Final Report

Implement Port of Houston's Current Inventory and Harmonize the Remaining 8-county Shipping Inventory for TCEQ Modeling

Work Order No. 582-7-84006-FY10-5
Project Tracking Number: 2010-11

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August 18, 2010

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INTRODUCTION

Large ports along the Texas coast are a growing component of the nitrogen oxide (NOx) emissions inventory because controls already reduce land-based mobile and stationary sources emissions. Slow turnover to new vessels/engines combined with regulation under international law means fewer emission reductions for ocean-going vessels. The shipping emissions inventory (EI) currently used by the TCEQ to model the Houston-Galveston-Brazoria (HGB) 8 county area provides excellent spatial resolution as a trip-based EI for ocean-going vessels (OGV) but uses outdated 1997-era ship movements. The Port of Houston has completed a well-documented high quality commercial marine vessel EI for 2007 for ships that use Port of Houston facilities (Goods Movement Emissions Inventory (GMEI, 2009, Port of Houston EI)). This project leveraged the Port of Houston EI by integrating it with emission estimates for other shipping (i.e., not using Port of Houston facilities) in the HGB 8-county area. The integrated HGB 8-county shipping inventory was formatted for use with version 3 of the Emissions Processing System (EPS3), used by the TCEQ to prepare emissions for photochemical modeling.

When the Port of Houston EI was prepared, only the area serviced by the Houston Pilot Association was included in the emission estimates, namely the port-owned terminals. This left a gap in the lower HGB 8-county region of Galveston, Texas City and the Port of Freeport. To fill this gap and complete the HGB 8-county region shipping EI, the Texas City/Galveston and Freeport vessel calls were collected and analyzed. To enable spatial allocation of the emissions for Texas City/Galveston and Freeport, shipping routes were defined for those ports using navigational charts and GIS software. Additionally, the spatial coverage on the Intra-Coastal Waterway (ICW) in the Port of Houston EI was limited to a few miles inland from Galveston Bay, for this project the ICW trip traffic on additional links was added. The result of this project is a complete shipping inventory for the HGB 8-county region that can be used to support photochemical modeling.

Chapter 2 details the vessel activity data for each of the ports and intra-coastal waterway (ICW). Chapter 3 summarizes emissions by source category and port region and compares emissions summaries to the Port of Houston EI. Chapter 4 describes the approach used to back and forecast activity to 2005, 2006, and 2018. Chapter 5 presents the methodology for preparing the emissions for the EPS3 emissions modeling system and sample output of running EPS3 with the HGB shipping emissions.

VESSEL TRAFFIC ACTIVITY

The overall purpose of this study is to expand the geographic extent of Port of Houston Goods Movement Emissions Inventory (GMEI, 2009) to include Freeport, Texas City, Galveston, and the ICW, and to reformat the EI into the EPS3 model-ready format. In addition, minor updates to the Port of Houston GMEI were performed. Methods for determining air quality emissions from commercial marine vessels follow those reported in the Port of Houston EI. This procedure follows the EPA guidance for preparing marine vessel emissions inventories as outlined in ICF (2009).

Vessel call activity was cross referenced to known vessel and engine characteristics such as power by individual inbound and outbound trips, shifts (movements between docks within a port or between neighboring ports), and anchorage hotelling activity away from dock.

These vessel trips and activity were disaggregated into traffic segments and plotted by a geographic information system (GIS) using start and ending coordinates in latitude and longitude. As such, each ship would have a separate emissions inventory for each traffic segment. Even with the same exact vessel, activity could change by segment length and ship speed, as well as any adjustments such as ocean-going vessels using the cubic relationship in the Propeller Law.

The modification and expansion of the Port of Houston EI can be summarized as five separate tasks:

1. Port of Houston - minor modifications. Several hundred Houston port shifts to Galveston and Texas City were added, and a few corrections to the GMEI 2009 inventory were made which included adding some missing route matching for Carpenter's Bayou and San Jacinto.

2. Freeport OGVs - inclusion. Freeport was not included in the Port of Houston EI at all because it is a completely different deepwater port.

3. Galveston and Texas City OGVs - inclusion. These two ports are treated as a new collocated port activity source in lower Galveston Bay and the combined port complex is called "Gal-Tex". As mentioned in Item #1, shifts to and from Houston ports north of Morgan's Point (the upper end of Galveston Bay and beginning of the Houston Ship Channel) were included in the Port of Houston EI, as amended. As such, inter-port shifts involving Houston ports were commanded by Houston Port Pilots, and thus would not appear in the data from the Galveston-Texas City Pilots.

4. Towboats - inclusion. Towboats mainly comprise of inland push-boats. They were added for the Intracoastal Waterway (ICW) for east and west segments which were not estimated in the Port of Houston EI.

5. Miscellaneous. This section explains any additional or special categories that do not fall into being either an ocean-going vessel or a towboat.

Port of Houston (Shifts to Other Ports in HGB)

During compilation of the Port of Houston EI, it was decided by the Port of Houston Authority to delete some of the inter-port shifts from the inventory, since the client was mainly concerned with emissions associated with its tenants. These shift trips were chiefly ships in tanker service, such as the ubiquitous "drug store" chemical tanker ship, although general cargo ships were common. Several hundred of these inter-port shifts were added back into the emissions inventory for the sake of completeness. As such, Inter-port shifts increased to 4,714 from 4,502 trips for a gain of 212 trips.

Freeport

Freeport was not included in the Port of Houston EI. Basic vessel call activity data for the Port of Freeport was obtained from the Brazos Pilots.

Table 1. Freeport vessel call summary for 2007.

Subtype	Arrivals	Departures	Shifts
Auto Carrier	1	1	
Bulk	12	12	1
Bulk, Self-Discharging	8	8	
Chemical Tanker	75	75	4
Chemical/Products Tanker	287	287	11
Containership 1000	101	101	1
Crude Tanker 1 - Handymax	9	9	
Crude Tanker 2 - Panamax	18	18	
Crude Tanker 3 - Aframax	167	167	12
Crude Tanker 4 - Suezmax	11	11	
General Cargo	63	63	7
Heavy Load Carrier	2	2	
ITB/ATB	9	9	1
LNG Tanker	1	1	
LPG Tanker	55	55	
MISC	18	18	
Products Tanker	14	14	1
Reefer	56	56	
Ro-Ro	1	1	
Total	**908**	**908**	**38**

The routes into the Port of Freeport were determined from navigational charts and are shown in Figure 1. The primary (and for this work assumed to be exclusive) route into Freeport is directly in from the 9 mile boundary. Figure 1 identifies the shipping channel and precautionary zone within the 3 mile boundary and the end of the jetty. Emissions are computed for each waterway segment and by ship type using ship type names and vessel source category codes (SCC).

