OCS Report
BOEM 2013-123

Improving Emission Estimates and Understanding of Pollutant Dispersal for Impact Analysis of Beach Nourishment and Coastal Restoration Projects

U.S. Department of the Interior
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Author
ENVIRON INTERNATIONAL CORPORATION

Prepared under BOEM Contract M10PC00088
By
ENVIRON International Corporation
773 San Marin Dr. Suite 2115
Novato, CA 94945

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U.S. Department of the Interior
Bureau of Ocean Energy Management
381 Elden Street
Herndon, VA 20710
Phone: (703) 787-1000
Fax: (703) 787-1026
Web site: www.boem.gov

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road
Springfield, Virginia 22312
Phone: (703) 605-6000, 1-800-553-6847
Fax: (703) 605-6900
Email: orders@ntis.gov

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1. INTRODUCTION

The Outer Continental Shelf Lands Act, National Environmental Policy Act (NEPA), and Clean Air Act (CAA) require the Bureau of Ocean Energy Management (BOEM) to ensure that beach nourishment and coastal restoration projects do not cause or contribute to the deterioration of air quality. Estimating a proposed activity's emissions and evaluating the degree of dispersion of pollutants over the shallow inner continental shelf and coastal region are key elements of evaluating the potential effect of the proposed activities on air quality and determining appropriate mitigation. The BOEM is required to ensure that proposed activities do not violate National Ambient Air Quality Standards (NAAQS) for criteria pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), lead (Pb), sulfur dioxide (SO_2) and particulate matter (PM). The BOEM is also interested in inventorying emissions of greenhouse gases (carbon dioxide equivalent; CO2, CH4, N2O). Large projects impacting areas that are in nonattainment of the NAAQS with emissions exceeding the *de minimus* thresholds under the General Conformity rule of the CAA would require more detailed analyses to demonstrate that the project action does not cause or contribute to any new violation of ambient air quality standards or that emission offsets would be required. Table 1 lists the General Conformity rule (40 CFR 93.153)[1]emission thresholds for the criteria pollutants and for emissions of VOC and NO_x (which are ozone and PM precursors)[2].

Table 1.

General conformity *de minimus* thresholds.

Attainment Status for	NAA Level[a]	VOC (tons/yr)	NO_x (tons/yr)	CO (tons/yr)	SO_2 or NO_2 (tons/yr)	PM_{10} or $PM_{2.5}$ (tons/yr)	Pb (tons/yr)
Ozone	Serious	50	50	---	---	---	
Ozone	Severe	25	25	---	---	---	
Ozone	Extreme	10	10	---	---	---	
Ozone	Other ozone: NAA's outside an ozone transport region	100	100	---	---	---	
Ozone	Other ozone: NAA's inside an ozone transport region	50	100	---	---	---	
Carbon Monoxide	All	---	---	100	---	---	
SO_2 or NO_2	All	---	---	---	100	---	
PM_{10}	Moderate	---	---	---	---	100	
PM_{10}	Serious	---	---	---	---	70	
$PM_{2.5}$	All	100 VOC[b] 100 NH_3[b]	100[c]	---	100 (SO_2)	100	
Lead (Pb)	All						25

[a]NAA = non-attainment area; an area designated by EPA to be in violation of the ambient air quality standard; [b]If determined to be a significant precursor of PM2.5; [c]Unless determined not to be a significant precursor.

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[1] *Conformity to State or Federal Implementation Plans of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Laws*, Code of Federal Regulation, Title 40, Part 93.

[2] VOC and NO_x are ozone precursors, meaning that they can participate in a series of chemical reactions in the atmosphere that lead to ozone formation.

In recognition of future promulgation of potentially more stringent NAAQS and generally greater scrutiny of air quality impacts for all types of projects, BOEM has determined that there may be an increasing need for development of accurate emission estimates in support of Environmental Assessments and Environmental Impact Statements for future beach nourishment projects and projects will need to be designed in a way that avoids impacts considered to be unacceptable. Furthermore, the impacts analysis must be performed in a defensible manner using best available science and engineering practices without undue cost. To meet this need, BOEM contracted with ENVIRON and the Woods Hole Group to develop a standardized, rigorous, technically sound and defensible procedure for calculating criteria pollutant and greenhouse gas (GHG) emissions for future proposed beach nourishment/coastal restoration projects.

