO ODMS	hopper	20
Brevard CO SPP	hopper	112
BIH-Jetty Ch (Rapid Response)	hopper	19
FY14 Chas Entrance Channel	hopper	43

Table C-1: 2014 Dredging Activities

Job Name	Dredge Type	Operating Days
Galveston Hrbr-Ent Ch/Redfish	hopper	248
Miss Riv SWP HDR 1-14	hopper	92
Dade Co. BEC, Contract G	hopper	41
Hudson River (NYC-Albany)	hopper	51
West Coast Regional Hopper	hopper	166
SH & BH Entr Channel	hopper	148
Port Orford Hoist	non-conventional (specialty) type	135
Manasquan Inlet, NJ	non-conventional (specialty) type	203
West of Shinnecock Inl	pipeline (cutterhead)	12
Rockaway, NY (1B)	pipeline (cutterhead)	175
Jones Inlet, NY	pipeline (cutterhead)	43
Sav & Bruns Inner Harbor	pipeline (cutterhead)	55
AIWW Inlet Crossing	pipeline (cutterhead)	80
Anna/Gasp/Manatee/Lee Co	pipeline (cutterhead)	60
Joint Base Chas. & TC Dock	pipeline (cutterhead)	27
Shem Creek & Anchorage Basin	pipeline (cutterhead)	177
Detroit River, MI	pipeline (cutterhead)	113
Lexington, MI - SOM	pipeline (cutterhead)	30
BIH-Brownsville Ship CH	pipeline (cutterhead)	20
Barbours Terminal Mn Ch & TB	pipeline (cutterhead)	8
Matoc KBIC AND USMC	pipeline (cutterhead)	161
SNWW-Neches River	pipeline (cutterhead)	252
Fire Isl to Jones Inl	pipeline (cutterhead)	38
FT Pierce Inlet O&M	pipeline (cutterhead)	25
IWW Jupit/Bakers O&M	pipeline (cutterhead)	59
Mayport Naval Base O&M	pipeline (cutterhead)	30
PB Boca/DelRay/OR	pipeline (cutterhead)	105
Pinellas Co Ti - Lk	pipeline (cutterhead)	49
Old River-Outflow Channels	pipeline (cutterhead)	9
GIWW-High Island to Bolivar	pipeline (cutterhead)	42
James R - Jordan PT TO#3	pipeline (cutterhead)	24
CC Inner Basn-Viola-LaQuinta	pipeline (cutterhead)	80
Noh & Var Bsar Chann 3-14	pipeline (cutterhead)	52
Noh Hou Laf Bap Cdr 2-14	pipeline (cutterhead)	240
LI Intracoastal, NY	pipeline (cutterhead)	350
Mattituck Harbor, NY	pipeline (cutterhead)	68
Miss Riv Swp Cdr 1-2014	pipeline (cutterhead)	286

Table C-1: 2014 Dredging Activities

Job Name	Dredge Type	Operating Days
James R - Dancing PT TO#3	pipeline (cutterhead)	39
E & W Calumet Floodgates	pipeline (cutterhead)	12
Sav and Bruns Inner Harbor	pipeline (cutterhead)	315
Tybee Island Beach Renourish	pipeline (cutterhead)	86
Morehead City Harbor Rng A-B	pipeline (cutterhead)	41
NC Hwy Protection Project	pipeline (cutterhead)	51
Wilm Hbr Anchorage Basin	pipeline (cutterhead)	35
Wrig'sville B, OIB Coast SDR	pipeline (cutterhead)	90
Shrewsbury River, NJ	pipeline (cutterhead)	22
Chnl To Victoria Lower Reach	pipeline (cutterhead)	71
HOMER 2012-2016	pipeline (cutterhead)	9
NINILCHIK 2012-2016	pipeline (cutterhead)	7
Nome Harbor 2013-2017	pipeline (cutterhead)	37
FY14 USCG Tradd Street Pier	pipeline (cutterhead)	14
Grand Haven (Outer) W/Hollan	pipeline (cutterhead)	30
Holland (Outer) W/Grand Hav	pipeline (cutterhead)	21
Miss Riv SWP CDR 2-14	pipeline (cutterhead)	49
Leland, MI	pipeline (cutterhead)	9
Dillingham 2014-2016	pipeline (cutterhead)	22
GIWW Corpus to Port Isabel	pipeline (cutterhead)	98
GIWW Turnstake to Live Oak	pipeline (cutterhead)	123
HSC Bayprt Flare-HSC Redfish	pipeline (cutterhead)	146
Bayou Coden 24 inch TO2	pipeline (cutterhead)	13
Atch Riv & Bay Ch, BF, & BLK	pipeline (cutterhead)	99
Atch Riv Crew Boat Cy Cut	pipeline (cutterhead)	20
Calcasieu MI 5-17/Dev'l's EB	pipeline (cutterhead)	101
Westhampton Interim NY	undefined	55

