Appendix A: Air Quality Calculations

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TAB A.

Emissions Summary for Alternative 1

This summary assumes breakwater and seawall stone delivery via rail

Alternative 1 includes beach renourishment, construction of 12 breakwaters, and seawall extensior

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e
Beach Renourishment	Onsite	35.41	110.24	675.33	0.75	17.78	17.24	76,973
	Offsite	0.26	0.82	5.05	0.01	0.13	0.13	558
Breakwater Construction	Onsite	2.04	6.52	27.79	0.03	1.31	1.27	10,427
	Offsite	107.99	592.33	2,667.82	2.08	72.28	66.23	207,049
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126
	Offsite	17.59	96.48	435.50	0.34	11.41	10.74	33,693
Subtotal Onsite		37.52	117.13	704.42	0.79	19.16	18.57	88,526
Onsite exceed 250-ton comparative threshold?		No	No	Yes	No	No	No	NA
Subtotal Offsite		125.84	689.63	3,108.37	2.43	83.83	77.10	241,301
Total		163.36	806.76	3,812.79	3.21	102.98	95.67	329,827

HAP emissions for Alternative 1

Activity	Location	Formaldehyde	Benzene	Total HAPs
Beach Renourishment	Onsite	1.51	0.19	1.70
	Offsite	0.01	0.00	0.01
Breakwater Construction	Onsite	0.08	0.52	0.61
	Offsite	0.07	0.01	0.07
Seawall Extension	Onsite	0.00	0.02	0.02
	Offsite	0.01	0.00	0.01
Subtotal Onsite		1.60	0.73	2.33
Onsite exceed 10-ton individual HAP comparative threshol		No	No	NA
Onsite exceed 25-ton total HAP comparative threshold?		NA	NA	No
Subtotal Offsite		0.08	0.01	0.09
Total		1.68	0.74	2.42

Emissions Summary for Alternative 2

This summary assumes seawall stone delivery via rail

Alternative 2 includes beach renourishment and seawall extensior

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e
Beach Renourishment	Onsite	35.41	110.24	675.33	0.75	17.78	17.24	76,973
	Offsite	0.26	0.82	5.05	0.01	0.13	0.13	558
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126
	Offsite	17.59	96.48	435.50	0.34	11.41	10.74	33,693
Subtotal Onsite		35.49	110.61	676.63	0.76	17.85	17.30	78,099
Onsite exceed 250-ton comparative threshold?		No	No	Yes	No	No	No	NA
Subtotal Offsite		17.85	97.30	440.54	0.35	11.54	10.87	34,252
Total		53.34	207.91	1,117.18	1.10	29.39	28.17	112,351

HAP emissions for Alternative 2

Activity	Location	Formaldehyde	Benzene	Total HAPs
Beach Renourishment	Onsite	1.51	0.19	1.70
	Offsite	0.01	0.00	0.01
Seawall Extension	Onsite	0.00	0.02	0.02
	Offsite	0.01	0.00	0.01
Subtotal Onsite		1.51	0.21	1.72
Onsite exceed 10-ton individual HAP comparative threshol		No	No	NA
Onsite exceed 25-ton total HAP comparative threshold?		NA	NA	No
Subtotal Offsite		0.02	0.00	0.02
Total		1.53	0.21	1.74

Emissions Summary for Alternative 3

This summary assumes breakwater and seawall stone delivery via rail

Alternative 3 includes construction of 12 breakwaters and seawall extensior

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e
Breakwater Construction	Onsite	2.04	6.52	27.79	0.03	1.31	1.27	10,427
	Offsite	107.99	592.33	2,667.82	2.08	72.28	66.23	207,049
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126
	Offsite	17.59	96.48	435.50	0.34	11.41	10.74	33,693
Subtotal Onsite		2.11	6.90	29.09	0.04	1.38	1.34	11,553
Onsite exceed 250-ton comparative threshold?		No	No	No	No	No	No	NA
Subtotal Offsite		125.58	688.81	3,103.32	2.42	83.69	76.97	240,743
Total		127.69	695.70	3,132.41	2.46	85.07	78.31	252,296

HAP emissions for Alternative 3

Activity	Location	Formaldehyde	Benzene	Total HAPs
Beach Renourishment	Onsite	0.08	0.52	0.61
	Offsite	0.07	0.01	0.07
Seawall Extension	Onsite	0.00	0.02	0.02
	Offsite	0.01	0.00	0.01
Subtotal Onsite		0.09	0.54	0.63
Onsite exceed 10-ton individual HAP comparative threshol		No	No	NA
Onsite exceed 25-ton total HAP comparative threshold?		NA	NA	No
Subtotal Offsite		0.07	0.01	0.08
Total		0.16	0.55	0.71

TAB B.

