Emissions Calculations Inputs Page 1

		Vessel Calls By Alternative															
		No-Action Alternative				Inner Harbor Only - Alternative B				Outer Harbor TB Only - Alternative C				Both Harbors - Alternatives D-1, D-2 (Preferred Alternative)			
	Vessel Class	2030 -2039	2040 - 2049	2050 - 2059	2060 - 2079	2030 -2039	2040 - 2049	2050 - 2059	2060 - 2079	2030 -2039	2040 - 2049	2050 - 2059	2060 - 2079	2030 -2039	2040 - 2049	2050 - 2059	2060 - 2079
Container Ship - Barges	SPX	128	134.5	141	141	103	92.5	82	82	119	116	112	112	94	73.5	53	53
	Panamax	233	179	125	125	199	132	65	65	210	149	88	88	176	102	28	28
	PPX Gen I	536	530.5	525	525	405	372	339	339	460	387	314	314	329	228.5	128	128
	PPX Gen II	580	649	718	718	582	618.5	655	655	548	528	507	507	550	497	444	444
	PPX Gen III	319	518	717	717	419	625.5	832	832	391	607	822	822	491	714	937	937
	PPX Gen IV	27	149.5	272	272	43	204.5	366	366	48	244	440	440	64	299	534	534
	Idling Hours	7.3850795	6.2314279	5.3895116	5.3895116	7.5602513	6.4733496	5.6596836	5.6596836	6.6649775	5.8324711	5.1848445	5.1848445	7.0305164	6.2591432	5.6403013	5.6403013

Emissions Calculations Inputs Page 2

Engine Specifications by Activity												Emissions Factors Main Engines				Emissions Factors Auxillary Engines			
Engine Quantities						3 mile line to Port - Time and Load Factor				Idling - Speed and Load Factor									
Main Engine Quantity	Main Engine Power Rating (HP)	Main Engine Power Rating (kW)	Auxiliary Engine Quantity	Auxillary Engine Power Rating (HP)	Auxillary Engine Power Rating (kW)	Speed (kts)	Speed (MPH)	Load Factor	Duration per call (ingress and egress) (hours)	Speed (kts)	Load Factor	CO (g/kWh)	CO2 (g/kWh)	CH4 (g/kWh)	N2O (g/kWh)	CO (g/kWh)	CO2 (g/kWh)	CH4 (g/kWh)	N2O (g/kWh)
1	28500	21252.45	2	3352.55	2500.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0003	0.033228
1	49707	37066.51	4	3218.45	2400.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0003	0.033228
1	93160	69469.41	4	4023.07	3000.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0003	0.033228
1	93322	69590.22	5	3486.66	2600.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0003	0.033228
1	68238	50885.08	4	5364.09	4000.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0004	0.033228
1	84812	63244.31	4	5498.19	4100.00	20	23	0.90	1.5	N/A	0.20	2	679.47	0.0004	0.033228	2	679.47	0.0004	0.033228

Emissions factors for containerships main and auxillary engines were obtained from Table H.6 and H.7 of the EPA Port Emissions Inventory Guidance with exception for nitrous oxide which was obtained from equation 4.3 in the EPA Port Emissions Inventory Guidance.

Table H.7. Average Harbor Craft Emission Factors by Engine Tier

Tier	NOx (g/kWh)	PM_{10} (g/kWh)	$PM_{2.5}$ (g/kWh)	VOC (g/kWh)	CO (g/kWh)	CO_2 (g/kWh)	SO_2 (g/kWh)
Tier 0	10.28152	0.258902	0.251135	0.295615	1.612632	679.47	0.006246
Tier 1	9.624039	0.258902	0.251135	0.295615	1.61	679.47	0.006246
Tier 2	5.642273	0.148049	0.143608	0.295615	0.918732	679.47	0.006246
Tier 3	4.749214	0.082975	0.080486	0.124798	0.918732	679.47	0.006246
Tier 4	1.3	0.03	0.0291	0.124798	0.918732	679.47	0.006246

USEPA. 2020. Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions, Available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10102U0.pdf. Accessed July 2021.

4.5.5 Nitrous Oxide (N_2O)

N_2O emission factors can be estimated from BSFC using Equation 4.3:

$$EF_{N_2O} = BSFC \times NCF \qquad \textbf{Equation 4.3}$$

Where EF_{N_2O} = N_2O emission factor (g/kWh)
$BSFC$ = brake specific fuel consumption (g/kWh) as determined according to Section 4.5.2
NCF = N_2O conversion factor (g N_2O/g fuel)
= 0.000156 for C1 and C2 engines[38]

4.5.2 Brake Specific Fuel Consumption (BSFC)

BSFC rates vary by engine power range. Note that particulate matter, carbon dioxide, nitrous oxide, and sulfur dioxide are calculated based on these values. BSFC rates for C1 and C2 engines are presented in Table 4.3.[17]

Table 4.3. Category 1 and 2 BSFC Rates (g/kWh)

Power Range	BSFC (g/kWh)
kW < 37	248
kW ≥ 37	213

USEPA. 2020. Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions, Available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10102U0.pdf. Accessed July 2021.

Assumptions:
17 miles from 3 mile limit to the Port

Idling Times by Alternative- obtained from Economic Analysis				
	No-Action	Alternative B	Alternative C	Alternative D-1 & D-2
Annual Idling time	13463	13238	11837	11980

$$CO_2eq = X*CO + X*CO_2 + Y*N_2O + Z*CH_4$$

Where X = 100 Year Global Warming Potential for Carbon Monoxide and Carbon Dioxide = 1

Where Y = 100 Year Global Warming Potential for Nitrous Oxide = 298

Where Z = 100 Year Global Warming Potential for Methane = 25

CFR Title 40 Chapter I Subchapter C Part 98: Table A-1 Global Warming Potentials

Example Calculation:
Emissions (CO, CO_2, CH_4, N_2O) = Vessel Quantity(Main Engine Quantity*Main Engine Power*Main Engine Emissions Factor + Auxillary Engine Quantity*Auxillary Engine Power*Auxillary Engine Emissions Factor)

Data Sources and Assumptions Page 2

SOCIAL COSTS

Year	SC-CO2 (2020 dollars) 3% Discount Rate	SC-CH4 (2020 dollars) 3% Discount Rate	SC-N2O (2020 dollars) 3% Discount Rate
2020	51	1500	18000
2021	52	1500	19000
2022	53	1600	19000
2023	54	1600	20000
2024	55	1700	20000
2025	56	1700	21000
2026	57	1800	21000
2027	59	1800	21000
2028	60	1900	22000
2029	61	1900	22000
2030	62	2000	23000
2031	63	2000	23000
2032	64	2100	24000
2033	65	2100	24000
2034	66	2200	25000
2035	67	2200	25000
2036	69	2300	26000
2037	70	2300	26000
2038	71	2400	27000
2039	72	2500	27000
2040	73	2500	28000
2041	74	2600	28000
2042	75	2600	29000
2043	77	2700	29000
2044	78	2700	30000
2045	79	2800	30000
2046	80	2800	31000
2047	81	2900	31000
2048	82	3000	32000
2049	84	3000	32000
2050	85	3100	33000

Summarized Social Costs By Decade

Year	3% Discount Rate	3% Discount Rate	3% Discount Rate
2030 to 2039	66.9	2210	25000
2040 to 2049	78.3	2760	30000
2050 to 2080	85	3100	33000
2030 to 2050	73.19048	2514.286	27761.9