Appendix D. Research Vessels

Table D-1: Research Vessel Engine Characteristics

Ship Name	Main Engine kW	Online Source
A.E. Verril	235	http://tidings.disl.org/pastissues/vol15_no3_2004/
Acadiana	650	http://lumconvessels.com/rv-acadiana
Agassiz	200	http://www.mtu.edu/greatlakes/fleet/agassiz/emergency/
Alaska Region Research Vessel (ARRV)	2,237	http://www.marinettemarine.com/data%20sheets/ARRV_WebReady2011.pdf
Alguita	56	http://www.researchvessels.org/ship_info_display.asp?shipID=477#Engineering
Annika Marie	455	http://www.researchvessels.org/ship_info_display.asp?shipID=769#Engineering
Apalachee	559	https://www.deere.com/en_US/products/engines_and_drivetrain/marine/propulsion_certified/6135_Series/6135SFM85_A.page
Aquaonitor	581	http://www.researchvessels.org/ship_info_display.asp?shipID=987
Aquarius (GLCBSC)	1,069	http://www.ship-technology.com/projects/aquarius-g-seismic-research-support-vessel/
Aquarius (U)	1,387	http://www.researchvessels.org/ship_info_display.asp?shipID=215
Arabella	522	http://marine.rutgers.edu/rumfs/MarineOps/MaropsArabella.htm
Barney Devine	175	http://dnr.wi.gov/topic/fishing/lakemichigan/BarneyDevine.html
Bellows	400	http://www.marine.usf.edu/geoweb/bell.html
Calanus	180	http://www.researchvessels.org/ship_info_display.asp?shipID=150
Cape Fear	403	http://www.researchvessels.org/ship_info_display.asp?shipID=748#Engineering
Capricorn	492	http://marine.unh.edu/specifications-and-drawings
Centennial	425	http://depts.washington.edu/fhl/fac_RVCentennialSpecifics.html#vesSpecs
Challenger	492	http://marine.unh.edu/specifications-and-drawings
Channel Cat	313	http://www.researchvessels.org/ship_info_display.asp?shipID=805#Engineering
Chinook	172	http://michigan.gov/documents/dnr/RV-FactSheet_454641_7.pdf
Clifford A. Barnes	298	http://www.researchvessels.org/ship_info_display.asp?shipID=76#Engineering
Coastal Surveyor	200	http://ccom.unh.edu/facilities/research-vessels/rv-coastal-surveyor
Connecticut	213	http://www.researchvessels.org/ship_info_display.asp?shipID=515#Engineering
Coral Sea	373	http://www.researchvessels.org/ship_info_display.asp?shipID=925#Engineering
Corwith Craer	373	http://www.researchvessels.org/ship_info_display.asp?shipID=224#Engineering
D. J. Angus	86	http://www.gvsu.edu/wri/education/dj-angus-24.htm
David Starr Jordan	1,068	http://www.researchvessels.org/ship_info_display.asp?shipID=87#Engineering
Delphinus	238	http://www.researchvessels.org/ship_info_display.asp?shipID=68#Engineering
Derek M. Baylis	100	http://www.researchvessels.org/ship_info_display.asp?shipID=971#Engineering
Dolphin (USS)	317	http://www.researchvessels.org/ship_info_display.asp?shipID=704#Engineering
Donald W. Pritchard	186	http://www.researchvessels.org/ship_info_display.asp?shipID=707#Engineering
Elakha	224	http://www.researchvessels.org/ship_info_display.asp?shipID=503#Engineering

Table D-1: Research Vessel Engine Characteristics

Ship Name	Main Engine kW	Online Source
elosira	2,144	http://www.researchvessels.org/ship_info_display.asp?shipID=122#Engineering
Explorer U.S.	168	http://www.researchvessels.org/ship_info_display.asp?shipID=230#Engineering
Fauna	138	http://www.researchvessels.org/ship_info_display.asp?shipID=955#Engineering
Fay Slover	522	http://www.researchvessels.org/ship_info_display.asp?shipID=953#Engineering
Flip (Floating Platform)	300	http://www.ship-technology.com/projects/flip-ship/
Flora	93	http://www.researchvessels.org/ship_info_display.asp?shipID=956#Engineering
Forerunner	242	http://www.researchvessels.org/ship_info_display.asp?shipID=234#Engineering
GS-1	216	http://www.researchvessels.org/ship_info_display.asp?shipID=817#Engineering
Gulf Challenger	447	http://www.researchvessels.org/ship_info_display.asp?shipID=700#Engineering
Hayes (USNS)	2,699	http://www.researchvessels.org/ship_info_display.asp?shipID=881#Engineering
Henry Stoel	172	http://www.researchvessels.org/ship_info_display.asp?shipID=744#Engineering
Independence	895	http://www.researchvessels.org/ship_info_display.asp?shipID=469#Engineering
Ira C	380	http://dmc.umaine.edu/facilities/research-vessels/
J.E. Henderson	82	http://www.apl.washington.edu/about/vessels.php
J.H. Martin	969	http://www.researchvessels.org/ship_info_display.asp?shipID=791#Engineering
John M. Kingsbury	109	http://www.researchvessels.org/ship_info_display.asp?shipID=960#Engineering
John B. Heiser	313	http://www.researchvessels.org/ship_info_display.asp?shipID=961#Engineering
John H. Martin	969	https://marineops.mlml.calstate.edu/JM-Specs
John N. Cobb	328	http://www.oldtacomamarine.com/fairbanks/johnncobb.html
Kaho	291	http://www.researchvessels.org/ship_info_display.asp?shipID=828#Engineering
Karluk	318	http://walrus.wr.usgs.gov/infobank/programs/html/karluk/specs.html
Katy	238	https://utmsi.utexas.edu/research/research-vessels
Kerhin	38	http://mddnr.chesapeakebay.net/eyesonthebay/documents/KerhinFlyer.pdf
Kila	544	http://www.researchvessels.org/ship_info_display.asp?shipID=245#Engineering
Laidly	485	http://www.researchvessels.org/ship_info_display.asp?shipID=781#Engineering
Lake Explorer II	317	http://www.researchvessels.org/ship_info_display.asp?shipID=990#Engineering
Langley	130	http://www.researchvessels.org/ship_info_display.asp?shipID=788#Engineering
Laurentian	254	http://www.researchvessels.org/ship_info_display.asp?shipID=134
NAVAIR Acoustic Pioneer	895	http://www.researchvessels.org/ship_info_display.asp?shipID=492#Engineering
NAVAIR-03	500	http://www.researchvessels.org/ship_info_display.asp?shipID=493#Engineering
Neeskay	254	http://home.freshwater.uwm.edu/neeskay/specifications/
Neil Armstrong	3,952	http://www.who.edu/main/ships/neil-armstrong/specifications
Noodin	11	http://www.d.umn.edu/~bann0036/LLO/facilities/noodin.html
Nucella	149	http://www.researchvessels.org/ship_info_display.asp?shipID=940#Engineering
Odyssey (WCI)	163	http://www.researchvessels.org/ship_info_display.asp?shipID=850#Engineering
Odyssey Explorer	2,075	http://www.researchvessels.org/ship_info_display.asp?shipID=714#Engineering
Osprey	320	http://www.mtu.edu/greatlakes/fleet/osprey/