Emissions Summary for Alternative 1

This summary assumes breakwater and seawall stone delivery via barge

Alternative 1 includes beach renourishment, construction of 12 breakwaters, and seawall extension

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Total HAPs
Beach Renourishment	Onsite	35.41	110.24	675.33	0.75	17.78	17.24	76,973	1.70
	Offsite	0.26	0.82	5.05	0.01	0.13	0.13	558	0.01
Breakwater Construction	Onsite	0.65	2.54	11.35	0.02	0.41	0.40	3,838	0.09
	Offsite	27.32	84.91	521.46	0.58	13.68	13.27	57,713	1.30
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126	0.02
	Offsite	1.59	4.96	30.43	0.03	0.80	0.77	3,368	0.08
Total		65.31	203.84	1,244.92	1.39	32.87	31.88	143,577	3.19

Emissions Summary for Alternative 2

This summary assumes seawall stone delivery via barge

Alternative 2 includes beach renourishment and seawall extension

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Total HAPs
Beach Renourishment	Onsite	35.41	110.24	675.33	0.75	17.78	17.24	76,973	1.70
	Offsite	0.26	0.82	5.05	0.01	0.13	0.13	558	0.01
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126	0.02
	Offsite	1.59	4.96	30.43	0.03	0.80	0.77	3,368	0.08
Total		37.34	116.39	712.11	0.80	18.78	18.21	82,026	1.81

Emissions Summary for Alternative 3

This summary assumes breakwater and seawall stone delivery via barge

Alternative 3 includes construction of 12 breakwaters and seawall extension

Activity	Location	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Total HAPs
Breakwater Construction	Onsite	0.65	2.54	11.35	0.02	0.41	0.40	3,838	0.09
	Offsite	27.32	84.91	521.46	0.58	13.68	13.27	57,713	1.30
Seawall Extension	Onsite	0.07	0.38	1.30	0.00	0.07	0.07	1,126	0.02
	Offsite	1.59	4.96	30.43	0.03	0.80	0.77	3,368	0.08
Total		29.63	92.78	564.54	0.63	14.96	14.51	66,046	1.48

TAB C.

Emission Calculations for Beach Renourishment 3,000,000 CY of sand + 100% for loss 3,000,000 6,000,000 Total CY

90 days

Material	Source Location	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled
Mobilization - supplies via truck	Newport News	114	5.1	90	456	20,520
Tug & barge - mob supplies	Norfolk	100	40	10	400	2,000

	VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**	**Formaldehyde**	**Benzene**
	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile	lb/mile
Dump/Supply Trucks	1.87E-03	9.87E-03	1.62E-02	1.28E-05	2.18E-03	1.00E-03	1.82E-05	9.62E-05	3.75	0.00	0.00
	VOCs	**CO**	**NOx**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**N2O**	**CH4**	**CO2**	**Formaldehyde**	**Benzene**
	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
Dump/Supply Trucks	0.02	0.10	0.17	0.00	0.02	0.01	0.00	0.00	38.48	0.00	0.00
									CO2e in metric tons/year	**35**	

Deliveries	**Engine HP**	**# Engines**	**Load Factor**	**VOC**	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**	**BSFC**	**Formaldehyde**	**Benzene**
				g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	lb/hp-hr	g/hp-hr	g/hp-hr
Tugboat - propulsion	2000	2	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.304	0.01	0.00
				VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**		**Formaldehyde**	**Benzene**
				Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton		Ton	Ton
			Tugboat Annual Emissions	0.26	0.82	5.05	0.01	0.13	0.13	0.03	0.00	607.68		0.01	0.00
											CO2e in metric tons/year	**558**			

Equipment Usage	Hours
Derrick barge	886
Work barge	886
Work Tug	18,598
Bulldozer	35,424
Trailing Suction Dredge-propulsion	35,424
Trailing Suction Dredge - pumps	24,797

Equipment and hours are from the 2019 SERP EA. Hours are factored due to increased material usage in this project.