No-Action Alternative Long Term Emissions Calculations - Idling

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079			
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)
SPX	21884.15	7434810	4.168428	363.5832	19403.24	6591960	3.695873	322.3655	17592.72	5976862	3.35101	292.2854	17592.72	5976862	3.35101	292.2854
Panamax	70812.68	24057546	13.43417	1176.482	45902.94	15594836	8.708443	762.6315	27724.22	9418888	5.25968	460.6102	27724.22	9418888	5.25968	460.6102
PPX Gen I	284386.6	96616087	54.78289	4724.799	237499.2	80686791	45.75072	3945.812	203281.5	69061848	39.15919	3377.319	203281.5	69061848	39.15919	3377.319
PPX Gen II	311965.4	1.06E+08	59.93785	5182.993	294547.6	1E+08	56.59138	4893.614	281836.4	95749684	54.14917	4682.43	281836.4	95749684	54.14917	4682.43
PPX Gen III	138953.6	47207389	27.79071	2308.575	190388.7	64681705	38.07774	3163.118	227925.2	77434178	45.58505	3786.75	227925.2	77434178	45.58505	3786.75
PPX Gen IV	14004.52	4757826	2.800904	232.6711	65430.18	22228922	13.08604	1087.057	102959.8	34979046	20.59196	1710.574	102959.8	34979046	20.59196	1710.574
Emissions Total	842006.9	2.86E+08	162.915	13989.1	853171.9	2.9E+08	165.9102	14174.6	861319.9	2.93E+08	168.0961	14309.97	861319.9	2.93E+08	168.0961	14309.97
Social Costs ($)	56330261	1.91E+10	360042.1	3.5E+08	66803356	2.27E+10	457912.1	4.25E+08	73212189	2.29E+10	463945.1	4.29E+08	73212189	2.29E+10	463945.1	4.29E+08

No-Action Alternative Long Term Emissions Calculations - 3 Mile Line to Port

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079				Project Lifetime Total
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
SPX	20002.22	6795454	3.809964	332.3169	21017.96	7140536	4.003439	349.1923	22033.69	7485617	4.196914	366.0678	22033.69	7485617	4.196914	366.0678	55849930.54
Panamax	64723.15	21988718	12.2789	1075.31	49722.93	16892620	9.433149	826.0968	34722.72	11796523	6.587394	576.8832	34722.72	11796523	6.587394	576.8832	123085107.5
PPX Gen I	259930.8	88307592	50.07184	4318.49	257263.6	87401450	49.55804	4274.178	254596.4	86495309	49.04425	4229.865	254596.4	86495309	49.04425	4229.865	675768821.3
PPX Gen II	285137.9	96871330	54.7835	4737.281	319059.5	1.08E+08	61.30084	5300.854	352981.1	1.2E+08	67.81819	5864.428	352981.1	1.2E+08	67.81819	5864.428	857432483.3
PPX Gen III	127004.3	43147792	25.40085	2110.049	206232.6	70064440	41.24652	3426.349	285461	96981088	57.0922	4742.649	285461	96981088	57.0922	4742.649	583993590.3
PPX Gen IV	12800.2	4348677	2.560041	212.6626	70875.2	24078787	14.17504	1177.521	128950.2	43808897	25.79004	2142.379	128950.2	43808897	25.79004	2142.379	216724076.4
Total	769598.5	2.61E+08	148.9051	12786.11	924171.8	3.14E+08	179.717	15354.19	1078745	3.66E+08	210.529	17922.27	1078745	3.66E+08	210.529	17922.27	2512854009
Social Costs ($)	51486143	1.75E+10	329080.3	3.2E+08	72362653	2.46E+10	496019	4.61E+08	91693332	2.87E+10	581060	5.38E+08	91693332	2.87E+10	581060	5.38E+08	1.91195E+11

Inner Harbor Only - Alternative B Long Term Emissions Calculations - Idling

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079			
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)
SPX	18027.6	6124607	3.433844	299.5105	13862.3	4709508	2.64045	230.3082	10744.11	3650150	2.046507	178.5026	10744.11	3650150	2.046507	178.502646
Panamax	61914.05	21034371	11.74598	1028.64	35164.38	11946569	6.671183	584.221	15139.29	5143346	2.872139	251.5241	15139.29	5143346	2.872139	251.524124
PPX Gen I	219978.6	74734431	42.37564	3654.725	173006	58776197	33.32706	2874.322	137841.8	46829695	26.5532	2290.104	137841.8	46829695	26.5532	2290.10422
PPX Gen II	320466.3	1.09E+08	61.57114	5324.228	291603	99067742	56.02563	4844.692	269995.6	91726949	51.8742	4485.707	269995.6	91726949	51.8742	4485.70661
PPX Gen III	186841.8	63476705	37.36836	3104.19	238825.2	81137291	47.76505	3967.842	277740.6	94358191	55.54811	4614.382	277740.6	94358191	55.54811	4614.38175
PPX Gen IV	22832.53	7757010	4.566506	379.3397	92976.19	31587265	18.59524	1544.706	145486.5	49426844	29.09729	2417.112	145486.5	49426844	29.09729	2417.11212
Emissions Total	830060.9	2.82E+08	161.0615	13790.63	845437.1	2.87E+08	165.0246	14046.09	856947.8	2.91E+08	167.9915	14237.33	856947.8	2.91E+08	167.9915	14237.3315
Social Costs	55531077	1.89E+10	355945.8	3.45E+08	66197725	2.25E+10	455467.9	4.21E+08	72840567	2.28E+10	463656.4	4.27E+08	72840567	2.28E+10	463656.4	427119944

Inner Harbor Only - Alternative B Long Term Emissions Calculations - 3 Mile Line to Port

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079				Project Lifetime Total
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
SPX	16095.54	5468217	3.065831	267.4112	14454.73	4910777	2.753295	240.1509	12813.92	4353338	2.440758	212.8905	12813.92	4353338	2.440758	212.890497	37872572.4
Panamax	55278.57	18780064	10.48713	918.3981	36667.19	12457128	6.956289	609.1887	18055.81	6134192	3.425445	299.9793	18055.81	6134192	3.425445	299.979283	88294382.6
PPX Gen I	196402.9	66724953	37.83413	3263.038	180399.7	61288105	34.75135	2997.161	164396.5	55851257	31.66857	2731.284	164396.5	55851257	31.66857	2731.28402	475070414
PPX Gen II	286121.1	97205369	54.9724	4753.617	304065.2	1.03E+08	58.41999	5051.739	322009.2	1.09E+08	61.86757	5349.861	322009.2	1.09E+08	61.86757	5349.86081	824909871
PPX Gen III	166817.5	56673746	33.3635	2771.506	249031.9	84604841	49.80637	4137.415	331246.2	1.13E+08	66.24924	5503.325	331246.2	1.13E+08	66.24924	5503.32472	711947100
PPX Gen IV	20385.51	6925671	4.077102	338.6849	96949.69	32937204	19.38994	1610.722	173513.9	58948736	34.70277	2882.76	173513.9	58948736	34.70277	2882.75952	301146823
Emissions Total	741101.2	2.52E+08	143.8001	12312.66	881568.4	2.99E+08	172.0772	14646.38	1022036	3.47E+08	200.3544	16980.1	1022036	3.47E+08	200.3544	16980.0989	2439241162
Social Costs ($)	49579671	1.68E+10	317798.2	3.08E+08	69026805	2.35E+10	474933.2	4.39E+08	86873023	2.72E+10	552978	5.09E+08	86873023	2.72E+10	552978	509402966	1.8557E+11