Table D-1: Research Vessel Engine Characteristics

Ship Name	Main Engine kW	Online Source
Outer Limits	373	http://www.researchvessels.org/ship_info_display.asp?shipID=978#Engineering
Palmetto	373	http://www.dnr.sc.gov/marine/mrri/vessels/palmetto.html
Parke Snavelly	231	http://walrus.wr.usgs.gov/mapping/Snavely.html
Perca (WDNR)	261	http://www.researchvessels.org/ship_info_display.asp?shipID=845#Engineering
Peter W. Anderson	1,081	http://www.researchvessels.org/ship_info_display.asp?shipID=214#Engineering
Point Lobos	895	http://www.mbari.org/dmo/vessels_vehicles/Point_Lobos/ptlobos.html
Polar Star	51,714	http://www.uscg.mil/pacarea/cgcpolarstar/history.asp
Pride of Michigan	1,014	http://www.researchvessels.org/ship_info_display.asp?shipID=849#Engineering
Pugettia	97	http://www.researchvessels.org/ship_info_display.asp?shipID=950#Engineering
Rafeal	298	http://www.researchvessels.org/ship_info_display.asp?shipID=926#Engineering
Retriever	20	http://www.shanarae.com/retriever.html
Robert C Seamans	339	http://www.researchvessels.org/ship_info_display.asp?shipID=695#Engineering
Robert Gordon Sproul	503	https://scripps.ucsd.edu/ships/sproul/specifications
Sally Ride	1,733	http://shipsked.ucsd.edu/Ships/AGOR28/AGOR28-Specs.pdf
Sea World UCLA	50	http://www.msc.ucla.edu/Sea_World/sea_world_specifications.html
Seahawk	168	http://www.researchvessels.org/ship_info_display.asp?shipID=946#Engineering
Seawatch	686	http://www.researchvessels.org/ship_info_display.asp?shipID=83#Engineering
Seth Green	175	http://www.researchvessels.org/ship_info_display.asp?shipID=912#Engineering
Seward Johnson	634	http://www.researchvessels.org/ship_info_display.asp?shipID=13#Engineering
Seward Johnson II	701	http://www.researchvessels.org/ship_info_display.asp?shipID=460#Engineering
Shana Rae	261	http://www.researchvessels.org/ship_info_display.asp?shipID=22#Engineering
Sheila B.	224	https://marineops.mlml.calstate.edu/SB-Specs
Silversides	101	http://www.researchvessels.org/ship_info_display.asp?shipID=941#Engineering
State of Maine T.V.	6,000	http://www.researchvessels.org/ship_info_display.asp?shipID=189#Engineering
State of Michigan	5,350	https://www.nmc.edu/maritime/about/ts-state-mich-specifications.html
Stephan	5,517	http://www.researchvessels.org/ship_info_display.asp?shipID=934#Engineering
Suncoaster	597	http://www.researchvessels.org/ship_info_display.asp?shipID=24#Engineering
Susan Hudson	522	http://sites.duke.edu/dumphotoarchive/files/2014/04/DUML_News_v9_no1_Spring1991.pdf
Tiglax	634	http://www.researchvessels.org/ship_info_display.asp?shipID=26#Engineering
Tioga	1,119	http://www.whoi.edu/main/tioga/specifications
Tom McIlwain	13.5	http://www.usm.edu/gcrl/research_vessels/tom.mcilwain.research.vessel.php
Musky II	186	http://www.researchvessels.org/ship_info_display.asp?shipID=837#Engineering
Mussel Point	373	http://www.researchvessels.org/ship_info_display.asp?shipID=853#Engineering
Vantuna	686	http://www.researchvessels.org/ship_info_display.asp?shipID=27#Engineering
Ventana (ROV)	30	http://www.mbari.org/dmo/vessels_vehicles/ventana/specifications.html
W. G. Jackson	410	http://www.gvsu.edu/wri/education/wg-jackson-25.htm
Weatherbird	447	http://www.researchvessels.org/ship_info_display.asp?shipID=268#Engineering

Table D-1: Research Vessel Engine Characteristics

Ship Name	Main Engine kW	Online Source
William Scandling	200	http://www.hws.edu/fli/sos_scandling.aspx
Mysis	340	http://www.atlanticpowercleaning.com/mysis/

Appendix E. Coast Guard Cutter Fleet

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Abbie Burgess	WLM 553	1093.6	3,400	2,535	2,772,691
Active	WMEC 618	2889.4	5,000	3,728	10,773,126
Adak	WPB 1333	1956.5	5,760	4,295	8,403,620
Adelie	WPB 87333	1592.3	3,000	2,237	3,562,134
AHI	WPB 87364	1376	3,000	2,237	3,078,249
Albacore	WPB 87309	1558.1	3,000	2,237	3,485,625
Alder	WLB 216	1806.5	6,200	4,623	8,352,062
Alert	WMEC 630	2935.9	5,000	3,728	10,946,501
Alex Haley	WMEC 39	2366.7	6,800	5,071	12,000,966
Alligator	WPB 87369	1500.1	3,000	2,237	3,355,873
Amberjack	WPB 87315	1288.6	3,000	2,237	2,882,727
Anacapa	WPB 1335	1810.5	5,760	4,295	7,776,516
Anthony Petit	WLM 558	1422.6	3,400	2,535	3,606,831
Anvil	WLIC 75301	437.4	673	502	219,512
Aspen	WLB 208	1500.1	6,200	4,623	6,935,471
Assateague	WPB 1337	1361.5	5,760	4,295	5,847,957
Axe	WLIC 75310	635.9	1,320	984	625,932
Bainbridge Island	WPB 1343	545.6	5,760	4,295	2,343,478
Baranof	WPB 1318	3039.6	5,760	4,295	13,055,785
Barbara Mabrity	WLM 559	994.1	3,400	2,535	2,520,421
Barracuda	WPB 87301	1303.2	3,000	2,237	2,915,388
Bayberry	WLI 65400	212.1	673	502	106,444
Bear	WMEC 901	3280.5	7,300	5,444	17,857,760
Beluga	WPB 87325	1635.7	3,000	2,237	3,659,224
Bernard C. Webber	WPC 1101	2474.9	5,800	4,325	10,704,089
Bertholf	WMSL 750	2456.1	49,875	37,192	91,346,734
Biscayne Bay	WTGB 104	1839	2,500	1,864	3,428,355
Blackfin	WPB 87317	1721.4	3,000	2,237	3,850,943
Blacktip	WPB 87326	1810.6	3,000	2,237	4,050,493
Block Island	WPB 1344	649.5	5,760	4,295	2,789,753
Blue Shark	WPB 87360	1695.7	3,000	2,237	3,793,450
Bluebell	WLI 313	721	660	492	354,849
Bluefin	WPB 87318	1474.1	3,000	2,237	3,297,709