In consultation with BOEM, we have developed the Dredging Project Emissions Calculator (DPEC), a database program designed to provide criteria pollutant (CO, VOC, NOx, SO_2, PM) and GHG emission estimates for proposed beach nourishment and coastal restoration projects given the project's design parameters and basic information about the diesel powered equipment to be used in the project.[3] Emissions associated with beach nourishment and coastal restoration projects result from use of main and auxiliary engines on marine vessels including dredges, tugs, barges and support craft, as well as shore-based equipment including construction equipment (e.g., loaders, dozers), and material handling equipment such as pumps, cranes and forklifts (to move pipes, for example) and other industrial equipment. Generally speaking, emissions from the dredge vessel dominate the total project emissions. The DPEC can be used to calculate emissions from each type of equipment used in the project during each mode of operation (i.e., dredging, transiting, and pumping). Emissions occurring within state territorial limits are calculated separately from those occurring outside state waters. In this way, the DPEC provides the emissions data needed for conformity determinations and for analyses of potential impacts on ambient air quality that would necessitate the use of dispersion models. Development of the the DPEC is described in sections 2 and 3. We also prepared a separate DPEC User's Guide (Shah et al., 2012) to assist analysts in applying the DPEC to their individual projects.

BOEM also tasked the ENVIRON team with preparation of an air quality modeling demonstration study in which emission estimates for a typical beach nourishment project generated using the DPEC are used in an air quality dispersion model to calculate the impacts of project emissions on on-shore criteria pollutant concentrations. Our dispersion modeling demonstration study is described in Section 4. Summary, conclusions and recommendations from this study are presented in Section 5.

2. DATA COLLECTION

Data from past (historical) beach nourishment projects were reviewed to determine typical project parameters, engine and equipment characteristics, and their relationship to fuel consumption and emissions. The ENVIRON Team collected activity data from five historical beach nourishment projects:

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[3] All or nearly all of the equipment used in coastal restoration and beach nourishment projects is diesel powered; emissions from any gas powered equipment (e.g., worker's pickup trucks) can be considered negligible in most cases.

1. Sandbridge Beach Erosion and Hurricane Protection Project, Sandbridge Beach, VA (Weeks Marine) 2007
2. Brevard County Shore Protection Project (South Reach), FL (Great Lakes Dredge and Dock) 2010
3. Surf City Beach Nourishment, Topsail Island, NC (Weeks Marine) 2011[4]
4. Patrick Air Force Base, FL (Weeks Marine) 2005
5. Holly Beach Sand Management Project, Holly Beach, LA (Weeks Marine) 2003

All of these projects except for the Holly Beach project involved the use of a trailing suction hopper dredge; summaries of the detailed activity data from these projects are provided in Appendix A. The Holly Beach project involved the use of a cutterhead dredge at the beginning of the project followed by use of a dustpan dredge. Unfortunately, the project was plagued by delays due to weather and maintenance issues. Furthermore, reported fuel consumption (a critical parameter for determining engine loads and estimating emissions) appeared inconsistent with reported equipment use. As a result, the Holly Beach project was not suitable for use as a representative project for our analysis. Without data from a representative historical cutterhead dredge project, it was not possible to develop a specific methodology for estimating emissions from these types of projects. However, the DPEC can still be applied to cutterhead dredge projects if sufficient engine use data are available. Fortunately, trailing suction hopper dredges are used on most beach nourishment projects involving federal mineral resources, which lie beyond the state territorial water boundary. As cutterhead dredges may not be well suited for all open-water conditions (Anderson and Barkdoll 2010), they are not typically used this far offshore. Nevertheless, cutterhead pipeline dredges or other dredge types may be used in some projects where and when conditions allow. Additional analysis of cutterhead dredge projects is therefore needed.

3. EMISSION CALCULATION PROCEDURES

Methods used to estimate project emissions in the DPEC are described in this section. Default activity inputs as described below were derived from an analysis of historic project data, but these input factors can be modified by the DPEC user to address specific conditions and equipment used on the proposed project being analyzed.

Historical data from the four trailing suction hopper dredge projects listed in Appendix A were used together with general rules of thumb typically employed by dredging companies to derive heuristic relationships between project design parameters, engine requirements and fuel consumption, thus providing a way to calculate air emissions from future projects using time in mode, fuel consumption and other operational data. The derived heuristic relationships are described in Section 3.1. Table 2 lists the essential project parameters and equipment specifications used as inputs to the emissions calculations performed by the DPEC. The volume of sand to be placed on site and the distance from the borrow area to the pump out location are the basic parameters from which equipment activity and emissions are calculated. The calendar year is used for identifying average fleet parameters for the shore-based equipment which change over time as older equipment is replaced by newer, lower emitting models. Activity occurring

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[4] This project did not involve the use of outer continental shelf sand resources; dredging occurred in state waters only.

within the state waters limit (generally 3 nm; 9 nm for Texas and Florida Gulf coast) is tracked separately for emissions reporting purposes.