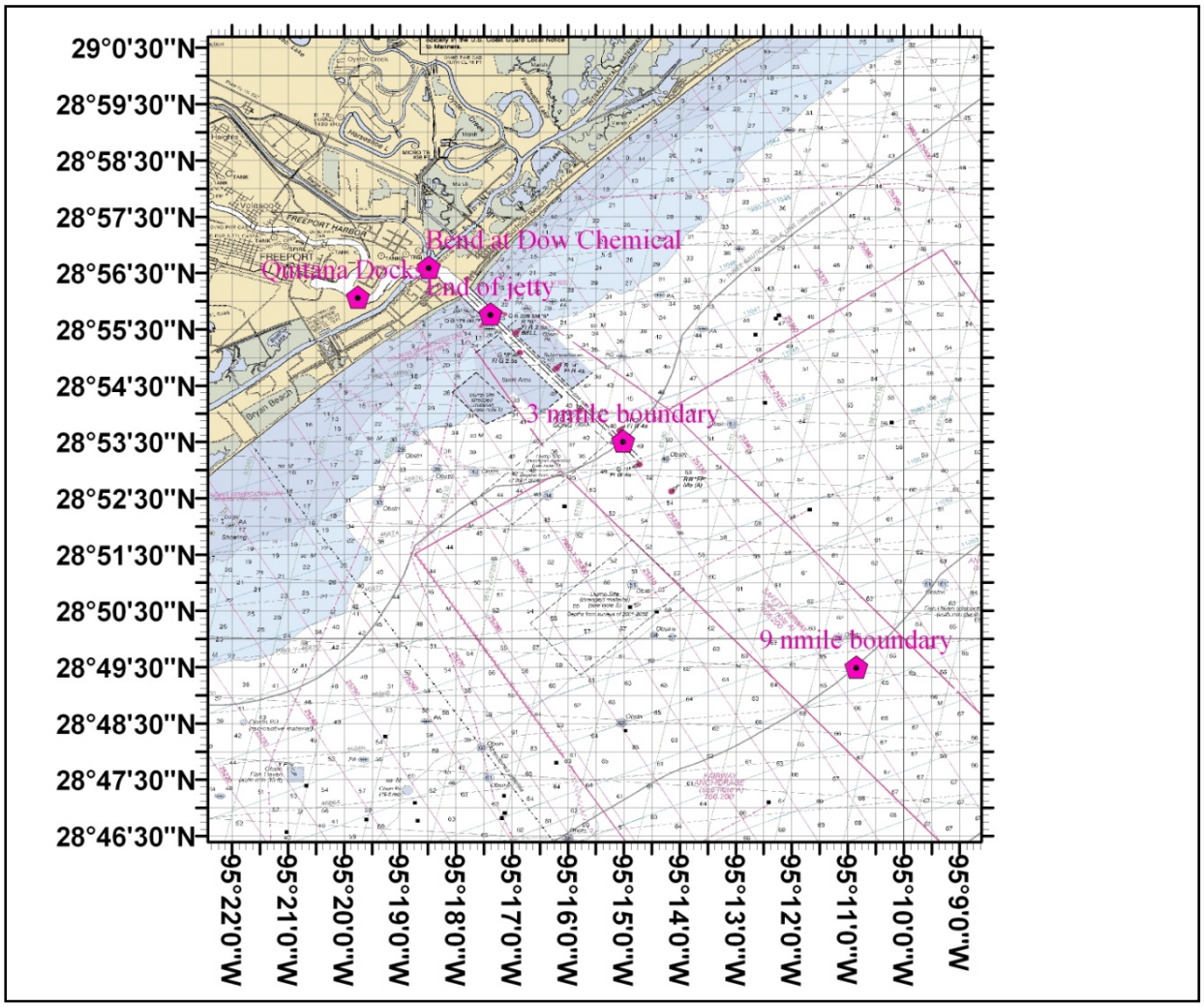

Figure 1. Entrance route and significant points near Freeport.

Texas City and Galveston

The port calls for the Ports of Texas City and Galveston were provided by the GalTex Pilots and a summary of the calls are shown in Table 2.

Table 2. Texas City / Galveston vessel call summary for 2007.

Subtype	Arrivals	Departures	Shifts	Anchorage
Auto Carrier	49	39		
Barge	32	25	5	5
Bulk	230	209	54	15
Bulk, Self-Discharging	2	1		
Bulk/Oil(OBO)	1	1		4
Chemical Tanker	160	160	21	11
Chemical/Products Tanker	497	506	40	61
Containership 2000	2	1		
Crude Tanker 1 - Handymax	12	12	1	5
Crude Tanker 2 - Panamax	50	49	4	17
Crude Tanker 3 - Aframax	370	371	4	75
Crude Tanker 4 - Suezmax	31	31		36
Crude Tanker 6 - ULCC	2	2	1	
Cruise	205	206	1	
Drill Rig	11	12	14	
General Cargo	34	26	1	5
ITB/ATB	125	110	8	38
LNG Tanker				11
LPG Tanker	12	9		12
MISC	19	20	14	1
Military	4	3		
Ocean Towing	60	45	10	8
Offshore	171	169	58	1
Other Tanker	2	2		3
Products Tanker	124	118	4	21
Reefer	51	53	28	
Ro-Ro	37	39	1	2
Total	**2293**	**2219**	**269**	**331**

Intra-Coastal Waterway (ICW)

The Port of Houston EI includes towboat activity that consists of vessel movements along individual routes shown in Table 3. However, because the Port of Houston EI only includes activity specifically relevant to the Port of Houston, an additional set of trips was added to extend the ICW to the entire HGB 8-county area. These additional trips are shown in Table 4. Specifically, inland towboat activity was extended west from Galveston to Freeport (ICW-West, and east from Bolivar towards Port Arthur (ICW-East) as shown in Figure 2. Additional waterway segments were created with GIS to enable spatial allocation of the additional emissions. Similarly to the ocean-going ships, each link segment has its own emissions inventory for a special SCC for inland towboats.

Table 3. ICW towboat movements for 2007.

Trip Type	Trips
A1) VTS Terminal Move	59,983
A2) Shift	23,156
B) Inbound ICW-East	8,192
B) Inbound ICW-West	4,124
B) Outbound ICW-East	8,254
B) Outbound ICW-West	4,131
C) ICW-Through	4,749
D) Galveston	1,799
D) Texas City	3,734
E) Inbound from Sea	286
E) Outbound to Sea	385
F) Anchorage Inbound	930
F) Anchorage Outbound	945
I) Anchorage Shift	102
Total	**120,770**

Table 4. Added ICW towboat movements for 2007.

Trip Type	Trips
B) Inbound ICW-East	6,210
B) Inbound ICW-West	3,175
B) Outbound ICW-East	6,243
B) Outbound ICW-West	3,237
C) ICW-Through	4,749
Total	**23,614**

Figure 2. ICW east and west routes near HGB.

Miscellaneous Sources

ENVIRON expanded the Port of Houston EI to include the additional miscellaneous sources:

1) Assist Tugs
2) Ocean Tugs
3) Off-shore support vessels (piloted)
4) Other Push or Tow Boats outside of ICW
5) Unknown (probably crew boats or other smaller support vessels)

VESSEL TRAFFIC AND EMISSIONS

Emissions Summaries

Table 5 reports emissions summaries for the Port of Houston OGV, Freeport OGV, Gal-Tex OGV, Port of Houston miscellaneous vessels, and ICW vessels. Tables 6-10 provide emissions summaries for the Port of Houston OGV, Freeport OGV, Gal-Tex OGV, Port of Houston miscellaneous vessels, and ICW vessels, respectively, by vessel type. For NOx, the Houston port contributes 71.4% of the total HGB 8-county area emissions, Gal-TX contributes 10.8%, Freeport contributes 4.5% and the ICW contributes 13.3%. The largest source category by vessel type is chemical and chemical/products tanker which emits 35.9% of the NOx emissions from Houston OGVs.

Table 5. Emissions summaries for 2007 in TPD.

Emissions Summary						
Port	**NOx [TPD]**	**VOC [TPD]**	**CO [TPD]**	**PM10 [TPD]**	**PM25 [TPD]**	**SO2 [TPD]**
Houston OGVs	21.087	0.878	1.875	2.879	2.303	37.472
Freeport OGVs	1.616	0.061	0.137	0.267	0.214	3.921
Galveston- Texas City OGVs	3.824	0.153	0.332	0.591	0.473	8.674
Houston MISC	4.268	0.149	1.086	0.168	0.162	0.100
Intracoastal Waterway	4.738	0.162	1.115	0.181	0.174	0.109
Total	**35.533**	**1.404**	**4.544**	**4.085**	**3.326**	**50.276**

Table 6. Port of Houston Ocean Going Vessels Emissions by Vessel Type (TPY).

Houston OGVs (TPY)						
Type	**NOx**	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Auto Carrier	99.22	4.14	8.47	9.85	7.88	83.91
Bulk	581.50	23.28	49.98	60.02	48.01	573.92
Bulk, Self Discharging	28.85	1.08	2.39	2.71	2.17	23.47
Chemical Tanker	637.31	26.94	56.67	115.36	92.29	1,811.47
Chemical/Products Tanker	2,125.21	85.53	185.81	350.98	280.78	5,173.91
Containership 1000	80.50	3.55	7.57	9.04	7.23	84.74
Containership 2000	165.54	8.56	17.07	16.89	13.51	133.58
Containership 3000	141.46	8.54	16.15	15.94	12.75	145.36
Containership 4000	228.65	11.77	23.58	25.20	20.16	218.66
Containership 5000	82.81	6.27	10.55	9.83	7.86	72.59
Containership 6000	70.57	4.38	8.16	8.38	6.71	66.64
Crude Tanker 1 – Handymax	72.14	2.91	6.16	12.01	9.61	184.92
Crude Tanker 2 – Panamax	132.07	5.79	12.34	21.68	17.35	327.91
Crude Tanker 3 – Aframax	876.87	35.95	76.64	131.09	104.87	1,889.24
Crude Tanker 4 – Suezmax	46.71	1.92	4.12	6.80	5.44	95.24
Cruise	17.88	0.58	1.38	1.82	1.46	16.07
General Cargo	853.26	33.02	72.42	101.86	81.48	1,104.75
Heavy Load Carrier	4.88	0.17	0.39	0.54	0.43	5.79
ITB/ATB	120.02	4.97	10.87	3.45	2.76	2.31
LPG Tanker	497.93	17.41	41.08	56.22	44.97	552.87
MISC	46.37	1.79	3.86	4.70	3.76	41.46
Ocean Towing	178.06	7.64	16.30	5.09	4.07	3.43
Other Tanker	155.86	6.20	13.17	14.84	11.87	135.90
Products Tanker	256.89	11.56	23.72	46.45	37.16	754.88
Reefer	42.19	1.43	3.38	4.70	3.76	44.34
Ro-Ro	154.12	4.98	12.05	15.40	12.32	129.77

Table 7. Freeport Ocean Going Vessels Emissions by Vessel Type.