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Bollard	WYTL 65614	437.5	500	373	163,122
Bonito	WPB 87341	874.4	3,000	2,237	1,956,120
Boutwell	WHEC 719	3576.3	36,000	26,845	96,006,472
Brant	WPB 87348	1397.6	3,000	2,237	3,126,570
Bridle	WYTL 65607	574.7	500	373	214,277
Bristol Bay	WTGB 102	1734.8	2,500	1,864	3,234,100
Buckthorn	WLI 642	622.9	600	447	278,698
Campbell	WMEC 909	1953.3	7,300	5,444	10,633,002
Capstan	WYTL 65601	644.2	500	373	240,190
Chandeleur	WPB 1319	1358.2	5,760	4,295	5,833,783
Charles David	WPC 1107	2210.8	5,800	4,325	9,561,841
Charles Sexton	WPC 1108	1836.5	5,800	4,325	7,942,971
Chena	WLR 75409	1094	600	447	489,477
Cheyenne	WLR 75405	338	600	447	151,228
Chinook	WPB 87308	1661.5	3,000	2,237	3,716,941
Chippewa	WLR 75404	1022.2	600	447	457,353
Chock	WYTL 65602	323.6	500	373	120,654
Cimarron	WLR 65502	700.6	673	502	351,600
Clamp	WLIC 75306	744.5	1,320	984	732,829
Cleat	WYTL 65615	683.5	500	373	254,843
Cobia	WPB 87311	1426.7	3,000	2,237	3,191,670
Cochito	WPB 87329	1581.3	3,000	2,237	3,537,526
Coho	WPB 87321	1234.7	3,000	2,237	2,762,147
Confidence	WMEC 619	2987	5,000	3,728	11,137,028
Cormorant	WPB 87313	843.6	3,000	2,237	1,887,217
Crocodile	WPB 87372	1473	3,000	2,237	3,295,248
Cushing	WPB 1321	1546.1	5,760	4,295	6,640,857
Cuttyhunk	WPB 1322	1805.8	5,760	4,295	7,756,329
Cypress	WLB 210	1218	6,200	4,623	5,631,227
Dauntless	WMEC 624	2287.1	5,000	3,728	8,527,451
Decisive	WMEC 629	2583.1	5,000	3,728	9,631,087
Dependable	WMEC 626	2469	5,000	3,728	9,205,665
Diamondback	WPB 87370	1066.3	3,000	2,237	2,385,419
Diligence	WMEC 616	1979.1	5,000	3,728	7,379,073

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Dolphin	WPB 87354	952.8	3,000	2,237	2,131,509
Dorado	WPB 87306	1177.5	3,000	2,237	2,634,185
Drummond	WPB 1323	2146.4	5,760	4,295	9,219,284
Eagle NRCB	WIX-327	2200.9	1,000	746	1,641,211
Edisto	WPB 1313	1727.9	5,760	4,295	7,421,730
Elderberry	WLI 65401	407	250	186	75,875
Elm	WLB 204	1646.8	6,200	4,623	7,613,715
Escanaba	WMEC 907	3801.6	7,300	5,444	20,694,424
Farallon	WPB 1301	2250	5,760	4,295	9,664,270
Finback	WPB 87314	1229.8	3,000	2,237	2,751,185
Fir	WLB 213	1903.1	6,200	4,623	8,798,677
Flying Fish	WPB 87346	1730.7	3,000	2,237	3,871,748
Forward	WMEC 911	162.7	7,300	5,444	885,675
Frank Drew	WLM 557	1324.1	3,400	2,535	3,357,096
Galveston Island	WPB 1349	1367.6	5,760	4,295	5,874,158
Gannet	WPB 87334	947.2	3,000	2,237	2,118,981
Gasconade	WLR 75401	439.5	600	447	196,641
George Cobb	WLM 564	955.3	3,400	2,535	2,422,048
Grand Isle	WPB 1338	1807.4	5,760	4,295	7,763,201
Greenbrier	WLR 75501	1246.4	1,080	805	1,003,796
Haddock	WPB 87347	1698.5	3,000	2,237	3,799,714
Halibut	WPB 87340	1791.5	3,000	2,237	4,007,764
Hammer	WLIC 75302	665.5	1,320	984	655,068
Hammerhead	WPB 87302	1794.8	3,000	2,237	4,015,146
Harriet Lane	WMEC 903	2030.3	7,300	5,444	11,052,159
Harry Claiborne	WLM 561	1236.2	3,400	2,535	3,134,236
Hatchet	WLIC 75309	451	1,320	984	443,930
Hawk	WPB 87355	1359.1	3,000	2,237	3,040,442
Hawksbill	WPB 87312	1783.3	3,000	2,237	3,989,420
Hawser	WYTL 65610	560.7	500	373	209,057
Healy	WAGB 20	3606.9	30,000	22,371	80,689,946
Henry Blake	WLM 563	1197.5	3,400	2,535	3,036,117
Heron	WPB 87344	1765.9	3,000	2,237	3,950,494
Hickory	WLB 212	1825.2	6,200	4,623	8,438,519