Outer Harbor Only - Alternative C Long Term Emissions Calculations - Idling

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079			
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)
SPX	18361.58	6238072	3.49746	305.0593	15595.49	5298334	2.970583	259.1035	13443.68	4567289	2.560713	223.3533	10925.76	4567289	2.560713	223.3533
Panamax	57599.39	19568530	10.92743	956.9563	35763.4	12150078	6.784826	594.1731	18776.66	6379088	3.5622	311.9554	14978.19	6379088	3.5622	311.9554
PPX Gen I	220265.1	74831766	42.43083	3659.484	162163.4	55092570	31.23838	2694.182	116964.6	39736980	22.53151	1943.25	100022.6	39736980	22.53151	1943.25
PPX Gen II	266012.7	90373841	51.10898	4419.536	224077.5	76126971	43.05197	3722.824	191455.1	65043992	36.78423	3180.835	161820	65043992	36.78423	3180.835
PPX Gen III	153709	52220325	30.7418	2553.721	208644.6	70883887	41.72893	3466.422	251380.4	85402715	50.27608	4176.434	192245.2	85402715	50.27608	4176.434
PPX Gen IV	22469.29	7633603	4.493857	373.3047	99952.06	33957215	19.99041	1660.604	160227.8	54434978	32.04555	2662.024	127782.5	54434978	32.04555	2662.024
Emissions Total	738417.1	2.51E+08	143.2004	12268.06	746196.5	2.54E+08	145.7651	12397.31	752248.2	2.56E+08	147.7603	12497.85	607774.3	2.56E+08	147.7603	12497.85
Social Costs ($)	49400105	1.68E+10	316472.8	3.07E+08	58427183	1.98E+10	402311.7	3.72E+08	63941097	2E+10	407818.4	3.75E+08	51660815	2E+10	407818.4	3.75E+08

Outer Harbor Only - Alternative C Long Term Emissions Calculations - 3 Mile Line to Port

Vessel Class	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079				Project Lifetime Total
	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
SPX	18595.81	6317649	3.542076	308.9508	18048.88	6131835	3.437898	299.8641	17501.94	5946022	3.333719	290.7773	17501.94	5946022	3.333719	290.7773	45799087.64
Panamax	58334.17	19818158	11.06682	969.1638	41389.48	14061455	7.852174	687.6448	24444.79	8304752	4.637526	406.1258	24444.79	8304752	4.637526	406.1258	96626900.44
PPX Gen I	223074.9	75786366	42.9721	3706.167	187673.9	63759399	36.15262	3118.015	152272.9	51732432	29.33313	2529.862	152272.9	51732432	29.33313	2529.862	460323024.2
PPX Gen II	269406.2	91526705	51.76096	4475.914	259328	88102804	49.82464	4308.476	249249.9	84678904	47.88833	4141.037	249249.9	84678904	47.88833	4141.037	656863846.2
PPX Gen III	155669.8	52886479	31.13396	2586.298	241467.3	82034909	48.29347	4011.739	327264.9	1.11E+08	65.45298	5437.179	327264.9	1.11E+08	65.45298	5437.179	662554870.2
PPX Gen IV	22755.92	7730982	4.551184	378.0668	115675.9	39299158	23.13518	1921.84	208595.9	70867333	41.71918	3465.613	208595.9	70867333	41.71918	3465.613	345140175.9
Emissions Total	747836.8	2.54E+08	145.0271	12424.56	863583.6	2.93E+08	168.696	14347.58	979330.3	3.33E+08	192.3649	16270.59	979330.3	3.33E+08	192.3649	16270.59	2267307905
Social Costs ($)	50030282	1.7E+10	320509.9	3.11E+08	67618593	2.3E+10	465600.9	4.3E+08	83243076	2.61E+10	530927	4.88E+08	83243076	2.61E+10	530927	4.88E+08	1.72383E+11

	Inner and Outer Harbor - Alternatives D-1 and D-2 Long Term Emissions - Idling															
	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079			
Vessel Class	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)
SPX	15299.58	5197803	2.914219	254.1872	10650.42	3618320	2.028661	176.9461	6920.582	2351164	1.318212	114.9785	6920.582	2351164	1.318212	114.97855
Panamax	50921.34	17299761	9.660504	846.0071	26273.32	8925967	4.984424	436.505	6499.205	2208008	1.232992	107.9778	6499.205	2208008	1.232992	107.977799
PPX Gen I	166177.5	56456325	32.01165	2760.874	102752	34908450	19.79366	1707.122	51868.23	17621455	9.991651	861.7388	51868.23	17621455	9.991651	861.738841
PPX Gen II	281626.2	95678292	54.1088	4678.938	226565.9	76972354	43.53006	3764.165	182393.1	61965330	35.04316	3030.279	182393.1	61965330	35.04316	3030.27949
PPX Gen III	203606.9	69172400	40.72139	3382.726	263594.9	89552398	52.71897	4379.365	311720.8	1.06E+08	62.34415	5178.929	311720.8	1.06E+08	62.34415	5178.92875
PPX Gen IV	31602.14	10736354	6.320429	525.038	131442.4	44655578	26.28848	2183.784	211540.2	71867610	42.30804	3514.529	211540.2	71867610	42.30804	3514.5289
Emissions Total	749233.8	2.55E+08	145.737	12447.77	761278.8	2.59E+08	149.3442	12647.89	770942.1	2.62E+08	152.2382	12808.43	770942.1	2.62E+08	152.2382	12808.4323
Social Costs ($)	50123739	1.7E+10	322078.8	3.11E+08	59608133	2.03E+10	412190.1	3.79E+08	65530080	2.05E+10	420177.5	3.84E+08	65530080	2.05E+10	420177.5	384252970

	Inner and Outer Harbor - Alternatives D-1 and D-2 Long Term Emissions - 3 Mile Line to Port																
	2030 -2039				2040 - 2049				2050 - 2059				2060 - 2079				Project Lifetime
Vessel Class	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
SPX	14689.13	4990412	2.797943	244.0452	11485.65	3902077	2.187753	190.8226	8282.169	2813743	1.577563	137.6	8282.169	2813743	1.577563	137.599956	28529953.2
Panamax	48889.59	16609504	9.275051	812.2516	28333.74	9625962	5.375314	470.7367	7777.889	2642421	1.475576	129.2218	7777.889	2642421	1.475576	129.221845	63251781.9
PPX Gen I	159547.1	54203727	30.7344	2650.715	110810.1	37646053	21.34592	1840.998	62073.03	21088380	11.95745	1031.281	62073.03	21088380	11.95745	1031.28128	265203321
PPX Gen II	270389.4	91860744	51.94987	4492.25	244333.7	83008708	46.94379	4059.36	218278	74156673	41.93771	3626.471	218278	74156673	41.93771	3626.47053	630628972
PPX Gen III	195483	66412433	39.09661	3247.755	284266.6	96575310	56.85332	4722.805	373050.1	1.27E+08	74.61003	6197.855	373050.1	1.27E+08	74.61003	6197.85489	800790789
PPX Gen IV	30341.22	10307976	6.068245	504.0891	141750.4	48157574	28.35008	2355.041	253159.6	86007173	50.63192	4205.993	253159.6	86007173	50.63192	4205.9934	437138588
Emissions Total	719339.5	2.44E+08	139.9221	11951.11	820980.1	2.79E+08	161.0562	13639.76	922620.8	3.13E+08	182.1902	15328.42	922620.8	3.13E+08	182.1902	15328.4219	2225543405
Social Costs ($)	48123810	1.63E+10	309227.9	2.99E+08	64282744	2.18E+10	444515.1	4.09E+08	78422768	2.45E+10	502845.1	4.6E+08	78422768	2.45E+10	502845.1	459852657	1.6917E+11