Table 2.

Project input data.

Calendar year for project
Volume to be Placed (Cubic Yards)
Borrow Area to Pump Out Distance, one way (nm)
Borrow Area to Pump Out Distance (portion beyond 3 nm from shore; 9 nm for Texas and Florida Gulf coast)
Dredge operating hours per day
Dredge plant characteristics (type, engine specifications, hopper size, hopper useable fraction, hopper sand capacity factor, dredge time per load, dump time per load)[a]
Project total fuel consumption by dredges (if available; used to estimate project-specific engine load factors)
Other equipment usage (if available; used in place of defaults)

[a] See Section 3.1 for definitions of these quantities.

In the DPEC, emissions are calculated by operational mode. Emissions by mode are then spatially and temporally allocated according to the location(s) and time(s) associated with each mode and the relative portion of activity within each mode that occurs in state vs. federal waters. This spatial and temporal allocation is required for conformity determinations and for air quality dispersion modeling of project emissions. Emissions associated with the dredge are calculated for the four operating modes which together compose a dredge cycle:

1. Dredging at borrow area,
2. Transiting to pump out location,
3. Pumping sand out of the dredge onto the beach,
4. Transiting back to borrow area.

3.1 DREDGE PLANT EMISSIONS CALCULATIONS

Emissions from the dredge plant are calculated based on operating hours and engine loads required to complete each dredging cycle mode enough times to achieve the total project placed ("pay") volume included in the beach design template. In calculating the time in each mode, it is important to use the dredging and pumping rates appropriate to each dredge and that are consistent with the volume loaded.

Dredge plant emissions calculation methods primarily applicable to trailing suction hopper dredges are described in this section. As noted in Section 2, available data from historical projects involving cutterhead or derrick dredges was insufficient for calculating default values of engine activity data (hours of use and fuel consumption or load factor) needed to computing emissions from such projects. Nevertheless, the DPEC includes an option for computing cutterhead or derrick project emissions if data on engine usage is available. For cutterhead/derrick dredge projects, the analyst simply selects either "cutterhead" or "derrick" as the dredge type in the DPEC, enters the operating hours per day, number of project days and the average dredge engine specifications and average load factors. DPEC will calculate emissions directly from these quantities via Eq. 1:

$$Emissions = Hours\ per\ day\ \times Engine\ Rated\ Power\ \times Load\ Factor\ \times Emission\ Factor \qquad (Eq.\ 1)$$

Emissions calculations for trailing suction hopper dredge projects are based on analyses of the historical project data presented in Appendix A. A dredging rate is defined in terms of either the gross volume or the discharged volume of material per dredge cycle. These volumes are smaller than the dredge hopper size; the ratio of the gross or discharge volume to the hopper size is the usable hopper fraction. Note that the usable hopper fraction must be expressed using the same volume measure (either gross or discharge) used as the basis for the dredging rate. The dredge mode time in each cycle is calculated as shown in Eq. 2:

$$Dredge\ mode\ (hours) = \ Hopper\ Size\ \times Usable\ Hopper\ Fraction/Dredge\ Rate \qquad (Eq.\ 2)$$

Where:

Hopper Size (cubic yards) = the hopper size specification of the selected dredge,
Usable Hopper Fraction = the fraction of the hopper size represented by either the gross or discharge volume, and
Dredging Rate (hours/load) = the time required to fill the hopper to achieve either the specified gross volume or the discharge volume.

The pumping mode refers to the time required to pump material onto shore and includes the time required for the dredge to moor at the pump-out site, hookup, pump, flush, and disconnect from the pipe along with any other time spent at the pump-out site (referred to collectively as the "setup time"). The placed ("pay") volume refers to the actual sand placed on shore where intended (within the design cross-section or template). The gross and discharged volume measures are higher than the volume of material placed at the beach site since material is lost during overflow, pumping, and discharge/equilibration at the beach. These losses are accounted for by the sand capacity factor which is the ratio of the placed volume to the gross or discharge volume and accounts for any lost sand on the vessel, in the pipe, or on shore. The effective pumping rate, therefore, is usually less than the dredging rate and accounts for sand volume losses and lost time (such hookup/disconnect, pump, and flush) in this mode. Pumping mode time (hours) is calculated as shown in Eq. 3:

$$Pumping\ Mode\ Time = \frac{Placed\ Volume}{(Pumping\ Rate \times Sand\ Capacity\ Factor)} + Setup\ Time \qquad (Eq.\ 3)$$

Where:

Placed Volume (cubic yards) = amount of material required to fill the project beach design template (i.e., the "pay" volume),
Pumping Rate (cubic yards/hour) = rate at which sand is pumped off the dredge,
Sand Capacity Factor = fraction of sand pumped out which becomes placed volume,

Setup Time (hours) = total additional time required for pumping operations, i.e., positioning, anchoring, attaching to pipe, flushing and disconnecting.