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Hollyhock	WLB 214	2177.7	6,200	4,623	10,068,246
Hudson	WLIC 801	939.1	500	373	350,143
Ibis	WPB 87338	1421	3,000	2,237	3,178,919
Ida Lewis	WLM 551	1263.6	3,400	2,535	3,203,706
James Rankin	WLM 555	1307.3	3,400	2,535	3,314,502
Jefferson Island	WPB 1340	1593.6	5,760	4,295	6,844,881
Joshua Appleby	WLM 556	925.7	3,400	2,535	2,347,001
Juniper	WLB 201	1763.1	6,200	4,623	8,151,409
Kanawha	WLR 75407	1484.2	600	447	664,061
Kankakee	WLR 75500	1326.3	540	403	534,072
Katherine Walker	WLM 552	1208.4	3,400	2,535	3,063,753
Kathleen Moore	WPC 1109	600.5	5,800	4,325	2,597,198
Katmai Bay	WTGB 101	1823.5	2,500	1,864	3,399,459
Kennebec	WLIC 802	980.8	500	373	365,691
Key Biscayne	WPB 1339	2470.9	5,760	4,295	10,613,087
Key Largo	WPB 1324	1865.8	5,760	4,295	8,014,042
Kickapoo	WLR 75406	1023.5	600	447	457,934
Kingfisher	WPB 87322	1153.4	3,000	2,237	2,580,271
Kiska	WPB 1336	1583.8	5,760	4,295	6,802,787
Kittiwake	WPB 87316	1326.3	3,000	2,237	2,967,065
Knight Island	WPB 1348	1878.4	5,760	4,295	8,068,162
Kodiak Island	WPB 1341	881.4	5,760	4,295	3,785,817
Kukui	WLB 203	1376.8	6,200	4,623	6,365,413
Legare	WMEC 912	2990.7	7,300	5,444	16,280,202
Liberty	WPB 1334	1159.8	5,760	4,295	4,981,609
Line	WYTL 65611	583.2	500	373	217,446
Long Island	WPB 1342	1805	5,760	4,295	7,752,892
Mackinaw	WLBB 30	2904.8	9,119	6,800	19,752,748
Mako	WPB 87303	774.6	3,000	2,237	1,732,857
Mallet	WLIC 75304	899.9	1,320	984	885,793
Manatee	WPB 87363	761.2	3,000	2,237	1,702,880
Man-O-War	WPB 87330	1229.1	3,000	2,237	2,749,619
Manta	WPB 87320	1536.1	3,000	2,237	3,436,409
Maple	WLB 207	1482	6,200	4,623	6,851,789

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Marcus Hanna	WLM 554	1373.8	3,400	2,535	3,483,104
Margaret Norvell	WPC 1105	2396.1	5,800	4,325	10,363,274
Maria Bray	WLM 562	1185.8	3,400	2,535	3,006,453
Marlin	WPB 87304	1517.2	3,000	2,237	3,394,128
Matinicus	WPB 1315	2126.2	5,760	4,295	9,132,521
Maui	WPB 1304	3240.2	5,760	4,295	13,917,408
Mellon	WHEC 717	3262.8	36,000	26,845	87,590,504
Midgett	WHEC 726	2872	36,000	26,845	77,099,401
Mohawk	WMEC 913	88.1	7,300	5,444	479,582
Monomoy	WPB 1326	2845.4	5,760	4,295	12,221,651
Moray	WPB 87331	1738.6	3,000	2,237	3,889,421
Morgenthau	WHEC 722	3154.7	36,000	26,845	84,688,538
Morro Bay	WTGB 106	1562.7	2,500	1,864	2,913,263
Munro	WHEC 724	2297.8	36,000	26,845	61,684,890
Muskingum	WLR 75402	807.1	600	447	361,113
Mustang	WPB 1310	1798.4	5,760	4,295	7,724,544
Nantucket	WPB 1316	1031.5	5,760	4,295	4,430,531
Narwhal	WPB 87335	1702.1	3,000	2,237	3,807,767
Naushon	WPB 1311	1725.1	5,760	4,295	7,409,703
Neah Bay	WTGB 105	1577.2	2,500	1,864	2,940,295
Northland	WMEC 904	3107.7	7,300	5,444	16,917,104
Oak	WLB 211	1632	6,200	4,623	7,545,290
Obion	WLR 65503	970	673	502	486,800
Ocracoke	WPB 1307	895.8	5,760	4,295	3,847,668
Orcas	WPB 1327	1250	5,760	4,295	5,369,039
Osage	WLR 65505	598.1	673	502	300,160
Osprey	WPB 87307	1322.9	3,000	2,237	2,959,459
Ouachita	WLR 65501	610.8	673	502	306,534
PAMLICO	WLIC 800	640.1	500	373	238,661
Patoka	WLR 75408	1132.3	600	447	506,614
Paul Clark	WPC 1106	2530.9	5,800	4,325	10,946,292
Pelican	WPB 87327	1302.3	3,000	2,237	2,913,375
Pendant	WYTL 65608	575	500	373	214,389
Penobscot Bay	WTGB 107	1494.9	2,500	1,864	2,786,867

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Petrel	WPB 87350	1682.5	3,000	2,237	3,763,920
Pike	WPB 87365	1646.3	3,000	2,237	3,682,937
Polar Star	WAGB-10	2508.1	78,000	58,165	145,882,608
Pompano	WPB 87339	1603.4	3,000	2,237	3,586,966
Razorbill	WPB 87332	1443.2	3,000	2,237	3,228,582
Reef Shark	WPB 87371	1684.4	3,000	2,237	3,768,171
Reliance	WMEC 615	2718.3	5,000	3,728	10,135,180
Resolute	WMEC 620	2700	5,000	3,728	10,066,948
Richard Etheridge	WPC 1102	2205.3	5,800	4,325	9,538,053
Ridley	WPB 87328	1732	3,000	2,237	3,874,657
Roanoke Island	WPB 1346	1806.9	5,760	4,295	7,761,053
Robert Yered	WPC 1104	2449.8	5,800	4,325	10,595,530
Saginaw	WLIC 803	929.3	500	373	346,489
Sailfish	WPB 87356	1660.4	3,000	2,237	3,714,480
Sangamon	WLR 65506	684.9	673	502	343,721
Sanibel	WPB 1312	1389.8	5,760	4,295	5,969,512
Sapelo	WPB 1314	1429.3	5,760	4,295	6,139,174
Sawfish	WPB 87357	1509.4	3,000	2,237	3,376,678
Scioto	WLR 65504	435.3	673	502	218,458
Sea Devil	WPB 87368	501.4	3,000	2,237	1,121,682
Sea Dog	WPB 87373	1231.9	3,000	2,237	2,755,883
Sea Dragon	WPB 87367	1139.9	3,000	2,237	2,550,070
Sea Fox	WPB 87374	692.7	3,000	2,237	1,549,639
Sea Horse	WPB 87361	1218.4	3,000	2,237	2,725,682
Sea Lion	WPB 87352	1514.1	3,000	2,237	3,387,193
Sea Otter	WPB 87362	1645	3,000	2,237	3,680,029
Seahawk	WPB 87323	1297.1	3,000	2,237	2,901,742
Seneca	WMEC 906	2441.5	7,300	5,444	13,290,572
Sequoia	WLB 215	1680.7	6,200	4,623	7,770,446
Shackle	WYTL 65609	575.4	500	373	214,538
Shearwater	WPB 87349	1618.5	3,000	2,237	3,620,746
Sherman	WHEC 720	1820.4	36,000	26,845	48,868,994
Shrike	WPB 87342	1115.8	3,000	2,237	2,496,156
Sitkinak	WPB 1329	1889.7	5,760	4,295	8,116,699