Hours factor: this project will dredge 6,000,000 CY of sand, the 2019 EA calculations were based on 1,625,000 CY of sand.

6,000,000 / 1,625,000 = 3.69

Equipment Emissions

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	N2O g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	BSFC lb/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Derrick barge	886	2,500	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00
Work barge	886	1,000	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00
Work Tug	18,598	500	0.5	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00
Trailing Suction Dredge-propulsion	35,424	4,000	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00
Trailing Suction Dredge - pumps	24,797	2,500	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	N2O lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Derrick barge	732	2,274	13,965	15	366	355	82	7	1,681,762	31	3
Work barge	293	910	5,586	6	147	142	33	3	672,705	12	1
Work Tug	2,260	7,023	43,128	48	1,132	1,098	254	20	5,193,677	96	11
Trailing Suction Dredge-propulsion	46,827	145,534	893,775	989	23,452	22,749	5,264	425	107,632,776	1,999	222
Trailing Suction Dredge - pumps	20,487	63,671	391,027	433	10,260	9,952	2,303	186	47,089,339	875	97
Tons/year:	**35.3**	**109.7**	**673.7**	**0.7**	**17.7**	**17.1**	**4.0**	**0.3**	**81,135.1**	**1.5**	**0.2**
CO2e in metric tons/year									**74,567**		

Vessel emission factors from page 3-22 of Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder, USEPA 2008.

All vessels are presumed to use 2 propulsion engines, table lists total HP.

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Bulldozer	35,424	215	0.58	0.02	0.09	0.29	0.00	0.02	0.02	0.00	536.77	0.00	0.00

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Bulldozer	190	860	2,854	14	161	156	15	5,227,457	8	43
Tons/year:	**0.1**	**0.4**	**1.4**	**0.0**	**0.1**	**0.1**	**0.01**	**2,613.7**	**0.00**	**0.02**
CO2e in metric tons/year								**2,371**		

Total Onsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	35.41	110.24	675.33	0.75	17.78	17.24	76,973	1.51	0.19

Total Offsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	0.26	0.82	5.05	0.01	0.13	0.13	558	0.01	0.00

Total Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	35.68	111.06	680.38	0.76	17.91	17.37	77,531	1.52	0.19

TAB D.

Emission Calculations for Breakwater Construction using Temporary Bulkhead

This is the highest emissions case among the three options for building breakwaters.
Assume all stones come via train, and are moved from the railhead to the beach by truck.

Bulkhead construction
Pile driving - vibratory hammer
construction of bulkhead - will be filled with sand, which will be spread on the beach after the bulkhead is removed.
pile removal - vibratory hammer

Equipment
crawler crane
hydraulic excavator
vibratory hammer
dozer

130	ft long			
12	ft wide at top	Type 2 stone (core stone)	300	average lb
14	ft depth		2.3	ft long
65	ft width at base (assumed all breakwaters are the maximum size)		0.78	ft wide
21.5	ft width of long sides		1.45	ft thickness type 2
70,070	CY volume of one breakwater (minus ends)		0.10	CY volume of 1 Type 2 stone
5,460	CY volume of one breakwater end		3114	lb/cy
80,990	CY Total volume of one breakwater	Type 1 stone (breakwater armor stone)	5300	average lb
12	total	tons	2.65	
1	month construction period per breakwater	Stone Density	165	lb/cf
Rocks brought by rail from quarry			4455	lb/cy
10,000	tons ave train capacity	CY per stone	1.190	
66,667	Type 2 stone capacity for 1 train			
3,774	Type 1 armor stone capacity for 1 train			

76,399	CY of Type 2 stone required for breakwater	Stone percentages from June 2019 Final Environmental Assessment for the Wallops facility, Appendix E
792,974	Total Type 2 stones for 1 breakwater	
12	barges to bring this number of Type 2 stone	
118,946	Total weight of Type 2 stones for 1 breakwater (tons)	
4,591	CY volume of Type 1 stone in 1 breakwater	Stone percentages from June 2019 Final Environmental Assessment for the Wallops facility, Appendix E
1	barges to bring this number of Type 1 stone	
3,859	Total Type 1 stones for 1 breakwater	
10,227	Total weight of Type 1 stones for 1 breakwater (tons)	
129,173	Total weight of all stones for 1 breakwater (tons)	