Freeport (TPY)						
Type	**NOx**	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Auto Carrier	0.56	0.02	0.04	0.06	0.05	0.57
Bulk	7.43	0.25	0.60	0.81	0.65	7.75
Bulk, Self-Discharging	5.52	0.19	0.44	0.57	0.46	5.08
Chemical Tanker	36.49	1.46	3.16	7.65	6.12	129.46
Chemical/Products Tanker	169.94	6.68	14.67	33.09	26.47	535.62
Containership 1000	28.45	1.12	2.47	3.38	2.70	33.83
Crude Tanker 1 – Handymax	7.06	0.28	0.60	1.39	1.11	23.02
Crude Tanker 2 – Panamax	14.23	0.57	1.24	2.73	2.18	43.52
Crude Tanker 3 – Aframax	131.90	5.48	11.53	24.71	19.77	396.61
Crude Tanker 4 – Suezmax	11.47	0.48	1.02	2.09	1.68	32.75
General Cargo	48.96	1.61	3.92	5.89	4.72	61.41
Heavy Load Carrier	1.14	0.05	0.10	0.14	0.11	1.59
ITB/ATB	3.00	0.12	0.27	0.09	0.07	0.06
LNG Tanker	0.59	0.03	0.06	0.07	0.06	0.71
LPG Tanker	32.69	1.19	2.75	3.92	3.14	40.24
MISC	7.20	0.24	0.57	0.76	0.61	7.08
Products Tanker	7.61	0.33	0.69	1.73	1.39	30.38
Reefer	74.88	2.28	5.78	8.44	6.75	81.01
Ro-Ro	0.59	0.02	0.05	0.07	0.05	0.62

Table 8. Combined Galveston-Texas City Ports Ocean Going Vessels Emissions by Vessel Type.

Galveston and Texas City (TPY)						
Type	**NOx**	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Auto Carrier	20.10	0.70	1.63	2.11	1.69	20.05
Barge	1.93	0.08	0.17	0.06	0.04	0.04
Bulk	79.90	3.06	6.65	8.96	7.17	90.20
Bulk, Self-Discharging	1.03	0.03	0.08	0.11	0.09	0.96
Bulk/Oil(OBO)	1.58	0.06	0.13	0.15	0.12	1.26
Chemical Tanker	77.31	3.25	6.80	16.23	12.99	269.83
Chemical/Products Tanker	319.67	13.16	28.07	63.31	50.65	1,016.19
Containership 2000	1.19	0.04	0.10	0.13	0.10	1.15
Crude Tanker 1 – Handymax	15.55	0.62	1.34	3.20	2.56	53.26
Crude Tanker 2 – Panamax	51.88	2.18	4.62	10.37	8.30	167.17
Crude Tanker 3 – Aframax	298.85	13.02	26.50	55.61	44.49	871.46
Crude Tanker 4 – Suezmax	38.68	1.61	3.39	6.48	5.18	95.92
Crude Tanker 6 – ULCC	5.38	0.22	0.48	1.05	0.84	16.68
Cruise	133.21	4.98	10.81	14.42	11.54	149.94
Drill Rig	1.51	0.05	0.13	0.05	0.04	0.03
General Cargo	9.11	0.32	0.74	1.13	0.91	12.83
ITB/ATB	31.11	1.21	2.76	0.91	0.72	0.60
LNG Tanker	6.67	0.24	0.58	1.14	0.91	15.78
LPG Tanker	13.86	0.55	1.19	2.77	2.22	45.49
MISC	3.07	0.16	0.27	0.28	0.23	1.93
Military	0.81	0.03	0.06	0.08	0.07	0.67
Ocean Towing	22.57	0.78	1.94	0.67	0.54	0.43
Offshore	126.19	4.36	11.08	3.87	3.10	2.46
Other Tanker	1.55	0.07	0.14	0.26	0.21	4.00
Products Tanker	74.90	3.26	6.72	16.17	12.94	273.81
Reefer	35.33	1.19	2.86	3.74	2.99	32.90
Ro-Ro	22.81	0.77	1.79	2.32	1.86	21.06

Table 9. Port of Houston Miscellaneous Emissions by Vessel Type.

Houston – MISC (TPY)						
Type	**NOx**	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Assist Tug	10.26	0.59	5.57	0.80	0.78	0.23
Ocean Tug	41.49	1.76	3.70	2.41	2.33	0.71
Offshore	0.72	0.02	0.11	0.02	0.02	0.02
Push Boat	1,009.01	34.76	267.53	38.22	36.85	23.99
Tow Boat	397.24	14.42	103.53	16.56	16.00	9.18
Unknown	99.20	3.01	15.89	3.18	3.06	2.22

Table 10. Intracoastal Waterway Emissions by Vessel Type.

Intracoastal Waterway (TPY)						
Type	**NOx**	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Tow Boat	1,729.27	59.17	407.13	65.89	63.59	39.95

Comparison of Emissions Summaries to Port of Houston EI Summaries

As a quality assurance measure the emissions estimates generated for this work are compared to the Port of Houston EI (GMEI 2009). As expected, for NOx, ENVIRON's Port of Houston OGV emissions estimates are slightly higher (255.4 TPY) than the Port of Houston EI because additional shifts were included, this represents 3.3% of ENVIRON's estimates. Including miscellaneous sources in the Houston emissions inventory increases the NOx emissions by 1813.3 TPY, which represents an increase of 24.4% over the Port of Houston EI estimates.

Table 11. Comparison of Port of Houston EI (GMEI 2009) with emissions estimates developed by ENVIRON.

Emission Comparison in TPY						
	NOx	**VOC**	**CO**	**PM10**	**PM25**	**SO2**
Port of Houston EI, (Table 3.12)	7,441.5	310.8	662.9	1,027.4	822.0	13,463.3
ENVIRON Houston OGV	7,696.9	320.3	684.3	1,050.8	840.7	13,677.1
ENVIRON Houston MISC	1,557.9	54.6	396.3	61.2	59.0	36.4
ENVIRON Houston OGV + MISC	9,254.8	374.9	1,080.6	1,112.0	899.7	13,713.5
ENVIRON Total HGB Area	**12,969.5**	**512.4**	**1,658.7**	**1,491.1**	**1,213.9**	**18,350.8**

HISTORIC 2005 AND 2006 AND FORECAST 2018 EMISSIONS

Emissions inventories for 2005, 2006 and 2018 were adjusted from the 2007 emissions inventory. The activity growth (or reduction) and the emission control scenarios are provided as separate estimates to allow revised forecasts to be incorporated should better information become available. Because of the unique market conditions and emission control scenarios, the larger ocean going vessels are forecasted separately from the smaller harbor craft, tug, and other vessels.

Large vessels use large, so called Category 3, diesel engines (or in rare cases steam boilers or gas turbines), while the small vessels use Category 1 or 2 diesel engines. EPA has chosen to regulate Category 3 engines in a separate rulemaking (EPA, 2009) from smaller Category 1 or 2 engines (EPA, 2008). The rules for each type of engine are unique in stringency and implementation schedule, so the expected emission reductions are unique to each category.

Ocean Going Vessels (OGV)

This source category includes large vessels with deep drafts and Category 3 engines.

Growth Estimates 2005 and 2006

OGV activity estimates for 2005 and 2006 were determined using the vessel calls for the area ports. Table 12 shows vessel calls in 2005 and 2006 relative to those in 2007; this forms the activity adjustment for the historic years.

Table 12. OGV relative vessel calls.

Adjustment Factors by Port Region			
Port	**Y2007**	**Y2006**	**Y2005**
Freeport	1.0000	0.9218	0.9429
Galveston – Texas City	1.0000	0.9140	0.9318
Houston	1.0000	1.0247	0.9509
Average	**1.0000**	**0.9937**	**0.9465**

Growth Estimates 2018

Forecasting for the OGV category is difficult given the economic downturn beginning around 2006 as shown in Table 13. At least in the years immediately after 2007, no growth might overestimate the actual activity. While it is uncertain when the activity will recover to 2007, 2010 was estimated as the year when the activity would recover to 2007 levels.

Table 13. OGV port activity trends (port tonnage, ACE, 2010).

Port Tonnage	2008	2007	2006	2005	2004
Houston, TX	212,207,921	216,064,325	222,146,750	211,665,685	202,047,327
Texas City, TX	52,606,030	56,786,525	48,875,403	57,839,378	68,282,902
Freeport, TX	29,842,295	29,597,892	32,146,579	33,601,511	33,908,024
Galveston, TX	9,781,368	9,790,903	9,357,250	8,008,106	8,113,263
Total	**304,437,614**	**312,239,645**	**312,525,982**	**311,114,680**	**312,351,516**

EPA (2009) forecasted activity at high levels through 2010, which now seem an overestimate of the actual activity trend. Because of the downward trend in activity in 2008, no growth in activity was forecasted through 2010. The long term average trend in Gulf OGV activity growth that EPA forecasted, by ship type, was used for years 2011 and later, and is shown in Table 14.

Table 14. Individual ship type and Gulf average activity forecasts (EPA, 2009, Figures 3-13 and 3-15).