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
Skipjack	WPB 87353	1651.5	3,000	2,237	3,694,570
SLEDGE	WLIC 75303	1294.8	1,320	984	1,274,502
Smilax	WLIC 315	1008.4	600	447	451,178
Sockeye	WPB 87337	1646	3,000	2,237	3,682,266
Spar	WLB 206	1736.7	6,200	4,623	8,029,353
Spencer	WMEC 905	2783.2	7,300	5,444	15,150,653
Staten Island	WPB 1345	1429.3	5,760	4,295	6,139,174
Steadfast	WMEC 623	1442.5	5,000	3,728	5,378,360
Steelhead	WPB 87324	1173.7	3,000	2,237	2,625,684
Stingray	WPB 87305	1586	3,000	2,237	3,548,040
Stratton	WMSL 752	3150.9	49,875	37,192	117,187,583
Sturgeon Bay	WPB 87336	1546.5	3,000	2,237	3,459,675
Sturgeon Bay	WTGB 109	1504	2,500	1,864	2,803,832
Swordfish	WPB 87358	1468.1	3,000	2,237	3,284,286
Sycamore	WLB 209	1724.9	6,200	4,623	7,974,798
Tackle	WYTL 65604	537.5	500	373	200,407
Tahoma	WMEC 908	2209	7,300	5,444	12,024,932
Tampa	WMEC 902	3563.8	7,300	5,444	19,399,934
Tarpon	WPB 87310	1501.9	3,000	2,237	3,359,900
Tern	WPB 87343	1368.4	3,000	2,237	3,061,247
Terrapin	WPB 87366	1813.3	3,000	2,237	4,056,533
Thetis	WMEC 910	3556.3	7,300	5,444	19,359,107
Thunder Bay	WTGB 108	1491.5	2,500	1,864	2,780,528
Tiger Shark	WPB 87359	1730.2	3,000	2,237	3,870,630
Tybee	WPB 1330	1590.7	5,760	4,295	6,832,424
Valiant	WMEC 621	1864.6	5,000	3,728	6,952,160
Venturous	WMEC 625	2980.9	5,000	3,728	11,114,284
Vigilant	WMEC 617	2054.3	5,000	3,728	7,659,456
Vigorous	WMEC 627	2589.8	5,000	3,728	9,656,068
WISE	WLIC 75305	621.3	1,320	984	611,560
Waesche	WMSL 751	3071.9	49,875	37,192	114,249,432
Wahoo	WPB 87345	1730.8	3,000	2,237	3,871,972
Walnut	WLB 205	1473.8	6,200	4,623	6,813,877
Washington	WPB 1331	823.3	5,760	4,295	3,536,264

Table E-1: Compilation of Coast Guard Cutter Data

Vessel Name	Vessel ID	Annual Underway Hours per Vessel (2014)	HP	Engine Power (kW)	kW-hrs
William Flores	WPC 1103	2507.1	5,800	4,325	10,843,356
William Tate	WLM 560	758.1	3,400	2,535	1,922,071
Willow	WLB 202	1158.1	6,200	4,623	5,354,289
Wire	WYTL 65612	565.1	500	373	210,697
Wyaconda	WLR 75403	627.9	600	447	280,935
Yellowfin	WPB 87319	1044.9	3,000	2,237	2,337,545

Appendix F. Marine Vessel HAP Profiles

Table F-1: C1/C2 HAP Profile In-port Maneuvering

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
	Copper	PM ₁₀	9.58E-04
	Zinc	PM ₁₀	5.00E-04
100414	Ethylbenzene	VOC	1.50E-03
100425	Styrene	VOC	1.58E-03
107028	Acrolein	VOC	2.63E-03
108883	Toluene	VOC	2.40E-03
110543	n-Hexane	VOC	4.13E-03
118741	HCB	PM ₁₀	2.00E-08
120127	Anthracene	PM _{2.5}	2.78E-05
123386	Propionaldehyde	VOC	4.58E-03
129000	Pyrene	PM _{2.5}	2.93E-05
1330207	Xylene	VOC	3.60E-03
1336363	PCB	PM ₁₀	2.50E-07
16065831	Chromium III	PM ₁₀	1.65E-05
18540299	Chromium VI	PM ₁₀	8.50E-06
191242	Benzo[g,h,i,l]Perylene	PM _{2.5}	6.75E-06
193395	Indeno[1,2,3-c,d]Pyrene	PM ₁₀	5.00E-06
205992	Benzo[b]Fluoranthene	PM ₁₀	5.00E-06
206440	Fluoranthene	PM _{2.5}	1.65E-05
207089	Benzo[k]Fluoranthene	PM ₁₀	2.50E-06
208968	Acenaphthylene	PM _{2.5}	2.78E-05
218019	Chrysene	PM _{2.5}	5.25E-06
50000	Formaldehyde	VOC	1.12E-01
50328	Benzo[a]Pyrene	PM ₁₀	2.50E-06
540841	2,2,4-trimethylpentane	VOC	3.00E-04
56553	Benz[a]Anthracene	PM _{2.5}	3.00E-05
628	Dioxin	PM ₁₀	2.50E-09
71432	Benzene	VOC	1.53E-02
7439921	Lead	PM ₁₀	7.50E-05
7439965	Manganese	PM ₁₀	1.53E-06
7439976	Mercury	PM ₁₀	2.50E-08
7440020	Nickel	PM ₁₀	5.00E-04
7440382	Arsenic	PM ₁₀	1.75E-05
7440439	Cadmium	PM ₁₀	2.83E-06
7440473	Chromium	PM ₁₀	
75070	Acetaldehyde	VOC	5.57E-02