Truck capacity	12	cy
Number of truck trips	6,749	
One way truck distance	10	miles

Sand required to fill the temporary bulkhead:

Length	130 feet	
Width	30 feet	
Depth	14 feet	Assumed linear depth progression from 0 at beach to 14 feet at breakwater (same height as breakwater)
Volume of temporary bulkhead	27,300 cubic feet	
	1,011 cubic yards of sand required to fill bulkhead	

Rail delivery from quarry to LeCato railhead

Material	Source Location	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled	
Stone	Quarry	250	14	13	185	6,459	Per breakwater

	VOC	CO	NOx	SO2	PM10	PM2.5	N2O	CH4	CO2
Stone Deliveries	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal
Rail - propulsion	4.85	26.62	120.50	0.09	3.04	2.95	0.26	0.80	10150
	VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**
	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
Rail Annual Emissions	8.93	48.97	221.64	0.17	5.60	5.43	0.48	1.47	18,669
								CO2e in metric tons/year	**17,088**

0.002 gal/ton-miles of freight transported from EPA 2021 SmartWay Rail Carrier Partner Tool: Technical Documentation.

Truck hauling from LeCato railhead to beach

Material	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled
Stone	10	0.57	6,749	3,857	134,983

	VOC	CO	NOx	SO2	PM10	PM2.5	N2O	CH4	CO2	Benzene	Formaldehyde
	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT
Highway	0.31	1.74	3.19	0.00	1.37	0.33	0.00	0.01	972.79	0.00	0.02
Side streets	0.61	3.40	5.80	0.00	4.37	0.89	0.01	0.03	1445.15	0.00	0.05
Idle	5.23	21.99	34.17	0.02	2.54	2.34	0.08	0.27	5727.82	0.04	0.41
	VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**	**Benzene**	**Formaldehyde**
	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
Annual Emissions	0.07	0.39	0.68	0.00	0.43	0.09	0.00	0.00	182.32	0.00	0.01
								CO2e in metric tons/year	**166**		

Equipment Usage	Hours
Crawler Crane	1,920
Vibratory Hammer	1,920
Dozer	1,920
Excavator	1,920

Assuming 60 days construction per breakwater, 2 8 hour shifts, and 2 units of each equipment

Equipment Emissions

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Crawler Crane	1,920	150	1	0.04	0.18	0.86	0.00	0.04	0.04	0.00	531	0.002	0.010
Vibratory Hammer	1,920	300	1	0.21	0.56	2.62	0.00	0.12	0.11	0.01	530	0.009	0.055
Dozer	1,920	275	0.58	0.02	0.09	0.29	0.00	0.02	0.02	0.00	537	0.001	0.004
Excavator	1,920	450	0.53	0.03	0.20	0.55	0.00	0.03	0.03	0.00	537	0.001	0.008

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Crawler Crane	26	111	548	1	26	25	2	337,103	1	6
Vibratory Hammer	268	711	3,331	2	148	144	16	673,592	11	70
Dozer	13	60	198	1	11	11	1	362,400	1	3
Excavator	32	205	554	1	33	32	3	541,859	1	8
Tons/year:	**0.2**	**0.5**	**2.3**	**0.0**	**0.1**	**0.1**	**0.0**	**957.5**	**0.007**	**0.044**
							CO2e in metric tons/year	**869**		

Total Onsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One Breakwater	0.17	0.54	2.32	0.00	0.11	0.11	869	0.01	0.04
12 Breakwaters	2.04	6.52	27.79	0.03	1.31	1.27	10,427	0.08	0.52

Total Offsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One Breakwater	9.00	49.36	222.32	0.17	6.02	5.52	17,254	0.01	0.00
12 Breakwaters	107.99	592.33	2667.82	2.08	72.28	66.23	207,049	0.07	0.01

Total Emissions (tons per year)

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One Breakwater	9.17	49.90	224.63	0.18	6.13	5.62	18,123	0.01	0.04
12 Breakwaters	110.02	598.85	2,695.61	2.11	73.59	67.50	217,476	0.15	0.53

TAB E.