Transiting times are based on the dredge plant's average speed and the distance between the borrow area and pump-out site(s) (Eq. 4):

$$Transisting\ modes\ (hours) = Distance\ (nm)/Avg.Speed\ (knots)\ (loaded\ or\ unloaded) \tag{Eq. 4}$$

The transiting time will be longer from the borrow area to the pump-out site(s) because the dredge is loaded, while the vessel will sail back to the borrow area at or near the designed speed of the vessel, depending on the distance (to allow for vessel acceleration and deceleration). A review of data from the historical projects indicates that the speed when loaded is 80 – 85% of the unloaded speed. Because the vessel will generally need to perform some slow speed maneuvering during turning and positioning and/or requires time to reach cruising speed, average transit speeds will be slower for situations in which the distance between the borrow area and pump-out site(s) is shorter.

Combining the time in each dredge cycle mode provides the overall cycle time:

$$Cycle\ time = Dredging + Sailing\ (loaded) + Pumping \tag{Eq. 5}$$

The number of dredge cycles (loads) needed to complete the project can be calculated as shown in Eq. 6:

$$Number\ of\ Loads\ (Cycles) = \frac{Project\ Placed\ Volume}{Hopper\ Volume \times Useable\ Fraction \times Sand\ Capacity\ Factor} \tag{Eq. 6}$$

From the cycle time and the number of cycles (loads), the minimum number of days for the project can be calculated:

$$Minimum\ number\ of\ days = Number\ of\ loads \times Cycle\ Time \tag{Eq. 7}$$

Due to a number of factors such as crew change, weather, maintenance, etc., the actual number of calendar days required to complete the project will be greater than the minimum number. This difference is accounted for by adjusting for the actual number of operating hours per day (with the remainder of the day accounted for by downtime) as shown in Eq. 8.

$$Actual\ Project\ Days = Minimum\ Days\ \times 24/Operating\ Hours\ per\ Day \tag{Eq. 8}$$

Where:

Operating Hours per Day = the average number of hours per day the dredge is actually operating.

If engine loads are known for each of the modes independently, a time weighted average load for the complete dredge cycle can be determined as shown in Eq. 9. A time-weighted average load is used because engine emission factors used to calculate emissions are formulated in terms of emissions per unit of work performed (e.g., grams of emissions per kW-hr).

$$\sum_i Load_i \times Mode\ Time_i / Cycle\ Time \qquad \textit{(Eq. 9)}$$

Where:

i = mode (Dredging, transiting to pump out, pumping, transiting to borrow),
$Load_i$ = actual engine load (load factor x installed power) in mode i and
$Mode\ Time_i$ = time spent in mode i per cycle.

Fuel consumption data from the historical projects described in Appendix A were used to calculate a default engine load factor by comparing the fuel consumed on the project with the theoretical fuel consumption assuming full engine load (Eq. 10):

$$Average\ load\ factor\ = Actual\ Fuel\ Consumed / (Rated\ Power \times Hours \times BSFC) \qquad \textit{(Eq. 10)}$$

The theoretical full load fuel consumption is equal to the product of the installed rated power of the dredge, operating hours of the dredge during the project and the brake-specific fuel consumption (BSFC). BSFC is a measure of the engine efficiency; values of BSFC in grams of fuel per kilowatt-hour (kW-h) estimated by the U.S. Environmental Protection Agency (EPA) are provided in Appendix B. Actual in-use engine load profiles can vary widely and the DPEC is designed to allow users to input alternative load factors if more refined engine load information is available.