Ship Type	Activity Growth (% per year)
Container	4.85
Other	2.85
General Cargo	2.15
Chemicals	1.85
Dry Bulk	1.30
Crude Oil	1.30
Petroleum	1.30
Natural Gas	0.60
Passenger	-0.75
Gulf Average	**2.20***

* 2.00% in 2011 and 2012

Control Factors 2005, 2006 and 2018

The emission control scenarios utilized for this work are based on EPA (2009) forecasted emission factor adjustments shown in Table 15. The Emission Control Area (ECA), which includes the HGB 8-county region, was declared in EPA rulemaking, and controls within the ECA will be implemented before 2018, but EPA ECA controls were not implemented before 2007. However, starting in 2000, NOx emissions from large Category 3 engines have been regulated under international rules, so baseline emissions reductions are used to estimate the historic year NOx emissions. Interpolation of the baseline NOx estimates were used to estimate emission control factors through 2014. In 2015, under the ECA regulations, more stringent NOx controls and significant particulate matter (PM) controls begin, so more significant emission reduction should begin in 2015.

Table 15. OGV relative particulate matter and NOx emission factors (EPA, 2009 Table 3-77 and 3-78).

Main	2020 PM EF ECA	2020 NOx EF Baseline	2020 NOx EF ECA	2030 NOx EF ECA
SSD (slow speed diesel)	0.1352	0.9037	0.5967	0.3138
MSD (medium speed diesel)	0.1328	0.8987	0.5515	0.2559
ST (steam boiler)	0.1108	1	0.9524	0.9524
GT (gas turbine)	0.1108	1	0.9344	0.9344
Auxiliary				
Pass (passenger)	0.1328	0.9025	0.5869	0.3003
Other (all except passenger)	0.1550	0.9025	0.5940	0.3039
Average*	**0.13694**	**0.90308**	**0.59191**	**0.30702**

* Average estimated as 80% slow speed propulsion, 10% medium speed propulsion, and 10% auxiliary

Table 16 shows the combined the activity forecast and emission reductions used for this work. This work only estimated 2005, 2006, 2007, and 2018 emissions, so the exact implementation schedule (such as partial control of fuel sulfur prior to 2015) and other considerations were not included. Likewise, as data for 2010 and other years become available, the activity forecasts might be improved at a later date.

Table 16. OGV forecasted growth and emission control factors.

Year	Annual Growth (% per year)	Activity Factor	NOx Control (Relative to Precontrol)	NOx Control (Relative to 2007)	PM Control
2002	N/A	N/A	0.9903	1.0251	1.00
2003	N/A	N/A	0.9855	1.0201	1.00
2004	N/A	N/A	0.9806	1.0150	1.00
2005	**N/A**	**0.9465**	**0.9758**	**1.0100**	**1.00**
2006	**N/A**	**0.9937**	**0.9709**	**1.0050**	**1.00**
2007	**0**	**1.0000**	**0.9661**	**1.0000**	**1.00**
2008	0	1.0000	0.9612	0.9950	1.00
2009	0	1.0000	0.9564	0.9900	1.00
2010	0	1.0000	0.9515	0.9850	1.00
2011	2	1.0200	0.9467	0.9799	1.00
2012	2	1.0404	0.9418	0.9749	1.00
2013	2.2	1.0633	0.9370	0.9699	1.00
2014	2.2	1.0867	0.9322	0.9649	1.00
2015	2.2	1.1106	0.8754	0.9062	0.13694
2016	2.2	1.1350	0.8187	0.8475	0.13694
2017	2.2	1.1600	0.7620	0.7888	0.13694
2018	**2.2**	**1.1855**	**0.7053**	**0.7301**	**0.13694**
2019	2.2	1.2116	0.6486	0.6714	0.13694
2020	2.2	1.2382	0.5919	0.6127	0.13694
2021	2.2	1.2655	0.5634	0.5832	0.13694
2022	2.2	1.2933	0.5349	0.5537	0.13694
2023	2.2	1.3218	0.5064	0.5242	0.13694

Harbor Craft, Tug, and Other Smaller Vessels

Growth Factors 2005, 2006, and 2018

Smaller craft are found in a number of occupations including assist tugs, tow boats (tug and barge), and push boats. The activity of smaller vessels at ports primarily facilitates OGV activity, therefore the same growth rates as for OGV (Tables 12 - 14) are used for these vessels.

The ICW represents a unique activity category for which activity trend data exists. As Table 17 shows, 2008 represented a significant change in the activity trend from the previous years, and Table 18 shows that the most recent data for inland water transports only started to recover in 2010. For the ICW, the Table 6 activity trend was used to estimate 2005 and 2006 activity. Table 18 was used to forecast activity through 2010 from 2007, and then the OGV trend (2% per year thru 2012, and 2.2% per year after 2012) was used to adjust the 2010 activity forward. By 2018, this prediction estimates that the ICW activity just recovers to 2007 levels (1.033 time 2007 levels). The ICW growth factors are summarized in Table 19.

Table 17. ICW activity trend (tons, ACE, 2010; Name & Description: Gulf Intracoastal Waterway, Texas Portion- Section Included: Sabine River, TX to Mexican Border).

Year	2008	2007	2006	2005	2004	2003	2002
Tons	69,145,055	77,360,885	74,161,085	69,549,084	72,259,629	68,553,000	63,390,000
Relative	0.8938	1	0.959	0.899	0.934	0.886	0.819

Table 18. Overall, US inland waterway activity trends (millions of tons, ACE, 2010).

Year	Relative to 2007	Total Tonnage in Year	First 6 Months Tonnage in Year
2007	1.000	536.8	272.3
2008	0.917	492.4	241.6
2009	0.847	454.7	220.5
2010	0.871	-	237.1

Table 19. Summary of ICW growth factors.

Year	Estimated Growth	Growth Factor Relative to 2007
2005	**-**	**0.899**
2006	**-**	**0.959**
2007	-	1.000
2008	-	0.917
2009	-	0.847
2010	-	0.871
2011	1.02	0.888
2012	1.02	0.906
2013	1.022	0.926
2014	1.022	0.946
2015	1.022	0.967
2016	1.022	0.989
2017	1.022	1.010
2018	**1.022**	**1.033**

Control Factors 2005, 2006 and 2018

EPA (2008, Tables 3-45 thru 3-50) provides forecasted emissions that include a growth rate of 0.9% per year. By accounting for the growth rate and comparing the emission estimates to those for year 2007, a relative emission control factor was calculated. Tables 20- 24 show the control factors for the small (Category 1 and 2) commercial marine engines.

Table 20. Smaller commercial marine PM emission control factors.

Year	Cat. 1 Prop	Cat. 1 Aux	Subtotal Cat. 1	Cat. 2	<37kW	Total
2002	1.140	1.144	1.140	0.948	1.277	1.051
2003	1.160	1.158	1.160	0.959	1.235	1.065
2004	1.160	1.155	1.159	0.969	1.193	1.069
2005	**1.155**	**1.143**	**1.153**	**0.980**	**1.146**	**1.070**
2006	**1.144**	**1.126**	**1.141**	**0.990**	**1.097**	**1.068**
2007	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.888	0.904	0.891	0.990	0.916	0.939
2009	0.860	0.882	0.864	0.981	0.864	0.920
2010	0.820	0.851	0.825	0.970	0.809	0.895
2011	0.782	0.821	0.789	0.959	0.754	0.870
2012	0.726	0.782	0.736	0.948	0.701	0.837
2013	0.669	0.743	0.682	0.924	0.650	0.797
2014	0.614	0.706	0.629	0.810	0.604	0.716
2015	0.558	0.669	0.577	0.747	0.558	0.659
2016	0.503	0.631	0.524	0.735	0.517	0.626
2017	0.451	0.591	0.475	0.708	0.486	0.587
2018	**0.406**	**0.547**	**0.430**	**0.683**	**0.461**	**0.552**

Table 21. Smaller commercial marine NOx emission control factors.

Year	Cat. 1 Prop	Cat. 1 Aux	Subtotal Cat. 1	Cat. 2	<37kW	Total
2002	1.108	1.093	1.106	1.058	1.160	1.081
2003	1.101	1.088	1.099	1.048	1.135	1.072
2004	1.080	1.070	1.078	1.038	1.105	1.057
2005	**1.057**	**1.048**	**1.056**	**1.028**	**1.070**	**1.041**
2006	**1.035**	**1.027**	**1.034**	**1.018**	**1.035**	**1.026**
2007	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.966	0.974	0.967	0.962	0.966	0.964
2009	0.932	0.948	0.935	0.926	0.932	0.930
2010	0.900	0.923	0.903	0.893	0.899	0.898
2011	0.868	0.898	0.873	0.862	0.868	0.867
2012	0.834	0.872	0.840	0.834	0.837	0.837
2013	0.800	0.846	0.807	0.807	0.807	0.807
2014	0.764	0.814	0.772	0.759	0.769	0.765
2015	0.730	0.784	0.738	0.727	0.733	0.732
2016	0.688	0.752	0.698	0.693	0.701	0.695
2017	0.645	0.721	0.656	0.660	0.673	0.658
2018	**0.600**	**0.685**	**0.613**	**0.627**	**0.648**	**0.621**

Table 22. Smaller commercial marine VOC emission control factors.