Table F-1: C1/C2 HAP Profile In-port Maneuvering

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
7782492	Selenium	PM ₁₀	2.83E-08
83329	Acenaphthene	PM _{2.5}	1.80E-05
85018	Phenanthrene	PM _{2.5}	4.20E-05
86737	Fluorene	PM _{2.5}	3.68E-05
91203	Naphthalene	PM _{2.5}	1.05E-03
NH ₃	Ammonia	PM ₁₀	1.00E-02

Table F-2: C1/C2 HAP Profile Underway

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
	Copper	PM ₁₀	1.75E-03
	Zinc	PM ₁₀	1.00E-03
100414	Ethylbenzene	VOC	1.25E-03
100425	Styrene	VOC	1.31E-03
107028	Acrolein	VOC	2.19E-03
108883	Toluene	VOC	2.00E-03
110543	n-Hexane	VOC	3.44E-03
118741	HCB	PM ₁₀	4.00E-08
120127	Anthracene	PM _{2.5}	2.31E-05
123386	Propionaldehyde	VOC	3.81E-03
129000	Pyrene	PM _{2.5}	2.44E-05
1330207	Xylene	VOC	3.00E-03
1336363	PCB	PM ₁₀	5.00E-07
16065831	Chromium III	PM ₁₀	3.30E-05
18540299	Chromium VI	PM ₁₀	1.70E-05
191242	Benzo[g,h,i,l]Perylene	PM _{2.5}	5.63E-06
193395	Indeno[1,2,3-c,d]Pyrene	PM ₁₀	1.00E-05
205992	Benzo[b]Fluoranthene	PM ₁₀	1.00E-05
206440	Fluoranthene	PM _{2.5}	1.38E-05
207089	Benzo[k]Fluoranthene	PM ₁₀	5.00E-06
208968	Acenaphthylene	PM _{2.5}	2.31E-05
218019	Chrysene	PM _{2.5}	4.38E-06
50000	Formaldehyde	VOC	9.35E-02
50328	Benzo[a]Pyrene	PM ₁₀	5.00E-06
540841	2,2,4-trimethylpentane	VOC	2.50E-04
56553	Benz[a]Anthracene	PM _{2.5}	2.50E-05
628	Dioxin	PM ₁₀	5.00E-09

Table F-2: C1/C2 HAP Profile Underway

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
71432	Benzene	VOC	1.27E-02
7439921	Lead	PM ₁₀	1.50E-04
7439965	Manganese	PM ₁₀	1.28E-06
7439976	Mercury	PM ₁₀	5.00E-08
7440020	Nickel	PM ₁₀	1.00E-03
7440382	Arsenic	PM ₁₀	3.00E-05
7440439	Cadmium	PM ₁₀	5.15E-06
7440473	Chromium	PM ₁₀	5.00E-05
75070	Acetaldehyde	VOC	4.64E-02
7782492	Selenium	PM ₁₀	5.15E-08
83329	Acenaphthene	PM _{2.5}	1.50E-05
85018	Phenanthrene	PM _{2.5}	3.50E-05
86737	Fluorene	PM _{2.5}	3.06E-05
91203	Naphthalene	PM _{2.5}	8.76E-04
NH3	Ammonia	PM ₁₀	2.00E-02

Table F-3: Category 3 Profile In-port Hoteling

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
	Copper	PM ₁₀	9.08E-04
	Zinc	PM ₁₀	6.00E-04
118741	HCB	PM ₁₀	1.60E-08
120127	Anthracene	PM _{2.5}	5.25E-07
129000	Pyrene	PM _{2.5}	5.53E-07
130498292	POM as 7-PAH	PM	4.50E-07
130498292	POM as 16-PAH	PM _{2.5}	2.49E-05
1336363	Polychlorinated Biphenyls	PM ₁₀	2.00E-07
16065831	Chromium III	PM ₁₀	3.96E-04
18540299	Chromium VI	PM ₁₀	2.04E-04
191242	Benzo[g,h,l]Perylene	PM _{2.5}	1.28E-07
193395	Indeno[1,2,3-c,d]Pyrene	PM ₁₀	4.00E-06
205992	Benzo[b]Fluoranthene	PM ₁₀	4.00E-06
206440	Fluoranthene	PM _{2.5}	3.12E-07
207089	Benzo[k]Fluoranthene	PM ₁₀	2.00E-06
208968	Acenaphthylene	PM _{2.5}	5.25E-07
218019	Chrysene	PM _{2.5}	9.93E-08
50000	Formaldehyde	VOC	1.57E-03

Table F-3: Category 3 Profile In-port Hoteling

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
50328	Benzo[a]Pyrene	PM ₁₀	2.00E-06
53703	Dibenzo[a,h]Anthracene	PM _{2.5}	0.00E+00
56553	Benz[a]Anthracene	PM _{2.5}	5.67E-07
628	Dioxin	PM ₁₀	2.00E-09
71432	Benzene	VOC	9.80E-06
7439921	Lead	PM ₁₀	6.00E-05
7439965	Manganese	PM ₁₀	5.73E-05
7439976	Mercury	PM ₁₀	1.40E-06
7440020	Nickel	PM ₁₀	1.54E-02
7440382	Arsenic	PM ₁₀	4.00E-04
7440417	Beryllium	PM ₁₀	5.46E-07
7440439	Cadmium	PM ₁₀	5.90E-06
7440484	Cobalt	PM ₁₀	2.92E-04
75070	Acetaldehyde	VOC	2.29E-04
7723140	Phosphorous	PM ₁₀	4.38E-03
7782492	Selenium	PM ₁₀	9.08E-06
83329	Acenaphthene	PM _{2.5}	3.40E-07
85018	Phenanthrene	PM _{2.5}	7.94E-07
86737	Fluorene	PM _{2.5}	6.95E-07
91203	Naphthalene	PM _{2.5}	1.99E-05
NH3	Ammonia	PM ₁₀	1.08E-02