Emissions are calculated for each individual mode, for a full dredge cycle, or for the entire project by multiplying together the operating hours, engine load factor and the engines' rated power (note that all engines on the dredge are combined for purposes of this calculation) and then multiplying the result by the appropriate emission factor (Eq. 11). Emission factors are provided by EPA in units of grams per kilowatt-hour (1.341 horsepower-hours is equal to 1 kilowatt-hour); values for marine engines are listed in Appendix B.

$$Dredge\ Emissions = Number\ of\ Cycles \times Cycle\ Time \times Load\ Factor \times Engine\ Power \times Emission\ Factor \qquad \textit{(Eq. 11)}$$

3.2 EMISSIONS CALCULATIONS FOR OTHER PROJECT EQUIPMENT

For diesel powered equipment other than the dredge plant (i.e., support vessels and shore equipment), available equipment and activity data are less specific and overall emissions are generally small in comparison to emissions from the dredge vessel, so a more general approach is used to calculate emissions. The primary activity variable is the average number of hours per day over the course of the project when engines on the vessels or equipment are operating. Emissions rates are derived by applying appropriate load and emission factors as developed by EPA. This calculation is shown in Eq. 12:

$$Equipment\ Emission = Hours\ per\ Day \times Actual\ Days \times Engine\ Power \times Load\ Factor \times Emission\ Factor \qquad (Eq.\ 12)$$

Where the Emission Factor is given as g/kW-h for vessels, and g/hp-h for shore-based equipment.

In the case of shore equipment, the EPA NONROAD model (http://www.epa.gov/otaq/nonrdmdl.htm) was run to develop gram per horsepower-hour emission factors for each type of equipment. NONROAD emission factors already incorporate a typical load factor for the selected equipment type. These load-adjusted emission factors are unique by equipment type, calendar year (thus accounting for fleet turnover), and rated power. The user choses the type of equipment (e.g., crawler tractors which represent tracked dozers) and enters the equipment engine's rated power. Based on the actual project days and operating hours per day, the horsepower-hour activity of equipment is calculated to determine the project emissions.

EPA's NONROAD model does not include information on commercial marine vessels. Thus, emissions from support vessels used in the project must be calculated from the installed power, hours of operation, engine load factor and an appropriate emission factor. A default load factor of 0.79 for support vessel engines was chosen for use in the DPEC based on a value cited in EPA (2008) for Category 1 (less than 5 liters per cylinder displacement) engines greater than 560 kW (nominally 750 hp). Actual average load factors can vary widely. For example, EPA (2008) cites a load factor of 0.45 for smaller engines (less than 560 kW) and a wide variety of load factors for Category 2 (5 to 30 liter per cylinder displacement) propulsion engines and for all auxiliary engines. Given this uncertainty in average load factors and in recognition of the fact that in-use engine loads can vary significantly, the DPEC was designed to allow users to input alternative load factors in the vessel emission calculations where appropriate.

3.3 EMISSIONS CALCULATOR INPUT PARAMETERS

Input parameters required for the emission calculations are listed in Table 3. These input data are used to determine the dredge characteristics in terms of engine loads, dredging cycle time, and calendar days for the project as described in the previous section. To accommodate different types of projects, the emissions calculator tool includes a provision for entry and manual editing of user-defined operating modes.

Table 3.

Dredge Emission calculations input requirements.

Input	Description
Dredge Name	User input
Dredge Type	Trailing Suction Hopper, Cutterhead, or Derrick
Engine Configuration	Diesel-electric or Propulsion/auxiliary
Avg. Speed (loaded)	Knots (specific to dredge and distance between borrow area and pump-out site)
Avg. Speed (unloaded)	Knots (specific to dredge and distance between borrow area and pump-out site)
Hopper Size	Hopper dredge volume specification (cubic yards)
Useable Fraction	% of hopper size used or delivered during each cycle: specified either in terms of gross volume or discharge volume
Sand capacity factor	% of gross or discharge volume (depending on which is used as the basis for defining the Useable Fraction) that becomes placed product
Dredging Mode (Loading) Rate	Time (hrs) required to fill dredge hopper (may be affected by material screening requirements)
Pumping Mode (Offloading) rate	Time (hrs) to offload each dredge load from arrival at pump out site until departure (including mooring, hookup/unhook, dump, flush, and other time)
Dredge Operating Hours per Day	Average number of hours per day dredge is operating (typically less than 24 due to factors such as maintenance, crew change, weather or other reasons)
Engine load factor – dredging mode, propulsion engine(s)	Load factor on dredge plant propulsion (main) engines during dredging (loading) mode[a]
Engine load factor – dredging mode, auxiliary engine(s)	Load factor on dredge plant auxiliary engines during dredging (loading) mode[a]
Engine load factor – Transiting, Propulsion	Load factor on dredge plant propulsion (main) engines during transiting mode[a]
Engine load factor – Transiting, Auxiliary	Load factor on dredge plant auxiliary engines during transiting mode[a]
Engine Load factor – Pump Out, Propulsion	Load factor on dredge plant propulsion (main) engines during pump out mode[a]
Engine Load factor – Pump Out, Auxiliary	Load factor on dredge plant auxiliary engines during pump out mode[a]

[a] Average value of 40% from historical projects.