Year	Cat. 1 Prop	Cat. 1 Aux	Subtotal Cat. 1	Cat. 2	<37kW	Total
2002	1.054	1.034	1.051	1.000	1.303	1.051
2003	1.054	1.034	1.051	1.000	1.239	1.047
2004	1.043	1.026	1.040	1.000	1.185	1.037
2005	**1.033**	**1.019**	**1.030**	**1.000**	**1.124**	**1.027**
2006	**1.022**	**1.011**	**1.021**	**1.000**	**1.061**	**1.017**
2007	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.978	0.989	0.980	1.000	0.940	0.983
2009	0.957	0.977	0.960	1.000	0.876	0.966
2010	0.936	0.966	0.941	1.000	0.813	0.950
2011	0.915	0.955	0.922	1.000	0.752	0.934
2012	0.884	0.938	0.893	1.000	0.693	0.912
2013	0.849	0.916	0.860	0.997	0.638	0.886
2014	0.802	0.881	0.815	0.968	0.584	0.845
2015	0.757	0.848	0.772	0.940	0.534	0.806
2016	0.708	0.814	0.725	0.909	0.492	0.764
2017	0.659	0.779	0.678	0.870	0.461	0.720
2018	**0.610**	**0.742**	**0.631**	**0.832**	**0.436**	**0.677**

Table 23. Smaller commercial marine CO emission control factors.

Year	Cat. 1 Prop	Cat. 1 Aux	Subtotal Cat. 1	Cat. 2	<37kW	Total
2002	1.093	1.109	1.095	1.018	1.244	1.055
2003	1.081	1.094	1.083	1.018	1.198	1.049
2004	1.069	1.075	1.070	1.018	1.149	1.042
2005	**1.057**	**1.056**	**1.057**	**1.018**	**1.099**	**1.036**
2006	**1.028**	**1.028**	**1.028**	**1.009**	**1.049**	**1.018**
2007	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.972	0.973	0.972	0.991	0.952	0.983
2009	0.946	0.946	0.946	0.982	0.904	0.965
2010	0.920	0.920	0.920	0.974	0.857	0.949
2011	0.894	0.894	0.894	0.965	0.812	0.933
2012	0.870	0.869	0.870	0.957	0.768	0.917
2013	0.846	0.845	0.846	0.949	0.726	0.902
2014	0.824	0.821	0.823	0.941	0.686	0.887
2015	0.802	0.798	0.802	0.933	0.653	0.873
2016	0.784	0.776	0.783	0.925	0.629	0.860
2017	0.768	0.755	0.766	0.918	0.610	0.849
2018	**0.755**	**0.735**	**0.752**	**0.910**	**0.594**	**0.838**

Table 24. Smaller commercial marine SOx emission control factors.

Year	Cat. 1 Prop	Cat. 1 Aux	Subtotal Cat. 1	Cat. 2	<37kW	Total
2002	1.980	1.980	1.980	1.000	1.975	1.366
2003	1.980	1.980	1.980	1.000	1.977	1.366
2004	1.980	1.981	1.980	1.000	1.978	1.366
2005	**1.980**	**1.981**	**1.980**	**1.000**	**1.978**	**1.366**
2006	**1.943**	**1.944**	**1.943**	**1.000**	**1.942**	**1.352**
2007	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.326	0.326	0.327	0.998	0.328	0.748
2009	0.326	0.326	0.326	0.999	0.327	0.748
2010	0.240	0.240	0.240	0.999	0.239	0.715
2011	0.177	0.177	0.177	0.999	0.177	0.692
2012	0.093	0.093	0.093	0.999	0.094	0.661
2013	0.033	0.033	0.033	0.981	0.034	0.627
2014	0.039	0.039	0.039	0.520	0.039	0.340
2015	0.042	0.042	0.042	0.190	0.043	0.135
2016	0.042	0.042	0.042	0.187	0.043	0.133
2017	0.042	0.042	0.042	0.140	0.043	0.103
2018	**0.042**	**0.042**	**0.042**	**0.108**	**0.042**	**0.083**

EPS3 FORMATTING AND MODELING

For the emissions to be processed by the EPS3 PRESHP module, they must be in a link-based format that specifies emissions on individual links that are straight lines defined by two end points where each endpoint has a non-zero width. Therefore all vessel routes are broken into multiple line segments. See Figure 3 for a depiction of a shipping lane link that is processed by EPS3 PRESHP.

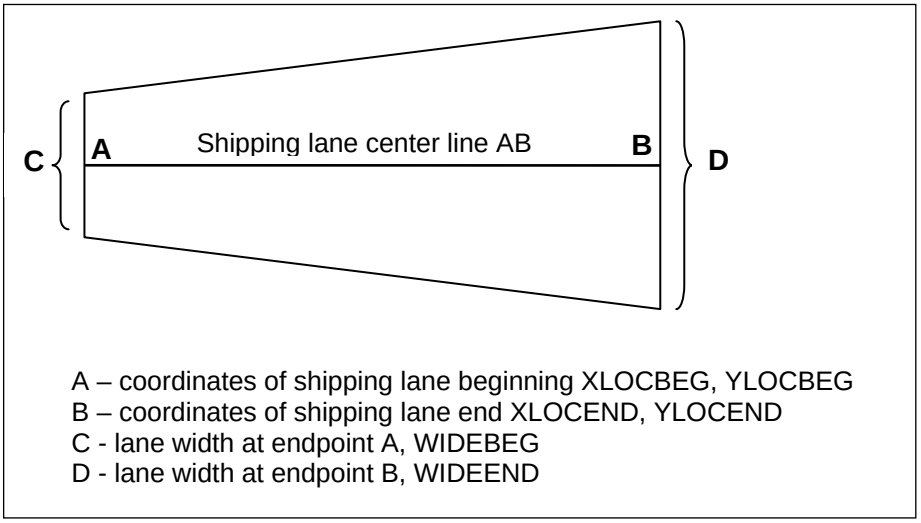

Figure 3. Schematic of shipping lane link for PRESHP.

Therefore the emissions input requirement for EPS3 PRESHP includes endpoint locations and endpoint widths for every shipping link in the inventory. Within the ICW and other inland locations, shipping lane widths were specified as 100m wide, within the Galveston Bay shipping land widths were set at 500m, and when shipping lanes headed into the open ocean the endpoints were defined as 4km wide at the ocean end and either 500m or 100m at the shore-side end.

Two ship-specific components of the EPS3 modeling system were utilized, as well as the control application module:

1. PRESHP
2. PSTSHP
3. CNTLEM

Other EPS3 modules were run to test the shipping emissions and produce spatial plots.

PRESHP

A major component of the work assignment was to format the emissions into a format that is EPS3 PRESHP-ready. The main task was to create a shipping input file that is in the format described by Table 25. To manipulate the data into the required format excel and PERL scripts were utilized and the ship link endpoint coordinates were converted to the standard TCEQ LCP projection. Additionally, vessel types were classified and assigned an SCC code from the list in Table 26. To test the shipping input file, PRESHP was run at three different grid cell resolutions: 1km, 2km, and 4km. The model was first tested using the 2007 emissions, after PRESHP was run the standard area source EPS3 processing stream was also applied to allocate all shipping emissions to layer 1.

PRESHP → SPCEMS → TMPRL → GRDEM

For more detail about input requirements and model set-up for the PRESHP module see the report ENVIRON 2009. Table 27 shows part of the PRESHP message file that summarizes domain-wide input and output emissions of the EPS3 PRESHP program, when PRESHP was run for the 2km domain. Note that the input emissions match those in Table 5 and the output emission summary are slightly higher due to round off error caused by summing emissions over many grid cells. Gridded modeling results of PRESHP run at 1km, 2km and 4km resolution are shown in Figures 4a-c, respectively.

Table 25. Format of shipping input file for PRESHP.

Line	Variable	Columns	Type	Description
1+	INFIPS	1-5	C	FIPS state/county/shipping lane code
	INSBRG	7-11	C	Subregion code (port ID) (optional)
	INSCC	13-22	C	Standard Industrial Classification (SCC)
	INVESL	24-33	C	Vessel Type (optional)
	IPEROD	35-36	C	Period Type Blank = annual PO = Peak O3 typical weekday PC = Peak CO typical weekday AD = Average Day S = Specified interval
	IBEGDT	38-45	I	Begin Period (YYMMDDHH)
	IENDDT	47-54	I	End Period (YYMMDDHH)
	XLOCBEG	56-65	R	X coordinate of beginning of channel link (km)
	YLOCBEG	67-76	R	Y coordinate of beginning of channel link (km)
	WIDEBEG	78-87	R	Channel width at beginning of channel (km)
	XLOCEND	89-98	R	X coordinate of end of channel link (km)
	YLOCEND	100-109	R	Y coordinate of end of channel link (km)
	WIDEEND	111-120	R	Channel width at end of channel (km)
	INZONE	122-123	I	UTM Zone (or zero)
	INPOL	125-129	I	Pollutant Code
	EMISSHIP	131-140	R	Emissions of specified pollutant Units depend on the Period Type Annual = tons/year PO/PC = tons/typical weekday AD = tons/average day S = tons/period (the period is specified using the beginning and ending time fields)

Table 26. SCC list.