Length	3170	feet
Stone weight	5-7	tons
Average Stone weight	6	tons
Height of wall	17.31	14 feet above MHWL (1.31), plus 2 feet excavation
Top width	14	feet
Bottom width	65.93	feet
Area	691.79415	square feet
Volume	2,192,987	cubic feet
	81,222	cubic yards
Stone density	165	lb/cf
	4455	lb/cy
	2.23	ton/cy
Stone volume	2.69	cy/stone
Number of stones required	30,154	
Total weight of stones	180,921.47	tons
10,000	tons avg train capacity with one engine	
18	Number of trains to deliver all stones	

Truck capacity	12	cy
Number of truck trips	6,768	
One way truck distance	10	miles

tracked excavator
bulldozer

Rail delivery from quarry to LeCato railhead

Material	Source Location	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled
Stone	Quarry	250	14	18	258	9,046

	VOC	CO	NOx	SO2	PM10	PM2.5	N2O	CH4	CO2
Stone Deliveries	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal	g/gal
Rail - propulsion	4.85	26.62	120.50	0.09	3.04	2.95	0.26	0.80	10150
	VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**
	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
Rail Annual Emissions	17.52	96.06	434.78	0.34	10.98	10.65	0.94	2.89	36,623
								CO2e in metric tons/year	**33,523**

0.002 gal/ton-miles of freight transported from EPA 2021 SmartWay Rail Carrier Partner Tool: Technical Documentation.

Truck hauling from LeCato railhead to beach

Material	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled
Stone	10	0.57	6,768	3,868	135,370

	VOC	CO	NOx	SO2	PM10	PM2.5	N2O	CH4	CO2	Benzene	Formaldehyde
	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT
Highway	0.31	1.74	3.19	0.00	1.37	0.33	0.00	0.01	972.79	0.00	0.02
Side streets	0.61	3.40	5.80	0.00	4.37	0.89	0.01	0.03	1445.15	0.00	0.05
Idle	5.23	21.99	34.17	0.02	2.54	2.34	0.08	0.27	5727.82	0.04	0.41
	VOC	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**	**N2O**	**CH4**	**CO2**	**Benzene**	**Formaldehyde**
	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
Annual Emissions	0.07	0.41	0.71	0.00	0.43	0.09	0.00	0.00	187.73	0.00	0.01
								CO2e in metric tons/year	**171**		

Equipment Usage	Hours
Crawler Crane	3,840
Dozer	3,840
Excavator	3,840

Assuming 120 days construction, 2 8 hour shifts, and 2 units of each equipment

Equipment Emissions

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Crawler Crane	3,840	150	1	0.0414138	0.1753584	0.8636454	0.0014719	0.040731732	0.0395098	3.58E-03	530.93	0.002	0.010
Dozer	3,840	275	0.58	0.0195561	0.0883136	0.2930742	0.0014402	0.016561595	0.0160647	1.58E-03	536.77	0.001	0.004
Excavator	3,840	450	0.53	0.0319626	0.2032897	0.5487676	0.0014798	0.032563556	0.0315866	2.82E-03	536.74	0.001	0.008

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Crawler Crane	53	223	1,097	2	52	50	5	674,206	2	12
Dozer	26	119	396	2	22	22	2	724,800	1	6
Excavator	65	410	1,108	3	66	64	6	1,083,718	3	16
Tons/year:	**0.1**	**0.4**	**1.3**	**0.0**	**0.1**	**0.1**	**0.0**	**1,241.4**	**0.00**	**0.02**
							CO2e in metric tons/year	**1,126**		

Total Onsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	0.07	0.38	1.30	0.00	0.07	0.07	1,126	0.00	0.02

Total Offsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	17.59	96.48	435.50	0.34	11.41	10.74	33,693	0.01	0.00

Total Emissions (tons per year)

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Seawall Extension	17.66	96.85	436.80	0.34	11.48	10.81	34,819	0.01	0.02

TAB F.