Tug Boat Emissions

	Assist Tugs	# Main	Main Engine Power Rating (HP)	Main Engine Power Rating (kW)	Auxiliary Engine Quantity	Auxillary Engine Power Rating (HP)	Auxillary Engine Power Rating (kW)	Idling Load Factor All Alternatives	Average Maneuvering Load Factor no action	Maneuvering Load Factor Alternative B	Maneuvering Load Factor Alternative C	Maneuvering Load Factor Alternative D
TUG BOATS	FAIRPLAY 34	1	8076	6022.2732	2	3352.555	2500	0.25	0.85	0.85	0.85	0.85
	FAIRPLAY XVIII	1	6798	5069.2686	2	3218.452	2400	0.25	0.85	0.85	0.85	0.85
	FAIRPLAY XVIII	1	6798	5069.2686	2	4023.066	3000	0.25	0.85	0.85	0.85	0.85
	A. THOMAS HIGGINS	1	5166	3852.2862	2	3486.657	2600	0.25	0.85	0.85	0.85	0.85
	CALYPSO	1	3548	2645.7436	2	5364.087	4000	0.25	0.85	0.85	0.85	0.85
	DOLPHIN	1	1450	1081.265	2	5498.19	4100	0.25	0.85	0.85	0.85	0.85

Maneuvering (propulsion) Load Factor of 0.85 was chosen for all alternatives despite variance of vessel size to give an upper bound on emissions possible as compared to the EPA Port Emissions Guidance Table 4.4 which has an average propulsion engine factor is 0.5 for tugboats.

		No-Action Alternative		Alternative B		Alternative C		Alternative D	
	Assist Tugs	Average Annual Idling Hours	Average Annual Propulsion Hours	Average Annual Idling Hours	Average Annual Propulsion Hours	Average Annual Idling Hours	Average Annual Propulsion Hours	Average Annual Idling Hours	Average Annual Propulsion Hours
TUG BOATS	FAIRPLAY 34	1404	1683	1428	1655	1597	1480	1578	1498
	FAIRPLAY XVIII								
	FAIRPLAY XVIII								
	A. THOMAS HIGGINS								
	CALYPSO								
	DOLPHIN								

Emissions Factors

CO (g/kWh)	CO2 (g/kWh)	CH4 (g/kWh)	N2O (g/kWh)
0.918732	679.47	0.0004	0.038688

Average annual idling and propulsion hours for tugs were taken from Table G.1 of the EPA Port Emissions Inventory Guidance for no-action alternative. With action idling and propulsion hours were computed by increasing the idling hours and decreasing the propulsion hours from the Table G.1 value by the percentage difference for idling hours in vessels for each with action alternative compared to the no-action alternative.

Emissions Factors were obtained from Table H6 of the EPA Port Emissions Inventory Guidance with exception for nitrous oxide which was obtained from equation 4.3 in the EPA Port Emissions Inventory Guidance. Since Tier IV engines would be required per CARB by 2030, no change in emissions requirements was modeled over project lifetime.

Tug Boat Emisssions

	No-Action Unloaded				No-Action Maneuvering Loaded				No-Action Total	Alternative B Unloaded				Alternative B Maneuvering Loaded				With-Action Total
Assist Tugs	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
FAIRPLAY 34	7836.13	5795396.95	3.41	329.98	31937.26	23619957.57	13.90	1344.88	29954670.92	7969.32	5893898.56	3.47	335.59	31403.51	23225209.71	13.67	1322.41	29652993.13
FAIRPLAY XVIII	7016.42	5189159.09	3.05	295.46	28596.41	21149149.67	12.45	1204.20	26821209.00	7135.67	5277356.76	3.11	300.48	28118.49	20795695.12	12.24	1184.08	26551088.76
FAIRPLAY XVIII	7869.54	5820106.65	3.43	331.39	32073.43	23720665.42	13.96	1350.62	30082387.92	8003.30	5919028.23	3.48	337.02	31537.41	23324234.48	13.73	1328.05	29779423.88
A. THOMAS HIGGINS	6435.60	4759598.21	2.80	271.00	26229.18	19398413.75	11.42	1104.52	24600937.51	6544.98	4840494.85	2.85	275.61	25790.83	19074218.32	11.23	1086.06	24353177.94
CALYPSO	7568.44	5597421.59	3.30	318.71	30846.26	22813081.08	13.43	1298.94	28931395.59	7697.08	5692558.31	3.35	324.13	30330.74	22431818.12	13.21	1277.23	28640023.36
DOLPHIN	6598.39	4879992.89	2.87	277.86	26892.65	19889099.24	11.71	1132.46	25223221.54	6710.54	4962935.82	2.92	282.58	26443.21	19556703.24	11.51	1113.53	24969194.86
Emissions Total	43324.52	32041675.39	18.86	1824.40	176575.20	130590366.73	76.88	7435.62	165613822.47	44060.89	32586272.53	19.18	1855.41	173624.19	128407878.99	75.59	7311.35	163945901.93

No Action Lifetime Emissions Totals From Tugboats (metric tons)

CO	CO_2	CH_4	N_2O	CO_2e
4987.25	3688437.06	2.17	210.01	3756062.78

Alternative B Lifetime Emissions Totals From Tugboats (metric tons)

CO	CO_2	CH_4	N_2O	CO_2e
4937.02	3651290.28	2.15	207.90	3718234.93

	Alternative C Unloaded				Alternative C Maneuvering Loaded				With-Action Total	Alternative D Unloaded				Alternative D Maneuvering Loaded				With-Action Total
Assist Tugs	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO (pounds)	CO_2 (pounds)	CH_4 (pounds)	N_2O (pounds)	CO_2e (pounds)
FAIRPLAY 34	8912.55	6591486.79	3.88	375.31	28080.02	20767246.36	12.23	1182.46	27860342.38	8806.16	6512807.11	3.83	370.83	28419.25	21018130.56	12.37	1322.41	28073153.18
FAIRPLAY XVIII	7980.24	5901972.53	3.47	336.05	25142.66	18594851.42	10.95	1058.76	24945961.44	7884.98	5831523.27	3.43	332.04	25446.41	18819491.43	11.08	1184.08	25136510.79
FAIRPLAY XVIII	8950.55	6619590.75	3.90	376.91	28199.75	20855791.17	12.28	1187.50	27979129.85	8843.71	6540575.61	3.85	372.41	28540.42	21107745.06	12.43	1328.05	28192848.00
A. THOMAS HIGGINS	7319.63	5413404.64	3.19	308.23	23061.34	17055561.43	10.04	971.12	22880923.77	7232.26	5348787.21	3.15	304.55	23339.94	17261605.64	10.16	1086.06	23055699.36
CALYPSO	8608.09	6366316.37	3.75	362.49	27120.79	20057820.75	11.81	1142.06	26908610.98	8505.34	6290324.45	3.70	358.16	27448.43	20300134.54	11.95	1277.23	27114151.99
DOLPHIN	7504.78	5550337.44	3.27	316.03	23644.68	17486984.16	10.29	995.68	23459699.82	7415.20	5484085.50	3.23	312.26	23930.33	17698240.28	10.42	1113.53	23638896.38
Emissions Total	49275.83262	36443108.53	21.453844	2075.0158	155249.2462	114818255.3	67.59283	6537.57879	154034668.3	48687.64864	36008103.15	21.19775893	2050.247	157124.7757	116205347.5	68.40941	7311.351527	155211259.7