SCC	Description
2280002021	Assist Tugboats
2280002023	Towboats
2280003011	Bulk Cargo Vessel
2280003012	General Cargo Vessel
2280003013	Container Ships
2280003014	Liquefied Gas Carrier
2280003015	Oil/Chemical Tankers
2280003016	Other Ocean-going Vessel
2280003017	Cruise Ships
2280003019	Roro/Auto
2280003020	Misc
2280003023	Military

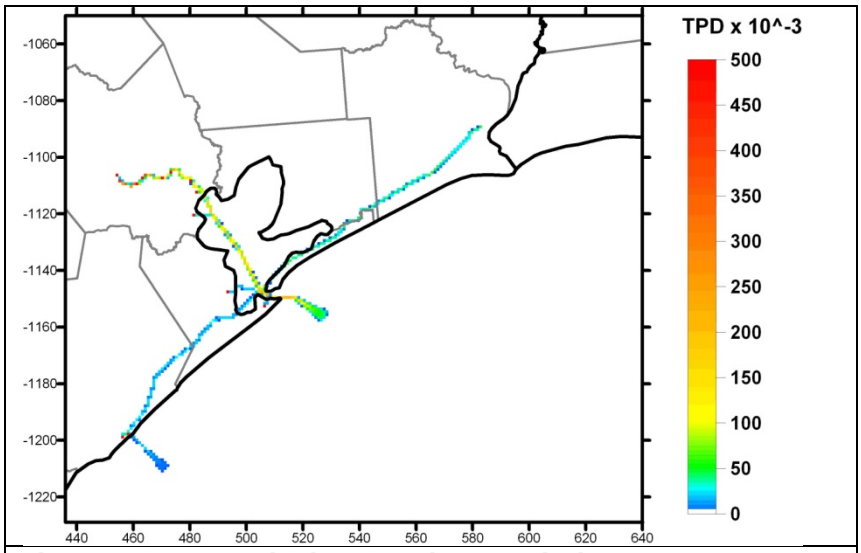

Figure 4a.NOx emissions at 1km resolution.

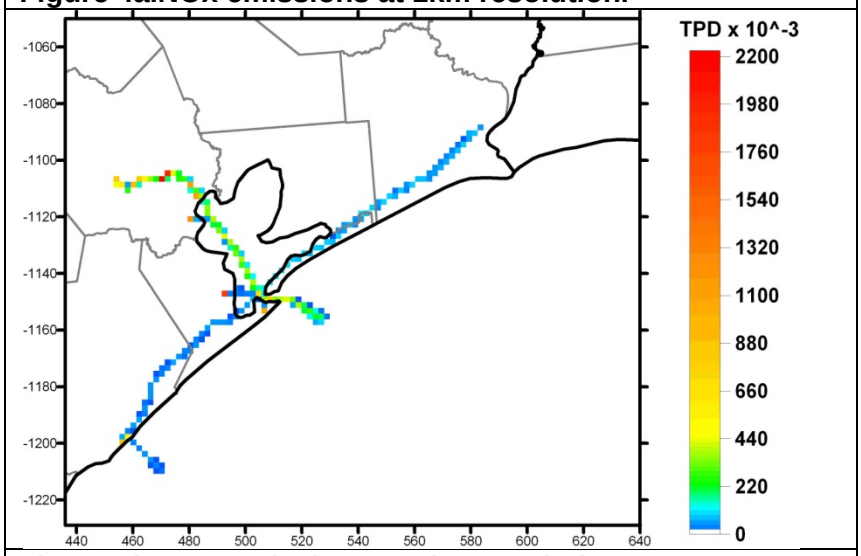

Figure 4b.NOx emissions at 2km resolution.

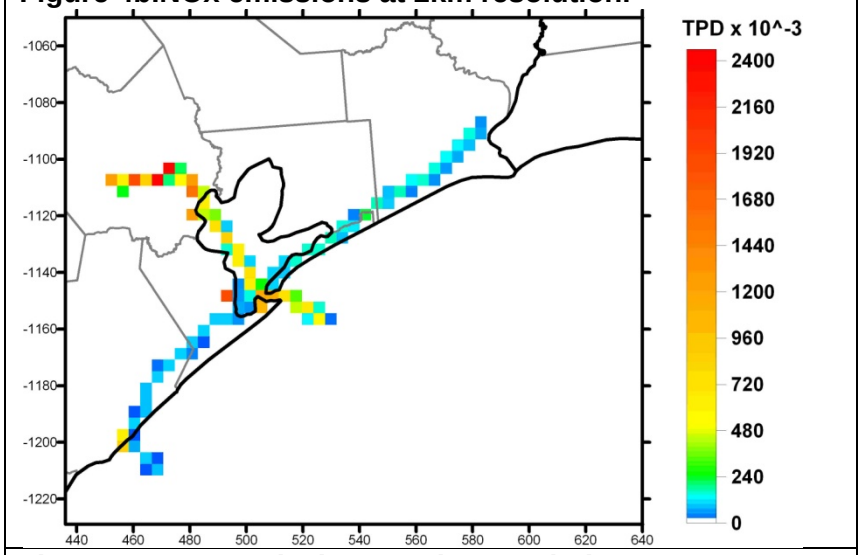

Figure 4c. NOx emissions at 4km resolution.

Table 27. Input emissions reported by PRESHP message file, run at 2km resolution.

2007						
Port	**NOx [TPD]**	**VOC [TPD]**	**CO [TPD]**	**PM10 [TPD]**	**PM25 [TPD]**	**SO2 [TPD]**
Houston OGVs	21.087	0.878	1.883	2.879	2.303	37.471
Freeport OGVs	1.617	0.061	0.137	0.268	0.214	3.928
Galveston- Texas City OGVs	3.825	0.153	0.334	0.591	0.473	8.679
Houston MISC	4.268	0.150	1.086	0.168	0.162	0.100
Intracoastal Waterway	4.738	0.162	1.116	0.181	0.174	0.110
Total	35.5352	1.404	4.555	4.086	3.326	50.286

Table 28. Total input and output emissions reported by PRESHP message file.

Total Emissions Processed
English Tons/Day

	NOX	CO	VOC	SO2	PM10	PM25
Input Emissions	35.5354	4.5447	1.4040	50.2866	4.0858	3.3261
Output Emissions	35.6516	4.5550	1.4089	50.3662	4.0954	3.3338
Outside Region	0.	0.	0.	0.	0.	0.
Written to ERR file	0.	0.	0.	0.	0.	0.
Total Skipped	0.	0.	0.	0.	0.	0.

PSTSHP

PSTSHP determines the distribution of shipping emissions to vertical layers. Plume heights of the vessel classes in the inventory are presented in Table 29. Emissions allocated to the vertical layers calculated by PSTSHP are presented in Table 30.

Table 29. SCC xref file used to assign stack/plume heights to each vessel type.

SCC	Plume Bottom (m)	Plume Top (m)	Ship Description
2280002021	7	10	Assist Tugboats
2280002023	7	10	Towboats
2280003011	40	60	Bulk Cargo Vessel
2280003012	40	60	General Cargo Vessel
2280003013	40	60	Container Ships
2280003014	50	60	Liquefied Gas Carrier
2280003015	55	60	Oil/Chemical Tankers
2280003016	40	60	Other Ocean-going Vessel
2280003017	50	60	Cruise Ships
2280003019	34	58	Roro /Auto
2280003020	34	58	Misc
2280003023	40	55	Military

Table 30. Emission percentages allocated to layers 1 and 2.

% Emissions						
Layer	**NOX**	**CO**	**VOC**	**SO2**	**PM10**	**PM25**
1	27.6	49.8	24.7	0.4	9.1	10.6
2	72.4	50.2	75.3	99.6	90.9	89.4

CNTLEM

To test the growth and control projections, the EPS3 model was run with the CNTLEM module for 2005, 2006, and 2018. Growth and controls can be applied by FIPS code and/or SCC number. The growth and control factors implementation strategy is presented below. Various port regions of the EI were assigned different "FIPS" codes, as shown in Table 31. 2005 and 2006 growth factors are based on FIPS code only, since historical activity data is available for each port. As discussed in the previous chapter the ICW is treated specially, and Houston –MISC is assigned the same growth factors as Houston OGV. The 2005 and 2006 growth factors are summarized in Table 32. 2018 growth factors are implemented by a combination of FIPS codes and SCC codes since growth factors by vessel type are known, the 2018 growth factors are presented in Table 33. Note for each SCC in the OGV categories an EPA vessel match was performed with the vessels types in Table 16, and the growth rates in Table 16 were used to get 2018 growth factors assuming flat growth from 2007 to 2010 and then growth according to the factors in Table 16 from 2011 to 2018. Control factors for all years are based on SCC code only, with the only SCC distinction being between OGVs and small vessels. OGV have SCC codes that end in 3xxx and smaller craft have SCCs that end in 2xxx. Control factors for all years are presented in Table 34. Sample growth and control factors files can be seen in Figures 5 and 6. The effect of growth and controls on the total emissions after processing through EPS3 CNTLEM module are shown in Tables 35 – 37. Spatial plots of emissions for 2005, 2006, 2007 and 2018 are shown in Figures 7a-d and 8a-d.

The processing stream for the CNTLEM modules is

PRESHP → CNTLEM (growth) → CNTLEM (controls) →SPCEMS → TMPRL → GRDEM

Table 31. Inventory components to FIPS code assignment.