Emission Calculations for Breakwater Construction

130 ft long
12 ft wide at top
14 ft depth
65 ft width at base (assumed all breakwaters are the maximum size)
21.5 ft width of long sides
70,070 CY volume of one breakwater (minus ends)
5,460 CY volume of one breakwater end
80,990 CY Total volume of one breakwater
12 total
1 month construction period

Rocks brought by water from Norfolk
1,500 tons ave barge capacity
10,000 Type 2 stone capacity for 1 barge
566 Type 1 armor stone capacity for 1 barge

Deposited using barge excavator
76,399 CY of Type 2 stone required for breakwater
792,974 Total Type 2 stones for 1 breakwater
79 barges to bring this number of Type 2 stone
4,591 CY volume of Type 1 stone in 1 breakwater
7 barges to bring this number of Type 1 stone
3,859 Total Type 1 stones for 1 breakwater

Type 2 stone (core stone) 300 average lb
2.3 ft long
0.78 ft wide
1.45 ft thickness type 2
0.10 CY volume of 1 Type 2 stone

Type 1 stone (breakwater armor stone) 5300 average lb
tons 2.65
Stone Density 165 lb/cf
4455 lb/cy
CY per stone 1.190

Stone percentages from June 2019 Final Environmental Assessment for the Wallops facility, Appendix E

Stone percentages from June 2019 Final Environmental Assessment for the Wallops facility, Appendix E

Material	Source Location	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled	
Tug & barge - riprap	Norfolk	100	40	86	3,445	17,223	Per breakwater

Deliveries	Engine HP	# Engines	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	N2O g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	BSFC lb/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Tugboat - propulsion	2000	2	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.350	0.01	0.00
				VOC Ton	**CO** Ton	**NOx** Ton	**SO2** Ton	**PM10** Ton	**PM2.5** Ton	**N2O** Ton	**CH4** Ton	**CO2** Ton		**Formaldehyde** Ton	**Benzene** Ton
			Tugboat Emissions	2.28	7.08	43.46	0.05	1.14	1.11	0.26	0.02	5,233		0.10	0.01
												CO2e in metric tons/year		**4,809**	

Equipment Usage	Hours	
Work Tug	1,920	assumed 2 units of each equipment, working 16 hours per day for 60 days
Excavator	1,920	

Equipment Emissions

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	N2O g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Work Tug	1,920	150	0.50	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	506.69	0.01	0.00
Excavator	1,920	450	0.53	0.03	0.20	0.55	0.00	0.03	0.03		0.00	536.74	0.00	0.01

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	N2O lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Work Tug	74	218	1,337	1	35	34	8	1	161,063	4	0
Excavator	34	205	554	1	33	32	0	3	541,859	1	8
Tons/year:	**0.1**	**0.2**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**351.5**	**0.00**	**0.00**
								CO2e in metric tons/year	**320**		

All vessels are presumed to use 2 propulsion engines, table lists total HP.

Total Onsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One Breakwater	0.05	0.21	0.95	0.00	0.03	0.03	320	0.00	0.00
12 Breakwaters	0.65	2.54	11.35	0.02	0.41	0.40	3,838	0.03	0.05

Total Offsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One Breakwater	2.28	7.08	43.46	0.05	1.14	1.11	4,809	0.10	0.01
12 Breakwaters	27.32	84.91	521.46	0.58	13.68	13.27	57,713	1.17	0.13

Total Emissions (tons per year)

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
One breakwater	2.33	7.29	44.40	0.05	1.17	1.14	5,129	0.10	0.02
12 breakwaters	27.97	87.45	532.81	0.60	14.09	13.67	61,551	1.20	0.18

TAB G.

Length	3170	feet
Stone weight	5-7	tons
Average Stone weight	6	tons
Height of wall	17.31	14 feet above MHWL (1.31), plus 2 feet excavation
Top width	14	feet
Bottom width	65.93	feet
Area	691.79415	square feet
Volume	2,192,987	cubic feet
	81,222	cubic yards
Stone density	165	lb/cf
	4455	lb/cy
	2.23	ton/cy
Stone volume	2.69	cy/stone
Number of stones required	30,154	
Total weight of stones	180,921.47	
1,500	tons avg barge capacity	
121	Number of barges to deliver all stones	

Truck capacity	12	cy
number of stones per truck	4	
Number of truck trips	7,538	

tracked excavator
bulldozer

Material deliveries via barge

Material	Source Location	One way distance (mi)	Total Round Trip Time (hrs)	Total # of trips	Computed Total time (hrs)	Total mi traveled
Stone	Norfolk	100	20	121	2,412	24,123