The following engine parameters must be defined for each type of engine (propulsion, auxiliary, and other vessel mounted engines such as winches or derrick/excavators) on each vessel involved in the project, including the dredge plant and all support vessels:

- Number of engines (usually two or more)
- Engine model year
- Engine displacement (liters/cylinder)
- Rated power of each engine (kW)

Support vessel types include tenders, tows or tugs, and survey or crew boats. Average expected operating hours per project day must be specified for each support vessel type. Engine parameters listed above are used to determine the appropriate emissions factors and fuel consumption rates from among the values listed in Appendix B.

For shore-based equipment, it is necessary to identify the type of equipment and engine power rating (hp). Table 4 shows typical equipment types. Appendix C provides a more extensive list of possible on-shore equipment types. Actual hours operating can be specified, if known, or a default of 8 hours per operating day can be used.

Table 4.

Required information for examples of shore-based equipment.

Equipment	EPA Equipment Name	Source Category Code[a]	Engine Rated Power (hp)	Hours Operating (days x hrs/day)
Dozer	Crawler Tractor	2270002069	X	X
Loader	Rubber-tired Loader	2270002060	X	X
Backhoe/Loader	Tractor/Backhoe/Loader	2270002066	X	X
Booster Pump	Pump	2270006010	X	X
Excavator	Excavator	2270002036	X	X
Rough-Terrain Forklift	Rubber-tired forklift	2270002057	X	X
Electrical Generators	Generators	2270006005	X	X

[a] Source category codes as used in EPA NONROAD model (http://www.epa.gov/otaq/nonrdmdl.htm).

4. EXAMPLE PROJECT APPLICATION

We present in this section a demonstration of the application of the DPEC emission calculations procedures described in Section 3 to a “typical” beach nourishment project involving the use of an offshore sand resource. Emissions estimated using DPEC are then used in an atmospheric dispersion model to demonstrate the project’s impacts on ambient criteria pollutant concentrations. Criteria pollutants include nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter less than 10 µm and 2.5 µm in aerodynamic diameter (PM_{10} and $PM_{2.5}$), and hydrocarbons (HC). Personnel responsible for preparing air quality impact analyses of future beach nourishment/restoration projects may find the emission calculation and dispersion modeling procedures described in this example application instructive. Model results developed under this task can also be used to evaluate the likely scale of ambient air quality impacts from future beach nourishment projects similar to the typical example project analyzed here. This will help guide development of future beach nourishment project designs so as to avoid, to the maximum possible extent, predictions of significant air quality impacts which might delay or complicate necessary permit approvals. Readers should keep in mind, however, that each situation is unique and modeling procedures will vary from one project to the next depending on project design, location and concerns raised by local residents and governments.

Equipment used for beach nourishment projects is almost exclusively diesel powered, resulting in emissions of several criteria pollutants including NO_x (= NO + NO_2), PM (almost all of which is $PM_{2.5}$), SO_2 (negligible for U.S. dredging projets due to use of low sulfur diesel fuel), and CO in addition to VOCs (which are PM and ozone precursors) and GHGs (most notably CO_2). Peak and average ambient concentrations of these emitted pollutants will depend on meteorological conditions, source locations, source emission rates and emission parameters (temperature and release height of exhaust gasses) and land (and water) surface properties. Production of secondary pollutants (O_3 and secondary PM) from these emissions also depend on the chemical characteristics of the atmosphere into which they are being emitted and the level of solar UV radiation.

4.1 PROJECT DESCRIPTION

Several historical beach nourishment projects, including those described in Appendix A, were reviewed as potential candidates for use in this demonstration. Based on discussions with BOEM, it was agreed that a project on the Atlantic coast would be of most interest given the level of expected future dredging projects in this area. To make the example as useful as possible, we chose a project for which sufficient data was available to determine realistic values for the emission calculator inputs. Based on these criteria, the 2010 Brevard County, FL South Reach Shore Protection Project was selected (Olsen, 2010).[5] This project involved renourishment of the South Reach segment of the Brevard County Federal Shore Protection Project via dredging of approximately 650,000 cubic yards[6] of sand from the Canaveral Shoals II (CSII) borrow area and transport to the 3.8 mile South Reach beach segment located approximately 24 miles south of Cape Canaveral as shown in Figure 1. Dredging took place between February and April 2010. Work was temporarily suspended during a three week period in March due to redeployment of the dredge to a project in North Carolina.