Table F-4: Category 3 Profile In-port Maneuvering

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
	Copper	PM ₁₀	1.91E-04
	Zinc	PM ₁₀	1.31E-04
118741	HCB	PM ₁₀	3.50E-09
120127	Anthracene	PM _{2.5}	5.25E-07
129000	Pyrene	PM _{2.5}	5.53E-07
130498292	POM as 7-PAH	PM ₁₀	4.90E-07
130498292	POM as 16-PAH	PM _{2.5}	2.49E-05
1336363	PCB	PM ₁₀	4.37E-08
16065831	Chromium III	PM ₁₀	1.27E-04
18540299	Chromium VI	PM ₁₀	6.53E-05
191242	Benzo[g,h,i,l]Perylene	PM _{2.5}	1.28E-07
193395	Indeno[1,2,3-c,d]Pyrene	PM ₁₀	8.74E-07

Table F-4: Category 3 Profile In-port Maneuvering

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
205992	Benzo[b]Fluoranthene	PM ₁₀	8.74E-07
206440	Fluoranthene	PM _{2.5}	3.12E-07
207089	Benzo[k]Fluoranthene	PM ₁₀	4.37E-07
208968	Acenaphthylene	PM _{2.5}	5.25E-07
218019	Chrysene	PM _{2.5}	9.93E-08
50000	Formaldehyde	VOC	1.57E-03
50328	Benzo[a]Pyrene	PM ₁₀	4.37E-07
53703	Dibenzo[a,h]Anthracene	PM _{2.5}	0.00E+00
56553	Benz[a]Anthracene	PM _{2.5}	5.67E-07
628	Dioxin	PM ₁₀	4.37E-10
71432	Benzene	VOC	9.80E-06
7439921	Lead	PM ₁₀	1.40E-05
7439965	Manganese	PM ₁₀	5.73E-05
7439976	Mercury	PM ₁₀	2.71E-07
7440020	Nickel	PM ₁₀	3.25E-03
7440382	Arsenic	PM ₁₀	8.74E-05
7440417	Beryllium	PM ₁₀	5.46E-07
7440439	Cadmium	PM ₁₀	2.26E-05
7440484	Cobalt	PM ₁₀	5.94E-05
75070	Acetaldehyde	VOC	2.29E-04
7723140	Phosphorous	PM ₁₀	1.79E-03
7782492	Selenium	PM ₁₀	1.91E-06
83329	Acenaphthene	PM _{2.5}	3.40E-07
85018	Phenanthrene	PM _{2.5}	7.94E-07
86737	Fluorene	PM _{2.5}	6.95E-07
91203	Naphthalene	PM _{2.5}	1.99E-05
NH3	Ammonia	PM ₁₀	2.38E-03

Table F-5: Category 3 Profile Underway

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
	Copper	PM ₁₀	3.48E-04
	Zinc	PM ₁₀	2.62E-04
118741	HCB	PM ₁₀	6.99E-09
120127	Anthracene	PM _{2.5}	5.25E-07
129000	Pyrene	PM _{2.5}	5.53E-07
130498292	POM as 7-PAH	PM ₁₀	4.90E-07
130498292	POM as 16-PAH	PM _{2.5}	2.49E-05

Table F-5: Category 3 Profile Underway

Pollutant Code	Pollutant	Associated basis for speciation	Fraction
1336363	PCB	PM ₁₀	8.74E-08
16065831	Chromium III	PM ₁₀	1.27E-04
18540299	Chromium VI	PM ₁₀	6.53E-05
191242	Benzo[g,h,i,l]Perylene	PM _{2.5}	1.28E-07
193395	Indeno[1,2,3-c,d]Pyrene	PM ₁₀	1.75E-06
205992	Benzo[b]Fluoranthene	PM ₁₀	1.75E-06
206440	Fluoranthene	PM _{2.5}	3.12E-07
207089	Benzo[k]Fluoranthene	PM ₁₀	8.74E-07
208968	Acenaphthylene	PM _{2.5}	5.25E-07
218019	Chrysene	PM _{2.5}	9.93E-08
50000	Formaldehyde	VOC	1.57E-03
50328	Benzo[a]Pyrene	PM ₁₀	8.74E-07
53703	Dibenzo[a,h]Anthracene	PM _{2.5}	0.00E+00
56553	Benz[a]Anthracene	PM _{2.5}	5.67E-07
628	Dioxin	PM ₁₀	8.74E-10
71432	Benzene	VOC	9.80E-06
7439921	Lead	PM ₁₀	2.62E-05
7439965	Manganese	PM ₁₀	5.73E-05
7439976	Mercury	PM ₁₀	5.24E-07
7440020	Nickel	PM ₁₀	5.89E-03
7440382	Arsenic	PM ₁₀	1.75E-04
7440417	Beryllium	PM ₁₀	5.46E-07
7440439	Cadmium	PM ₁₀	2.26E-05
7440473	Chromium	PM ₁₀	1.92E-04
7440484	Cobalt	PM ₁₀	1.54E-04
75070	Acetaldehyde	VOC	2.29E-04
7723140	Phosphorus	PM ₁₀	5.73E-03
7782492	Selenium	PM ₁₀	3.48E-06
83329	Acenaphthene	PM _{2.5}	3.40E-07
85018	Phenanthrene	PM _{2.5}	7.94E-07
86737	Fluorene	PM _{2.5}	6.95E-07
91203	Naphthalene	PM _{2.5}	1.99E-05
NH3	Ammonia	PM ₁₀	4.77E-03