Alternative C Lifetime Emissions Totals From Tugboats (metric tons)

CO	CO_2	CH_4	N_2O	CO_2e
4638.56	3430554.11	2.02	195.33	3493451.67

Alternative D Lifetime Emissions Totals From Tugboats (metric tons)

CO	CO_2	CH_4	N_2O	CO_2e
4667.75	3452147.10	2.03	212.32	3520136.34

Containership and Tugboat Emissions Summary Tables

	No-Action Containership Project Lifetime Total (metric tons)				
Vessel Class	CO	CO_2	CH_4	N_2O	CO_2e
SPX	73.28265	24896.68053	0.013958665	1.21751792	25333.13249
Panamax	161.5043	54868.65855	0.030639665	2.68323221	55830.53203
PPX Gen I	886.6998	301242.95	0.170809654	14.7316302	306523.9458
PPX Gen II	1125.067	382224.6484	0.216158925	18.6918637	388925.2948
PPX Gen III	766.2779	260331.422	0.15325558	12.730941	264895.3517
PPX Gen IV	284.371	96610.79837	0.05687421	4.72454061	98304.50438
Total	3297.203	1120175.158	0.641696698	54.7797256	1139812.761

	Alternative B Containership Project Lifetime Total (metric tons)				
Vessel Class	CO	CO_2	CH_4	N_2O	CO_2e
SPX	49.69392759	16882.76649	0.009465554	0.825614913	17178.7303
Panamax	115.8541556	39359.71156	0.021979184	1.924800942	40049.70588
PPX Gen I	623.3564174	211775.9925	0.120080433	10.35644352	215488.5711
PPX Gen II	1082.39298	367726.7791	0.207959967	17.98287697	374173.2685
PPX Gen III	934.170061	317370.2657	0.186834012	15.52030139	322934.1564
PPX Gen IV	395.1450126	134244.5909	0.079029003	6.564939239	136598.0635
Total	3200.612554	1087360.106	0.625348153	53.17497698	1106422.496

	Alternative C Project Lifetime Total (metric tons)				
Vessel Class	CO	CO_2	CH_4	N_2O	CO_2e
SPX	58.95578	20417.35649	0.01144727	0.99846634	20774.14141
Panamax	125.0696	43075.85971	0.02405435	2.10653107	43829.2769
PPX Gen I	596.3433	205209.4814	0.116357115	10.0353226	208799.2598
PPX Gen II	848.4906	292828.7472	0.165602996	14.3201519	297948.7831
PPX Gen III	842.6151	295378.6636	0.173887685	14.44485	300530.1913
PPX Gen IV	438.1958	153870.3178	0.090582553	7.52469265	156553.1366
Total	2909.67	1010780.426	0.581931969	49.4300146	1028434.789

	Alternative D-1 & D-2 Containership Project Lifetime Total (metric tons)				
Vessel Class	CO	CO_2	CH_4	N_2O	CO_2e
SPX	37.43514999	12718.03068	0.007130538	0.621947582	12940.98447
Panamax	82.99488113	28196.26594	0.015745312	1.378876955	28690.55979
PPX Gen I	347.9825045	118221.8362	0.067033705	5.78138133	120294.3462
PPX Gen II	827.4702441	281120.6034	0.158981708	13.74759063	286048.8302
PPX Gen III	1050.744894	356974.8167	0.210148979	17.45707568	363233.0239
PPX Gen IV	573.5844434	194866.7109	0.114716889	9.529531942	198282.9638
Total	2920.212117	992098.2637	0.57375713	48.51640412	1009490.708

Tug Boats Project Lifetime Total (metric tons)					
Alternative	CO	CO_2	CH_4	N_2O	CO_2e
Total No-Action Alternative	4987	3688437	2	210	3756063
Total Alternative B	4937	3651290	2	208	3718235
Total Alternative C	4639	3430554	2	195	3493452
Total Alternative D	4668	3452147	2	212	3520136

Long-Term Dredging Emissions Calculations (page 1)

	Inner Harbor	Outer Harbor	Combined
O&M Dredging Pre-Project - No Action Alternative (cubic yards)	125749	138323	264072
O&M Dredging With Project (cubic yards)	296347	301797	598144

Appendix B Emissions Data From SF Bay Programmatic Dredging EA

Maximum Engine Power Mechanical Dredging(HP)	Engine Power (kw)
1800	1342.26
1200	894.84
895	667.4015
300	223.71

Appendix H. Tables of C1 and C2 Emission Factors

Model Year	Power Range	Engine Group	NOx (g/kWh)	PM10 & DPM10 (g/kWh)	PM2.5 & DPM2.5 (g/kWh)	BC (g/kWh)	HC (g/kWh)	VOC (g/kWh)	CH4 (g/kWh)	CO (g/kWh)
2017	3700 < kW	Propulsion	1.3000	0.0461	0.0447	0.0344	0.0178	0.0187	0.0004	2.0000
2018+	0 < kW ≤ 8	All	4.3900	0.2400	0.2328	0.1793	0.4300	0.4528	0.0086	4.1100
2018+	8 < kW ≤ 19	All	2.3200	0.1900	0.1843	0.1419	0.2100	0.2211	0.0042	2.1600
2018+	19 < kW ≤ 37	All	2.3200	0.1800	0.1746	0.1344	0.4100	0.4317	0.0082	1.5300
2018+	37 < kW ≤ 600	Propulsion	4.6920	0.0613	0.0595	0.0458	0.1038	0.1093	0.0021	1.1019
2018+	37 < kW ≤ 600	Auxiliary	4.5798	0.0770	0.0747	0.0575	0.1236	0.1301	0.0025	0.9299
2018+	600 < kW ≤ 1000	Propulsion	1.3000	0.0300	0.0291	0.0224	0.0395	0.0416	0.0008	1.1237
2018+	600 < kW ≤ 1000	Auxiliary	1.3000	0.0300	0.0291	0.0224	0.0400	0.0421	0.0008	0.9000
2018+	1000 < kW ≤ 1400	Propulsion	1.3000	0.0300	0.0291	0.0224	0.0381	0.0402	0.0008	1.1840
2018+	1000 < kW ≤ 1400	Auxiliary	1.3000	0.0300	0.0291	0.0224	0.0400	0.0421	0.0008	0.9000
2018+	1400 < kW ≤ 2000	Propulsion	1.3000	0.0308	0.0299	0.0230	0.0324	0.0341	0.0006	1.4048
2018+	1400 < kW ≤ 2000	Auxiliary	1.3000	0.0300	0.0291	0.0224	0.0400	0.0421	0.0008	0.9000
2018+	2000 < kW ≤ 3700	Propulsion	1.3000	0.0338	0.0328	0.0252	0.0162	0.0171	0.0003	2.0000