Deliveries	**Engine HP**	**# Engines**	**Load Factor**	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM10** g/hp-hr	**PM2.5** g/hp-hr	**N2O** g/hp-hr	**CH4** g/hp-hr	**CO2** g/hp-hr	**BSFC** lb/hp-hr	**Formaldehyde** g/hp-hr	**Benzene** g/hp-hr
Tugboat - propulsion	2000	2	0.68	0.22	0.69	4.21	0.00	0.11	0.11	0.02	0.00	507	0.350	0.01	0.00
				VOC Ton	**CO** Ton	**NOx** Ton	**SO2** Ton	**PM10** Ton	**PM2.5** Ton	**N2O** Ton	**CH4** Ton	**CO2** Ton		**Formaldehyde** Ton	**Benzene** Ton
		Tugboat Annual Emissions		1.59	4.96	30.43	0.03	0.80	0.77	0.18	0.01	3,665		0.07	0.01
											CO2e in metric tons/year			**3,368**	

Equipment Usage	Hours
Crawler Crane	3,840
Dozer	3,840
Excavator	3,840

Assuming 120 days construction, 2 8 hour shifts, and 2 units of each equipment

Equipment Emissions

Off-road Equipment	Hours of Operation	Engine HP	Load Factor	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM10 g/hp-hr	PM2.5 g/hp-hr	CH4 g/hp-hr	CO2 g/hp-hr	Formaldehyde g/hp-hr	Benzene g/hp-hr
Crawler Crane	3,840	150	1	0.041414	0.175358	0.863645	0.001472	0.040731732	0.03951	3.58E-03	530.93	0.00	0.01
Dozer	3,840	275	0.58	0.019556	0.088314	0.293074	0.00144	0.016561595	0.016065	1.58E-03	536.77	0.00	0.00
Excavator	3,840	450	0.53	0.031963	0.20329	0.548768	0.00148	0.032563556	0.031587	2.82E-03	536.74	0.00	0.01

	VOC lb	CO lb	NOx lb	SO2 lb	PM10 lb	PM2.5 lb	CH4 lb	CO2 lb	Formaldehyde lb	Benzene lb
Crawler Crane	53	223	1,097	2	52	50	5	674,206	2	12
Dozer	26	119	396	2	22	22	2	724,800	1	6
Excavator	65	410	1,108	3	66	64	6	1,083,718	3	16
Tons/year:	**0.1**	**0.4**	**1.3**	**0.0**	**0.1**	**0.1**	**0.0**	**1,241.4**	**0.00**	**0.02**

CO2e in metric tons/year	**1,126**

Total Onsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	0.07	0.38	1.30	0.00	0.07	0.07	1,126	0.00	0.02

Total Offsite Emissions

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Tons per Year	1.59	4.96	30.43	0.03	0.80	0.77	3,368	0.07	0.01

Total Emissions (tons per year)

	VOC	CO	NOx	SO2	PM10	PM2.5	CO2e	Formaldehyde	Benzene
Seawall Extension	1.67	5.33	31.73	0.04	0.87	0.84	4,494	0.07	0.03

TAB H.

average passenger vehicle

	400	grams of CO_2 per mile	Source: https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#driving
	0.88	lb of CO_2 per mile	

	CO_2e Tons/yr		
		748,542,112	miles
Alt 1	329,827	64,529	cars driving 11,600 miles in a single year (annual mileage source: Virginia DMV)
		9,218	cars driving 11,600 miles per year (annual mileage source: Virginia DMV) for seven years
		254,980,116	miles
Alt 2	112,351	21,981	cars driving 11,600 miles per year (annual mileage source: Virginia DMV)
		572,584,755	miles
Alt 3	252,296	49,361	cars driving 11,600 miles per year (annual mileage source: Virginia DMV)

TAB I.

EQUIPMENT DATA AND EMISSION FACTORS

Construction			Emissions Factors									
		Load	VOC	CO	NOx	SO_2	PM10	PM2.5	CO_2	CH4	Formaldehyde	Benzene
Equipment	HP	Factor	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr
Dozer	275	0.58	0.02	0.09	0.29	1.44E-03	0.02	0.02	536.77	1.58E-03	0.001	0.00
Excavator	450	0.53	0.03	0.20	0.55	1.48E-03	0.03	0.03	536.74	2.82E-03	0.001	0.01
MOBILE CRANE	150	1	0.04	0.18	0.86	1.47E-03	0.04	0.04	530.93	3.58E-03	0.002	0.01
Pile Driver/Extractor	300	1	0.21	0.56	2.62	1.70E-03	0.12	0.11	530.44	0.01	0.009	0.05

Note: The MOVES model does not include emission factors for N2O for nonroad equipment. N2O for nonroad equipment is estimated using ratio
N2O/CH4 ratio of 0.26/0.57 from EPA (2016), Table B-8.