Sand was excavated from the CSII borrow area located in federal waters approximately five miles offshore of the Cape Canaveral Air Station and 29 miles from the South Reach work site. A 6,540 cubic yard (cy) capacity trailing suction hopper dredge (the *Liberty Island*) was used to excavate sand from the borrow area and transport it to a single fixed pump-out site located approximately 0.8 miles offshore of the work site where the sand was pumped directly out of the hopper dredge up onto the beach via pipeline. Three pieces of construction equipment (two bulldozers and an excavator) were used to place the sand and achieve the target beach template. Beach construction was conducted in four phases with the location of the beach end of the pump-out pipeline being moved once during the middle of the project:

1. A 5,000 ft segment north of the first (northern) pipeline landing
2. A 5,000 ft segment south of the first (northern) pipeline landing
3. A 5,000 ft segment south of the second (southern) pipeline landing
4. A 5,000 ft segment north of the second (southern) pipeline landing

Two support vessels, a crew boat and a tow boat provided necessary supplies and services to the *Liberty Island*.

Specifications of all equipment used in the project relevant to the emission calculations are listed in Table 5.

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[5] Note that Brevard County is classified as being in attainment of the NAAQS.

[6] For purposes of the example calculations presented here, an exact value of 650,000 cubic yards was used for the amount of material dredged.

Table 5.

Project equipment specifications.

Equipment		Specifications
Dredge	Type	Trailing suction hopper
	Hopper Size	6,540 cy
	Hopper Useable Fraction	0.8060
	Hopper Sand Capacity Factor	0.8990
	Propulsion Engines (two)	MY 2001, 12 cylinder, 4962 bhp (3700 bkW) 18.5 l/cylinder, 0.4 LF
	Auxiliary Engine (one)	MY 2001, 12 cylinder, 5097 bhp (3801 bkW) 18.5 l/cylinder, 0.4 LF
	Generator (one)	MY 2001, 2 l/cyl, 416 bkW, 0.4 LF
Support (Auxiliary) Vessels	Crew Boat (one main engine)	MY 1999, 2 l/cyl, 447 bkW, 0.79 LF
	Tow Boat (two main engines)	MY 2006, 4 l/cyl, 447 bkW, 0.79 LF
Shore Construction Equipment	Bulldozer (Crawler Tractor)	150 hp diesel
	Bulldozer (Crawler Tractor)	150 hp diesel
	Excavator	138 hp diesel

Based on the locations of the borrow area and the pump-out station and tracking data from the Silent Inspector dredge monitoring system, we used Geographic Information System software to determine that the transiting distance between these two sites totaled 25 nm, 5 nm of which were inside the 3 nm state waters limit. The distance travelled within state waters is important as separate estimates must be reported for emissions released within the state of Florida and emissions released outside of state waters. Based on these distances and averages of the daily project tracking data, we calculated that the average speed of the dredge when loaded was 12.32 kts and the average speed when empty was 15.27 kts. Daily project operations data also showed that the average dredging time per load was 0.46 hrs and the dump time per load was 0.92 hrs (including hookup, flush and disconnect time). These speed and time values are used in the DPEC to calculate the time spent in and hence emissions associated with each portion (mode) of the dredging cycle.

Daily dredging reports indicated that the dredge operated an average of 17.26 hours per day. Support vessels and on-shore construction equipment were assumed to operate an average of 8 hours per day (detailed activity data for the support vessels and shore equipment were not available).