Worst Case CH4 Emissions Factor	Equivalent CO Emissions Factor	Ratio CH4:CO
0.0008	1.184	0.000675676

Air Quality Emissions Outputs from the 2015 USACE SF Bay Programmatic Dredging EA/EIR

Table B-5
Calculation of Air Pollutants Emission Rates from Dredging Activities (pounds/cubic yard)

Dredge Equipment Specifications			Calculated Emissions (lbs/CY)				
Dredge Equipment Type	Activity	Engine Type	ROG	CO	NO_X	PM	CO_2
Hopper (Essayons)	Transit	Main engine	0.0011	0.0039	0.0210	0.00007	1.86
		Ship service	0.0002	0.0009	0.0033	0.0001	0.45
		Pump	0	0	0	0	0
Mechanical (Paula Lee)	Transit	Tug – main engine	0.0008	0.0019	0.0105	0.0004	0.36
		Main	0.0000	0.0002	0.0006	0.0000	0.06
		Main	0.0000	0.0002	0.0006	0.0000	0.04
		Deck	0	0	0	0	0
		Deck Winch	0	0	0	0	0
Hopper (Essayons)	Pumping	Main engine	0.0003	0.0009	0.0049	0.0002	0.44
		Ship service	0.0004	0.0020	0.0074	0.0002	1.02
		Pump	0.0021	0.0073	0.0395	0.0013	3.50
Mechanical (Paula Lee)	Pumping	Tug – main engine	0.0019	0.0047	0.0255	0.0011	0.88
		Main	0.0003	0.0016	0.0056	0.0001	0.58
		Main	0.0002	0.0015	0.0059	0.0003	0.44
		Deck	0.0006	0.0029	0.0117	0.0003	1.17
		Deck Winch	0.0016	0.0173	0.0305	0.0011	4.68

Notes:
CO = carbon monoxide
CO_2 = carbon dioxide
lbs/CY = pounds per cubic yard
NO_X = nitrogen oxides
PM = particulate matter
ROG = reactive organic gas

= data used for GHG emissions analysis for Oakland Turning Basin Project

0.0019

0.000675676*0.0019 =

CH_4 per cubic yard
1.28378E-06

Worst case scenario nitrous oxide emissions assumed, where all NOx emissions assumed to be nitrous oxide

Long-Term Dredging Emissions Calculations (page 2)

Input Parameters						
Dredge Location	Project Alternative		Emissions Per Cubic Yard Dredged (lbs)			
	O&M Dredging No-Action (cubic yards)	O&M Dredging with Project (cubic yards)	CO	CO_2	CH_4	N_2O
Inner Harbor (Alternative B)	N/A	296347	0.0019	0.36	1.283784E-06	0.0105
Outer Harbor (Alternative C)	N/A	301797	0.0019	0.36	1.283784E-06	0.0105
Combined (Alternatives D-1 & D-2	264072	598144	0.0019	0.36	1.283784E-06	0.0105

Example Calculation:

Emissions (CO, CO_2, CH_4, N_2O) = Cubic Yards Dredged * (Pounds of Emissions/Cubic Yard Dredged)

Conversion Factors

2204.62 pounds per metric ton

O&M Dredging Emissions Greenhouse Gas Analysis Results (pounds)									
No-Action Alternative O&M Dredging Emissions					Alternative B (Inner Harbor Only) O&M Dredging Emissions				
CO	CO_2	CH_4	N_2O	CO_2e	CO	CO_2	CH_4	N_2O	CO_2e
501.7368	95065.92	0.339011351	2772.756	921857.4201	563.0593	106684.92	0.380445473	3111.6435	1034527.253

Alternative C (Outer Harbor Only) O&M Dredging Emissions					Alternatives D-1 & D-2 (Both Harbors) O&M Dredging Emissions				
CO	CO_2	CH_4	N_2O	CO_2e	CO	CO_2	CH_4	N_2O	CO_2e
573.4143	108646.92	0.387442095	3168.8685	1053552.833	1136.4736	215331.84	0.767887568	6280.512	2088080.087

Total Long Term Emissions from O&M Dredging Over Project Lifetime (Metric Tons)						
Alternative	CO	CO_2	CH_4	N_2O	CO_2e	Net CO2e Compared to Baseline (no-action alternative)
No-Action Alternative	11	2156	0	63	20907	-
Alternative B	13	2420	0	71	23463	2555
Alternative C	13	2464	0	72	23894	2987
Alternatives D-1 & D-2	26	4884	0	142	47357	26450

Emissons Summary Tables

Project Lifetime Total Long-Term Emissions (metric tons)						
Alternative	CO	CO_2	CH_4	N_2O	CO_2e	Net CO2e Compared to Baseline (No-Action)
No-Action	8296	4810768	2.82	328	4916783	-
Alternative B	8150	4741070	2.78	332	4848120	-68663
Alternative C	7860	4664535	2.74	329	4770564	-146219
Alternative D-1 & D-2	7883	4648272	2.74	399	4775083	-141700

Total Long Term Emissions from O&M Dredging Over Project Lifetime (Metric Tons)					
Alternative	CO	CO_2	CH_4	N_2O	CO_2e
No-Action Alternative	11	2156	0.01	63	20907
Alternative B	13	2420	0.01	71	23463
Alternative C	13	2464	0.01	72	23894
Alternatives D-1 & D-2	26	4884	0.02	142	47357

Long-Term Emissions From Containerships and Tugs Over the Project Lifetime (metric tons)							
Alternative	Idling Hours	CO	CO_2	CH_4	N_2O	CO_2e	CO_2e Compared to Baseline (no-action alternative)
No-Action	13463	8284	4808612	2.81	265	4895876	-
Alternative B	13238	8138	4738650	2.77	261	4824657	-71218
Alternative C	11837	7548	4441335	2.60	245	4521886	-373989
Alternative D-1 & D-2	11980	7588	4444245	2.61	261	4529627	-366248

	SC-CO2 (2020 dollars)	SC-CH4 (2020 dollars)	SC-N2O (2020 dollars)
Year	3% Discount Rate	3% Discount Rate	3% Discount Rate
2030	62	2000	23000
2031	63	2000	23000
2032	64	2100	24000
2033	65	2100	24000
2034	66	2200	25000
2035	67	2200	25000
2036	69	2300	26000
2037	70	2300	26000
2038	71	2400	27000
2039	72	2500	27000
2040	73	2500	28000
2041	74	2600	28000
2042	75	2600	29000
2043	77	2700	29000
2044	78	2700	30000
2045	79	2800	30000
2046	80	2800	31000
2047	81	2900	31000
2048	82	3000	32000
2049	84	3000	32000
2050	85	3100	33000