Inventory Component	"FIPs" code
Houston OGV	48000
Freeport OGV	48039
Gal-Tex OGV	48167
Houston - MISC	TOW48
ICW	ICWTR

Table 32. Growth Factors for 2005 and 2006 by FIPS.

FIPS	2005	2006
48000	0.9509	1.0247
48039	0.9429	0.9218
48167	0.9318	0.914
TOW48	0.9509	1.0247
ICWTR	0.899	0.959

Table 33. Growth Factors for 2018 by FIPS and SCC.

FIPS	SCC	Description	Gross Factor	EPA Match
TOW48	all	miscellaneous vessels	1.1855	general cargo
ICWTR	all	ICW - vessels	1.033	NA
48000, 48039, 47167	2280003011	OGV - bulk goods	1.1089	bulk
48000, 48039, 47167	2280003012	OGV - general cargo	1.1855	general cargo
48000, 48039, 47167	2280003013	OGV - container ships	1.4607	container
48000, 48039, 47167	2280003014	OGV - liquefied gas	1.049	natural gas
48000, 48039, 47167	2280003015	OGV - oil/chemical tanker	1.1579	chemicals
48000, 48039, 47167	2280003016	OGV - reefer and other	1.2521	other
48000, 48039, 47167	2280003017	OGV - cruise	0.9416	passenger
48000, 48039, 47167	2280003019	OGV - auto and roro	1.2521	other
48000, 48039, 47167	2280003020	OGV - misc	1.2521	other
48000, 48039, 47167	2280003023	OGV - military	1.2521	other
48000, 48039, 47167	2280002021	Assist Tugboats	1.1855	general cargo
48000, 48039, 47167	2280002023	Towboats	1.1855	general cargo

Table 34.Control Factors for 2005, 2006 and 2018.

Year	Vessel Type	SCC	NOx	CO	VOC	SO2	PM10	PM25
2005 controls	OGV	2280003xxx	1.010	1.000	1.000	1.000	1.000	1.000
2005 controls	smaller craft	2280002xxx	1.041	1.036	1.027	1.366	1.070	1.070
2006 controls	OGV	2280003xxx	1.005	1.000	1.000	1.000	1.000	1.000
2006 controls	smaller craft	2280002xxx	1.026	1.018	1.017	1.352	1.068	1.068
2018 controls	OGV	2280003xxx	0.730	1.000	1.000	0.189	0.137	0.137
2018 controls	smaller craft	2280002xxx	0.621	0.838	0.677	0.083	0.552	0.552

```
#  growth factors to backcast 2007 tceq hgb shipping inventory to 2005

/SOURCE CATEGORY/
TOW48          0000000000   0.9509  0.9509  0.9509  0.9509  0.9509  0.9509  0.9509
ICWTR          0000000000   0.8990  0.8990  0.8990  0.8990  0.8990  0.8990  0.8990
48000          0000000000   0.9509  0.9509  0.9509  0.9509  0.9509  0.9509  0.9509
48039          0000000000   0.9429  0.9429  0.9429  0.9429  0.9429  0.9429  0.9429
48167          0000000000   0.9318  0.9318  0.9318  0.9318  0.9318  0.9318  0.9318
/END/
```

Figure 5.Sample growth factor file for 2005.

Figure 6. Sample control factor file for 2005.

```
# control factors to backcast 2007 tceq hgb shipping inventory to 2005

/SOURCE CATEGORY/
00000   2280003011   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003012   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003013   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003014   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003015   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003016   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003017   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003019   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003020   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280003023   1.0100   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000
00000   2280002021   1.0410   1.0360   1.0270   1.3660   1.0700   1.0700   1.0000
00000   2280002023   1.0410   1.0360   1.0270   1.3660   1.0700   1.0700   1.0000
```

Table 35. Output of EPS3 CNTLEM, 2005 emissions summary.

2005						
Port	**NOx [TPD]**	**VOC [TPD]**	**CO [TPD]**	**PM10 [TPD]**	**PM25 [TPD]**	**SO2 [TPD]**
Houston OGVs	20.362	0.839	1.793	2.746	2.197	35.696
Freeport OGVs	1.540	0.058	0.129	0.252	0.202	3.703
Galveston- Texas City OGVs	3.629	0.144	0.312	0.553	0.442	8.104
Houston MISC	4.435	0.150	1.039	0.174	0.168	0.134
Intracoastal Waterway	4.226	0.146	1.070	0.171	0.165	0.129
Total	**34.192**	**1.336**	**4.342**	**3.896**	**3.174**	**47.767**

Table 36. Output of EPS3 CNTLEM, 2006 emissions summary.

2006						
Port	**NOx [TPD]**	**VOC [TPD]**	**CO [TPD]**	**PM10 [TPD]**	**PM25 [TPD]**	**SO2 [TPD]**
Houston OGVs	21.825	0.904	1.931	2.959	2.368	38.466
Freeport OGVs	1.498	0.057	0.126	0.247	0.197	3.621
Galveston- Texas City OGVs	3.540	0.141	0.306	0.542	0.434	7.949
Houston MISC	4.662	0.158	1.089	0.185	0.179	0.142
Intracoastal Waterway	4.488	0.156	1.133	0.184	0.177	0.138
Total	**36.015**	**1.415**	**4.584**	**4.117**	**3.355**	**50.315**

Table 37. Output of EPS3 CNTLEM, 2018 emissions summary.

2018						
Port	**NOx [TPD]**	**VOC [TPD]**	**CO [TPD]**	**PM10 [TPD]**	**PM25 [TPD]**	**SO2 [TPD]**
Houston OGVs	18.217	1.041	2.230	0.478	0.382	8.295
Freeport OGVs	1.393	0.072	0.162	0.043	0.035	0.866
Galveston- Texas City OGVs	3.207	0.175	0.381	0.095	0.076	1.881
Houston MISC	3.040	0.113	0.966	0.103	0.099	0.009
Intracoastal Waterway	3.143	0.120	1.079	0.110	0.106	0.010
Total	**29.000**	**1.522**	**4.817**	**0.829**	**0.698**	**11.061**