Construction Trucks	Emissions Factors										
	VOC	CO	NOx	SO2	PM10	PM2.5	CO2	CH4	N2O	Formaldehyde	Benzene
	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle	g/hr-vehicle
Onsite trucks - Idle	5.23	21.99	34.17	0.02	2.54	2.34	5,727.82	0.27	0.08	3.88E-02	4.06E-01
	VOC	CO	NOx	SO2	PM10	PM2.5	CO2	CH4	N2O	Formaldehyde	Benzene
	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT
Onsite trucks - 10 MPH	0.85	4.48	7.34	0.01	0.99	0.46	1,701.05	0.04	0.01	4.52E-03	4.74E-02

Boat Equipment	Engine kW	Load	Emissions Factors											
			VOC	CO	NOx	SO_2	PM10	PM2.5	CO_2	CH4	N_2O	BSFC	Formaldehyde	Benzene
		Factor	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)
Work tug - propulsion	112	0.5	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014
Ocean Tug- propulsion	1118	0.68	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014
Derrick Barge	2500	0.68	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014
Work Barge	1000	0.68	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014
Trailing Suction Dredge - Propulsion	4000	0.68	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014
Trailing Suction Dredge - Pumps	2500	0.68	0.30	0.92	5.64	6.25E-03	0.15	0.14	679	2.68E-03	0.03	213	0.013	0.0014

Hazardous Air Pollutant (HAP) Speciation Profiles/Emission Factors from USEPA Port Emissions Inventory Guidance (2020), Appendix D.

Benzene = 0.004739 X VOC

Formaldehyde = 0.042696 X VOC

For Harborcraft:

SO2 Emission factor calculated based on equation 4.5 in EPA (2020), Port Emission Guidance

CO2 Emission factor calculated based on equation 4.4 in EPA (2020)

CH4 Emission factor calculated based on 4.5.4 in EPA (2020)

N2O Emission factor calculated based on equation 4.3 in EPA (2020)

For ocean going vessels:

CO2 Emission factor calculated based on equation 3.4 in EPA (2020)

PM2.5 calculated as 92% of PM10 as per 3.5.3 in EPA (2020)

Rail Movement of Materials

Locomotives - EPA Tier 1 engines assumed

	g/gal								
	VOC	CO	Nox	SO2	PM10	PM2.5	CO2	CH4	N20
Large Line Haul, Tier 1+	4.85	26.62	120.5	0.0939	3.042	2.951	10,150	0.8	0.26

diesel fuel density assumed at 3200 g/gal.

Sulfur content assumed at 15 ppm

Carbon content assumed at 87 % by mass

Emission data from EPA, 2020 National Emissions Inventory: 453.59 g/lb

Locomotive Component, Table 5. ERG 2022.

No EFs for formaldehyde or benzene

0.002 gal/ton-miles of freight transported from EPA 2021 SmartWay Rail Carrier Partner Tool: Technical Documentation

Truck/Transit Emission Factors

Road Type	Vehicle Type	Speed (MPH)	Emission Factor Units	Maximum Emission Factor											
				VOC	CO	NOx	SO2	PM10	PM2.5	CO2	CH4	N2O	Total GHGs (CO2e)	Benzene	Formaldehyde
Highway	SUSH Truck	35	g/VMT	3.07E-01	1.74E+00	3.19E+00	3.31E-03	1.37E+00	3.33E-01	9.73E+02	1.46E-02	2.36E-03	9.74E+02	2.30E-03	2.41E-02
Sidestreets	SUSH Truck	15	g/VMT	6.07E-01	3.40E+00	5.80E+00	4.92E-03	4.37E+00	8.88E-01	1.45E+03	3.12E-02	5.52E-03	1.45E+03	4.52E-03	4.74E-02
Idle	SUSH Truck	0	g/hr	5.23E+00	2.20E+01	3.42E+01	1.95E-02	2.54E+00	2.34E+00	5.73E+03	2.70E-01	8.27E-02	5.76E+03	3.88E-02	4.06E-01

SUSH = Single Unit Short Haul