	No- Action Alternative				Alternative B			
Year	SC-CO (2020 dollars)	SC-CO2 (2020 dollars)	SC-CH4 (2020 dollars)	SC-N2O (2020 dollars)	SC-CO	SC-CO2 (2020 dollars)	SC-CH4 (2020 dollars)	SC-N2O (2020 dollars)
2030	705.5111901	133675.8044	15.37731452	1446357.83	791.7390888	150013.7221	17.2567369	1623132.343
2031	716.8904029	135831.8658	15.37731452	1446357.83	804.5090741	152433.2983	17.2567369	1623132.343
2032	728.2696156	137987.9272	16.14618025	1509242.953	817.2790594	154852.8744	18.11957374	1693703.314
2033	739.6488284	140143.9885	16.14618025	1509242.953	830.0490447	157272.4506	18.11957374	1693703.314
2034	751.0280411	142300.0499	16.91504597	1572128.076	842.81903	159692.0267	18.98241059	1764274.285
2035	762.4072539	144456.1113	16.91504597	1572128.076	855.5890153	162111.6029	18.98241059	1764274.285
2036	785.1656793	148768.234	17.6839117	1635013.2	881.1289859	166950.7552	19.84524743	1834845.257
2037	796.5448921	150924.2953	17.6839117	1635013.2	893.8989713	169370.3314	19.84524743	1834845.257
2038	807.9241048	153080.3567	18.45277742	1697898.323	906.6689566	171789.9076	20.70808428	1905416.228
2039	819.3033176	155236.4181	19.22164315	1697898.323	919.4389419	174209.4837	21.57092112	1905416.228

Social Costs from O&M Dredging Page 2

2040	830.6825303	157392.4794	19.22164315	1760783.446	932.2089272	176629.0599	21.57092112	1975987.2
2041	842.0617431	159548.5408	19.99050887	1760783.446	944.9789125	179048.636	22.43375797	1975987.2
2042	853.4409558	161704.6022	19.99050887	1823668.569	957.7488978	181468.2122	22.43375797	2046558.171
2043	876.1993813	166016.7249	20.7593746	1823668.569	983.2888684	186307.3645	23.29659481	2046558.171
2044	887.578594	168172.7862	20.7593746	1886553.692	996.0588537	188726.9407	23.29659481	2117129.142
2045	898.9578068	170328.8476	21.52824033	1886553.692	1008.828839	191146.5169	24.15943166	2117129.142
2046	910.3370195	172484.909	21.52824033	1949438.815	1021.598824	193566.093	24.15943166	2187700.114
2047	921.7162323	174640.9703	22.29710605	1949438.815	1034.36881	195985.6692	25.0222685	2187700.114
2048	933.095445	176797.0317	23.06597178	2012323.938	1047.138795	198405.2453	25.88510535	2258271.085
2049	955.8538705	181109.1544	23.06597178	2012323.938	1072.678766	203244.3977	25.88510535	2258271.085
2050	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2051	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2052	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2053	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2054	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2055	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2056	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2057	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2058	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2059	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2060	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2061	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2062	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2063	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2064	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2065	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2066	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2067	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2068	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2069	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2070	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2071	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2072	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2073	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2074	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2075	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2076	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2077	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2078	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2079	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
2080	967.2330833	183265.2158	23.8348375	2075209.061	1085.448751	205663.9738	26.74794219	2328842.057
Totals	46506.84249	8811822.787	1121.006228	98918298.57	52190.92994	9888807.777	1258.01612	111008138

Social Costs from O&M Dredging Page 3

	Alternative C				Alternatives D-1 & D-2			
Year	SC-CO	SC-CO2 (2020 dollars)	SC-CH4 (2020 dollars)	SC-N2O (2020 dollars)	SC-CO	SC-CO2 (2020 dollars)	SC-CH4 (2020 dollars)	SC-N2O (2020 dollars)
2030	806.299648	152772.5649	17.57409869	1652982.725	1598.038737	302786.287	34.83083559	3276115.067
2031	819.304481	155236.6385	17.57409869	1652982.725	1623.813555	307669.9368	34.83083559	3276115.067
2032	832.3093141	157700.7121	18.45280363	1724851.539	1649.588374	312553.5866	36.57237737	3418554.853
2033	845.3141471	160164.7858	18.45280363	1724851.539	1675.363192	317437.2363	36.57237737	3418554.853
2034	858.3189801	162628.8594	19.33150856	1796720.353	1701.13801	322320.8861	38.31391915	3560994.639
2035	871.3238132	165092.933	19.33150856	1796720.353	1726.912829	327204.5359	38.31391915	3560994.639
2036	897.3334792	170021.0803	20.2102135	1868589.167	1778.462465	336971.8355	40.05546093	3703434.424
2037	910.3383123	172485.1539	20.2102135	1868589.167	1804.237284	341855.4853	40.05546093	3703434.424
2038	923.3431453	174949.2275	21.08891843	1940457.981	1830.012102	346739.1351	41.79700271	3845874.21
2039	936.3479783	177413.3012	21.96762337	1940457.981	1855.78692	351622.7849	43.53854449	3845874.21
2040	949.3528114	179877.3748	21.96762337	2012326.796	1881.561739	356506.4347	43.53854449	3988313.995
2041	962.3576444	182341.4484	22.8463283	2012326.796	1907.336557	361390.0845	45.28008627	3988313.995
2042	975.3624774	184805.522	22.8463283	2084195.61	1933.111375	366273.7342	45.28008627	4130753.781
2043	1001.372143	189733.6693	23.72503323	2084195.61	1984.661012	376041.0338	47.02162805	4130753.781
2044	1014.376977	192197.7429	23.72503323	2156064.424	2010.43583	380924.6836	47.02162805	4273193.566
2045	1027.38181	194661.8165	24.60373817	2156064.424	2036.210649	385808.3334	48.76316982	4273193.566
2046	1040.386643	197125.8902	24.60373817	2227933.238	2061.985467	390691.9832	48.76316982	4415633.352
2047	1053.391476	199589.9638	25.4824431	2227933.238	2087.760285	395575.633	50.5047116	4415633.352
2048	1066.396309	202054.0374	26.36114804	2299802.052	2113.535104	400459.2828	52.24625338	4558073.137
2049	1092.405975	206982.1847	26.36114804	2299802.052	2165.08474	410226.5824	52.24625338	4558073.137
2050	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2051	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2052	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2053	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2054	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2055	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2056	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2057	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2058	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2059	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2060	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2061	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2062	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2063	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2064	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2065	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2066	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2067	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2068	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2069	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2070	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2071	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2072	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923

2073	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2074	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2075	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2076	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2077	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2078	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2079	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
2080	1105.410808	209446.2583	27.23985297	2371670.866	2190.859559	415110.2321	53.98779516	4700512.923
Totals	53150.7526	10070668.91	1281.151795	113049644.6	105341.6825	19959476.69	2539.167914	224057782.7

Social Costs from O&M Dredging

Alternative		CO	CO_2	CH_4	N_2O
No-Action Alternative		46507	8811823	1121	98918299
Alternative B		52191	9888808	1258	111008138
Alternative C		53151	10070669	1281	113049645
Alternatives D-1 & D-2		105342	19959477	2539	224057783

Sequestration of CO_2 Calcualtions

Conversion Factors and Data Used:		
	1613 cubic yards per acre-foot	
	453.92 grams per pound	
	Depth of wetland created: 5 feet	
	4046.8 square meters per acre	
Cubic yards of material From Tables 11 and 12, Appendix B.1		

	Material Placed for Wetland (cy)	Depth of Wetland (ft)	Total Acres Wetlands Created (5 ft depth)	Area of wetlands created (m^2)	CO_2 Sequestration Rate (grams/m^2/yr)	Sequestered CO_2 per year (grams)	Sequestered CO_2 per year (pounds)	Sequestered CO_2 per year (metric tons)	Sequestered CO_2 over 50 year project lifetime (metric tons)
Alternative B (inner harbor	907450	5	113	455334	210	95620139	210806	96	4781
Alternative C (outer harbor	1341853	5	166	673306	210	141394204	311721	141	7070
Alternatives D-1 and D-2	2170000		204.5	827571	210	173789826	383141	174	8690