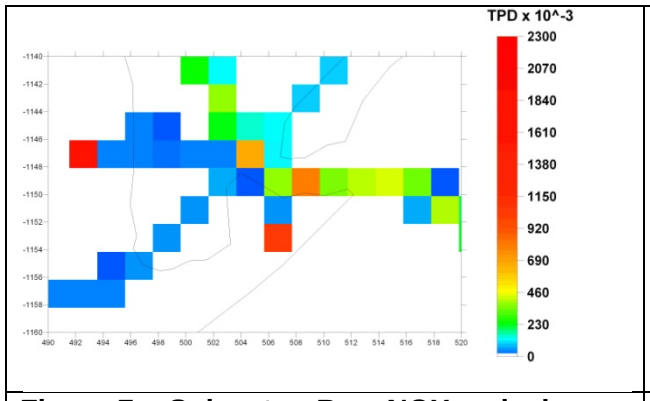

Figure 7a. Galveston Bay NOX emissions 2005

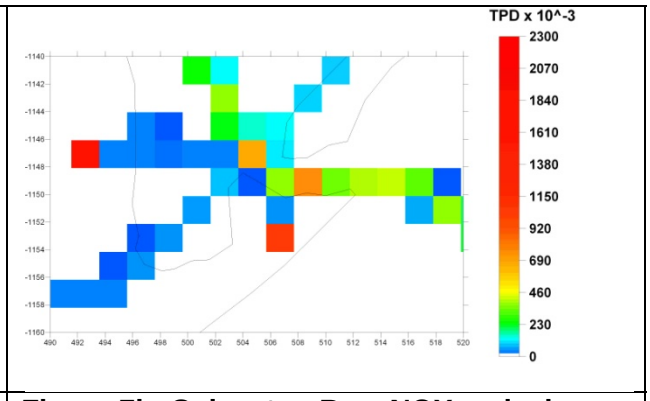

Figure 7b. Galveston Bay NOX emissions 2006

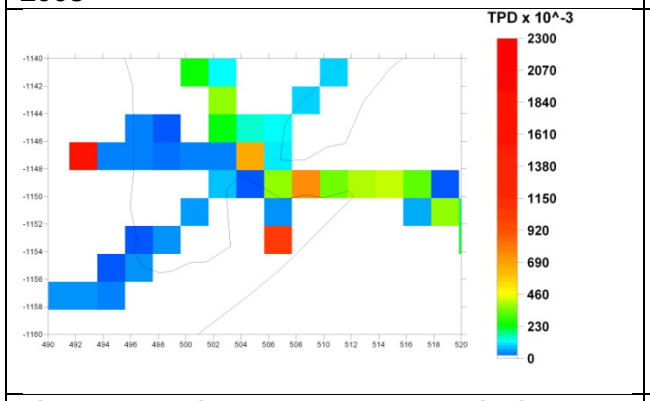

Figure 7c. Galveston Bay NOX emissions 2007

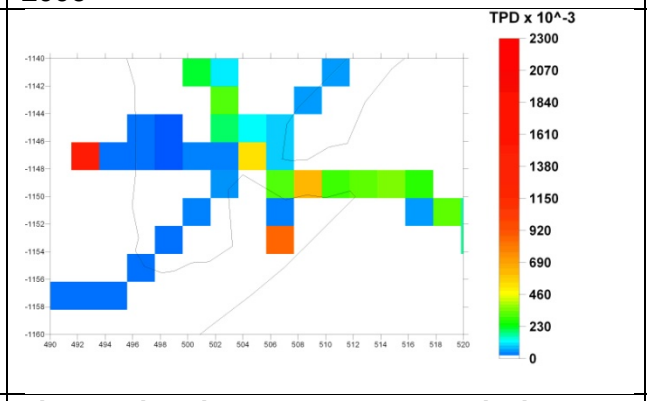

Figure 7d. Galveston Bay NOX emissions 2018

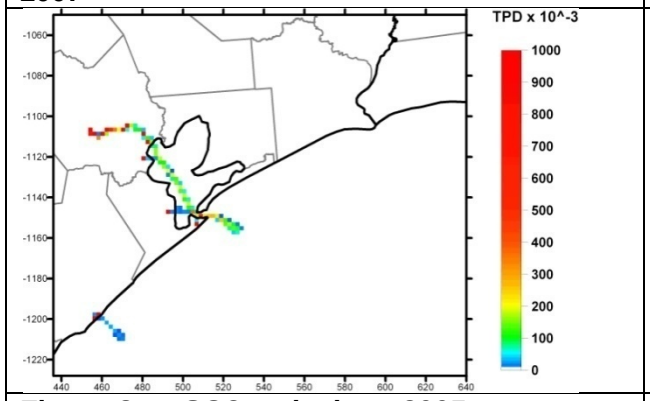

Figure 8a. SO2 emissions 2005

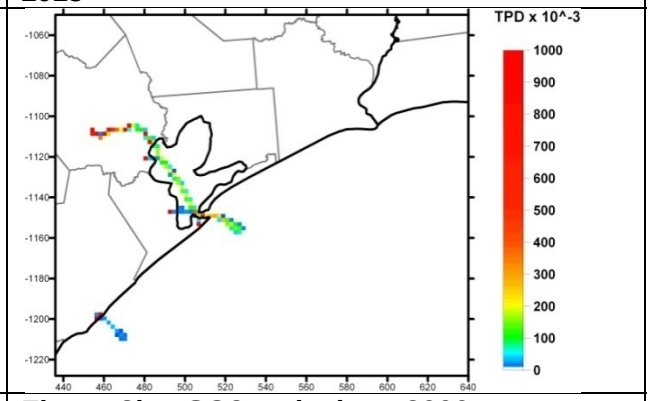

Figure 8b. SO2 emissions 2006

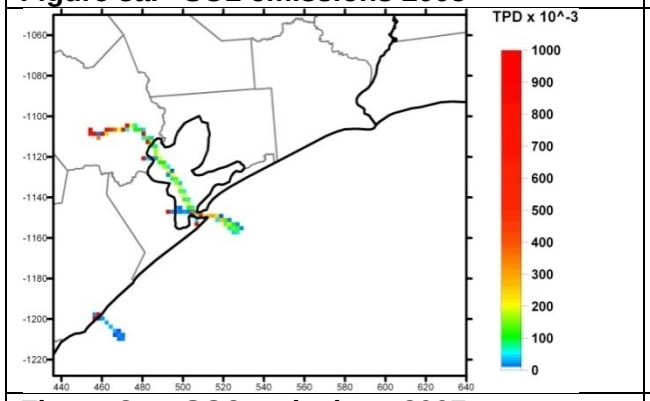

Figure 8c. SO2 emissions 2007

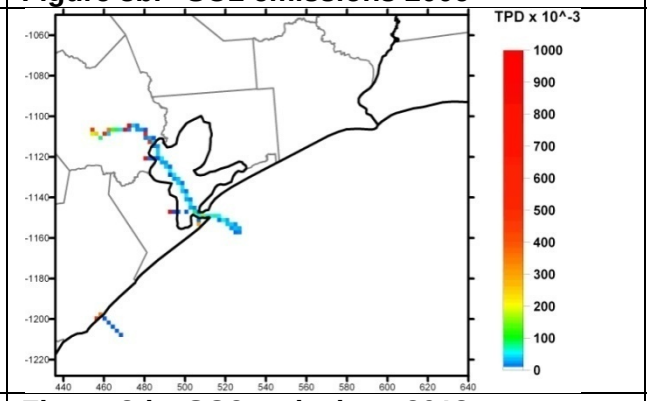

Figure 8d. SO2 emissions 2018

CONCLUSIONS

The current work revised the 2007 commercial marine vessels emission inventory for the most significant commercial marine vessel categories including ocean going vessels, tugs, push boats, and large support vessels. Vessel activity for the Ports of Texas City, Galveston, and Freeport and the Intracoastal Waterway was combined with Port of Houston vessel activity to create a complete Houston-Galveston-Brazoria 8-county area commercial marine emission inventory. Also included are revised emission control forecasts including the 2009 EPA Emission Control Area (ECA) rule, the emission control forecasts are expected to produce significant emission reductions near ports. Lastly, revised growth forecasts were prepared that account for vessel activity between 2007 and 2010 that show little or no growth in those years, this revises future year forecasts lower than previous estimates.

FUTURE WORK

Suggested future work is to determine emissions from vessel activity for smaller commercial marine vessels including fishing boats, excursion, small offshore support vessels, and other vessels not already specifically included in current emissions inventories. Additionally, the spatial allocation of shipping emissions for other Texas ports and Louisiana ports could be compared to recent EPA inventories and potentially improved.

REFERENCES

ACE. 2010. "2008 Waterborne Commerce, Army Corps of Engineers," available online at: http://www.ndc.iwr.usace.army.mil/wcsc/wcmthind.htm.

ENVIRON. 2009. "Shipping Lane Processing for EPS3 and TexAQS II Ship Emissions Rate Data Comparison to Enhance the Shipping Emissions Inventory for TCEQ Modeling." Final Report, August 2009.

EPA. 2008. "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder." EPA420-R-08-001a, May 2008.

EPA. 2009. "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines." EPA-420-R-09-019, December 2009.

ICF. 2009, "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories." Final Report, April 2009.

Port of Houston. 2009. "2007 Goods Movement Air Emissions Inventory." Port of Houston Authority, January 2009 prepared by Starcrest Consulting Group. (GMEI 2009).

APPENDIX A

Detailed Vessel to SCC Matching

Table A-1. Vessel Matching for all vessel types in inventory.

Inventory vessel Types	Match with vessel types with defined SCCs	SCC
Auto Carrier	Roro Sabine Pass	2280003019
Barge	Towboats	2280002023
Bulk	Bulk Cargo Vessel	2280003011
Bulk, Self Discharging	Bulk Cargo Vessel	2280003011
Bulk, Self-Discharging	Bulk Cargo Vessel	2280003011
Bulk/Oil(OBO)	Bulk Cargo Vessel	2280003011
Chemical Tanker	Oil/Chemical Tankers	2280003015
Chemical/Products Tanker	Oil/Chemical Tankers	2280003015
Containership 1000	Container Ships	2280003013
Containership 2000	Container Ships	2280003013
Containership 3000	Container Ships	2280003013
Containership 4000	Container Ships	2280003013
Containership 5000	Container Ships	2280003013
Containership 6000	Container Ships	2280003013
Crude Tanker 1 - Handymax	Oil/Chemical Tankers	2280003015
Crude Tanker 2 - Panamax	Oil/Chemical Tankers	2280003015
Crude Tanker 3 - Aframax	Oil/Chemical Tankers	2280003015
Crude Tanker 4 - Suezmax	Oil/Chemical Tankers	2280003015
Crude Tanker 6 - ULCC	Oil/Chemical Tankers	2280003015
Cruise	Cruise Ships	2280003017
Drill Rig	Towboats	2280002023
General Cargo	General Cargo Vessel	2280003012
Heavy Load Carrier	Other Ocean-going Vessel	2280003016
ITB/ATB	Towboats	2280002023
LNG Tanker	Liquefied Gas Carrier	2280003014
LPG Tanker	Liquefied Gas Carrier	2280003014
Military	Military Sabine Pass	2280003023
MISC	Misc Sabine Pass	2280003020
Ocean Towing	Towboats	2280002023
Offshore	Other Ocean-going Vessel	2280003016
Other Tanker	Oil/Chemical Tankers	2280003015
Products Tanker	Oil/Chemical Tankers	2280003015
Reefer	Other Ocean-going Vessel	2280003016
Ro-Ro	Roro Sabine Pass	2280003019
UNKNOWN	Other Ocean-going Vessel	2280003016
Bulk_ Self-Discharging	Bulk Cargo Vessel	2280003011
ASSIST TUG	Assist Tugboats	2280002021
OCEAN TUG	Towboats	2280002023
OFFSHORE	Towboats	2280002023
PUSH BOAT	Towboats	2280002023
TOW BOAT	Towboats	2280002023
UNKNOWN	Towboats	2280002023