Source for sequestration rate: Estimates of Carbon Sequestration in Tidal Coastal Wetlands Along the US east Coast | Science Inventory | US EPA

Note: the material placed and total wetland acres for Alternatives D-1 and D-2 were obtained from the USFWS CAR (Appendix A02), which is a more conservative estimate, while Alternatives B and C had total acres of wetlands calculated from Appendix B.1.

$$\boldsymbol{Sequestered\ CO_2 = SR\ x\ Volumex1/D\ x\ Time}$$

Where:

Sequestered CO_2 = the amount of CO_2 in metric tons or pounds sequestered

SR = sequestration rate of CO_2 per unit area, per unit of time = 210 grams per meter per year

Volume = volume of excavated material from expanding turning basins

D = depth of wetland to be created, estimated at approximately 9 feet

Time = the unit of time over which benefits are calculated, estimated at 50 years

Alternative B			Alternative C			Alternative D-1 & D-2		
Year	SC-CO_2 (2020 dollars)	Social Cost of CO_2 Reductions from Sequestration	Year	SC-CO_2 (2020 dollars)	Social Cost of CO_2 Reductions from Sequestration	Year	SC-CO_2 (2020 dollars)	Social Cost of CO_2 Reductions from Sequestration
2030	62	296423	2030	62	438322.9097	2030	62	538750
2031	63	301204	2031	63	445392.634	2031	63	547439
2032	64	305985	2032	64	452462.3584	2032	64	556129
2033	65	310766	2033	65	459532.0827	2033	65	564818
2034	66	315547	2034	66	466601.8071	2034	66	573508
2035	67	320328	2035	67	473671.5314	2035	67	582197
2036	69	329890	2036	69	487810.9801	2036	69	599576
2037	70	334671	2037	70	494880.7045	2037	70	608266
2038	71	339452	2038	71	501950.4288	2038	71	616955
2039	72	344233	2039	72	509020.1532	2039	72	625645
2040	73	349014	2040	73	516089.8775	2040	73	634334
2041	74	353795	2041	74	523159.6019	2041	74	643024
2042	75	358576	2042	75	530229.3262	2042	75	651713
2043	77	368138	2043	77	544368.7749	2043	77	669092
2044	78	372919	2044	78	551438.4993	2044	78	677782
2045	79	377700	2045	79	558508.2236	2045	79	686471
2046	80	382481	2046	80	565577.948	2046	80	695161
2047	81	387262	2047	81	572647.6723	2047	81	703850
2048	82	392043	2048	82	579717.3967	2048	82	712540
2049	84	401605	2049	84	593856.8454	2049	84	729919
2050	85	406386	2050	85	600926.5697	2050	85	738608
2051	85	406386	2051	85	600926.5697	2051	85	738608
2052	85	406386	2052	85	600926.5697	2052	85	738608
2053	85	406386	2053	85	600926.5697	2053	85	738608
2054	85	406386	2054	85	600926.5697	2054	85	738608
2055	85	406386	2055	85	600926.5697	2055	85	738608
2056	85	406386	2056	85	600926.5697	2056	85	738608
2057	85	406386	2057	85	600926.5697	2057	85	738608
2058	85	406386	2058	85	600926.5697	2058	85	738608
2059	85	406386	2059	85	600926.5697	2059	85	738608
2060	85	406386	2060	85	600926.5697	2060	85	738608
2061	85	406386	2061	85	600926.5697	2061	85	738608
2062	85	406386	2062	85	600926.5697	2062	85	738608
2063	85	406386	2063	85	600926.5697	2063	85	738608
2064	85	406386	2064	85	600926.5697	2064	85	738608
2065	85	406386	2065	85	600926.5697	2065	85	738608
2066	85	406386	2066	85	600926.5697	2066	85	738608
2067	85	406386	2067	85	600926.5697	2067	85	738608
2068	85	406386	2068	85	600926.5697	2068	85	738608
2069	85	406386	2069	85	600926.5697	2069	85	738608
2070	85	406386	2070	85	600926.5697	2070	85	738608
2071	85	406386	2071	85	600926.5697	2071	85	738608
2072	85	406386	2072	85	600926.5697	2072	85	738608
2073	85	406386	2073	85	600926.5697	2073	85	738608
2074	85	406386	2074	85	600926.5697	2074	85	738608
2075	85	406386	2075	85	600926.5697	2075	85	738608
2076	85	406386	2076	85	600926.5697	2076	85	738608
2077	85	406386	2077	85	600926.5697	2077	85	738608
2078	85	406386	2078	85	600926.5697	2078	85	738608
2079	85	406386	2079	85	600926.5697	2079	85	738608
2080	85	406386	2080	85	600926.5697	2080	85	738608
	Total	19540015		Total	28893963		Total	35514022

	Social Cost of CO_2 Reductions from Sequestration
Alternative B (inner harbor only)	19540015
Alternative C (outer harbor only)	28893963
Alternatives D-1 and D-2	35514022

Social Costs of Greenhouse Gases Summary Tables

Tug Boats Social Costs (2020 Dollars)				
Alternative	CO	CO_2	CH_4	N_2O
No Action	788935.0792	583475615	12191	12760854
Alternative B	780989.601	577599348	12068	12632338
Alternative C	733775.4264	542680987	11338	11868659
Alternative D	738394.0409	546096793	11410	12900830

Social Costs from O&M Dredging				
Alternative	CO	CO_2	CH_4	N_2O
No-Action Alternative	46507	8811823	1121	98918299
Alternative B	52191	9888808	1258	111008138
Alternative C	53151	10070669	1281	113049645
Alternatives D-1 & D-2	105342	19959477	2539	224057783

Social Costs from Direct Emissions (2020 Dollars)					
Alternative	CO	CO_2	CH_4	N_2O	Total
B	$1,335	$694,396	$298	$14,578	$710,607
C	$1,032	$562,463	$119	$9,409	$573,023
D-1	$2,384	$1,266,386	$423	$24,412	$1,293,606
D-2	$1,820	$967,053	$442	$17,729	$987,044

Social Costs from Long-Term Emissions (2020 Dollars)					
Alternative	CO	CO_2	CH_4	N_2O	Total
No-Action	$577,628,908	$187,717,167,140	$3,746,375	$3,600,857,511	$191,899,399,934
B	$560,595,650	$182,204,412,604	$3,650,740	$3,510,042,639	$186,278,701,633
C	$508,351,167	$169,279,205,912	$3,395,006	$3,270,687,224	$173,061,639,310
D-1 & D-2	$510,887,884	$166,136,042,322	$3,348,006	$3,323,771,422	$169,974,049,633

Alternative	Social Cost of CO_2 Reductions from Sequestration
B	19540015
C	28893963
D-1 & D-2	35514022

Project Lifetime NET Social Costs (2020 Dollars)					
Alternative	CO	CO_2	CH_4	N_2O	Total
B	-$17,031,923	-$5,531,600,155	-$95,337	-$90,800,294	-$5,639,527,709
C	-$69,276,709	-$18,466,292,729	-$351,250	-$330,160,877	-$18,866,081,565
D-1	-$66,738,640	-$21,615,372,455	-$397,946	-$277,061,677	-$21,959,570,717
D-2	-$66,739,204	-$21,615,671,788	-$397,927	-$277,068,360	-$21,959,877,279