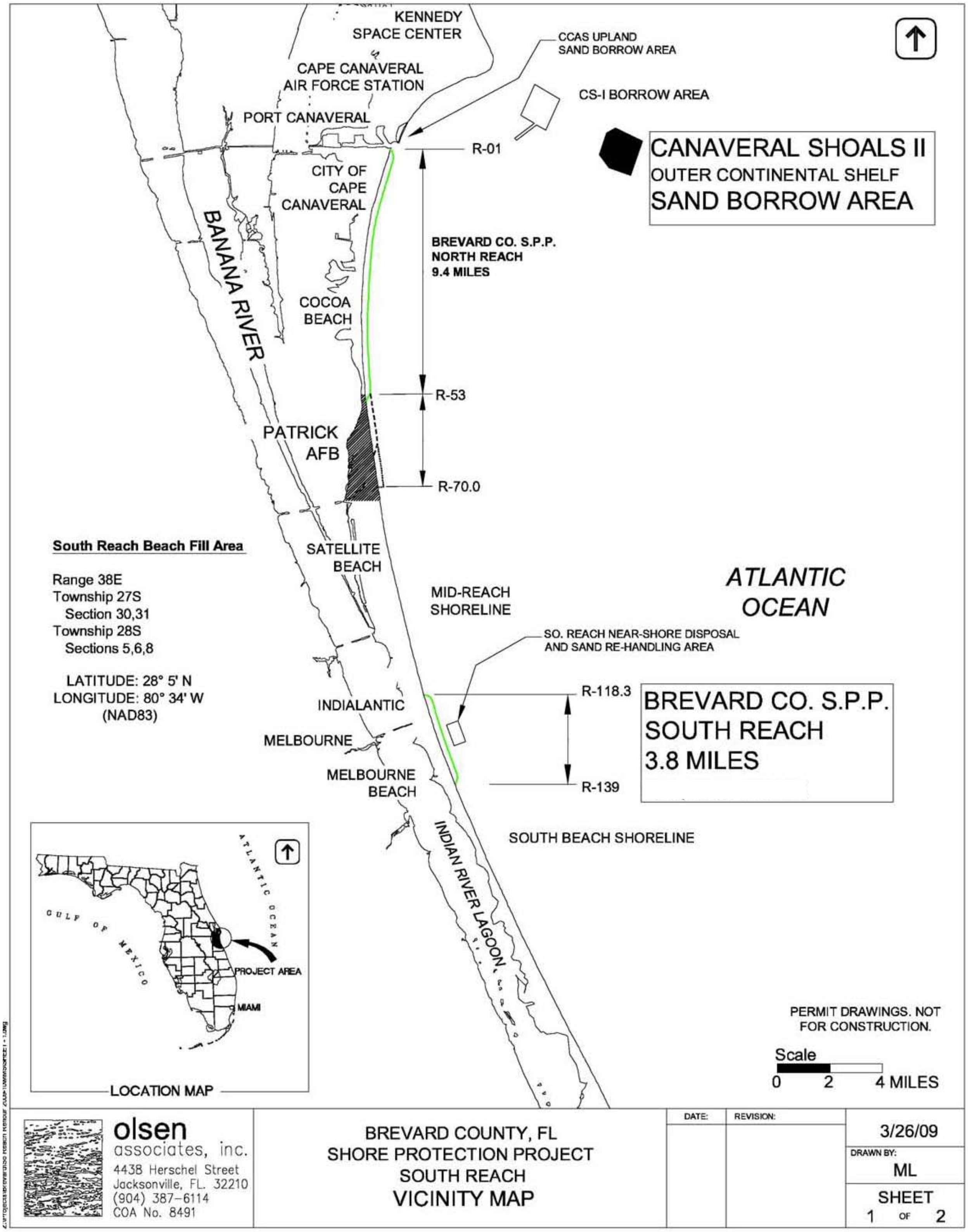

Figure 1. Map of Brevard County South Reach Shore Protection Project area (from Olsen, 2010).

4.2 EMISSIONS CALCULATIONS

Information from the project description (Section 4.1 above) was entered into the DPEC to calculate project emissions. A project year of 2012 was selected for purposes of this example, although the actual Brevard South Reach Shore Protection Project took place in 2010. The DPEC uses the project year entered by the user to look up the appropriate on-shore construction equipment emissions factors in the EPA NONROAD emissions model (http://www.epa.gov/otaq/nonrdmdl.htm). Emission factors change from one year to the next as older equipment is retired and replaced by newer, lower emitting models. As shown below, however, the on-shore construction equipment emissions are only a minor portion of the total project emissions. As a result, the selection of project year has relatively little effect on total project emissions.

Since only a single borrow area and pump-out station location were used for this project, only a single set of DPEC inputs and a single DPEC run were needed to calculate total project emissions. If multiple borrow areas or pump-out stations had been utilized during the project (i.e., if this had been a multi-phase project), then a separate DPEC run would have been required for each borrow area / pump-out station pair to capture the differing amounts of dredge and auxiliary vessel activities occurring during each phase of the project. Total project emissions would then be calculated by summing up the emissions from each phase. Calculation of total project emissions in this way is facilitated by the availability of a spreadsheet compatible output file from the DPEC (see the DPEC User's Guide[7] for more information).

DPEC input data for the example project are shown in Figures 2, 3 and 4. Resulting total project emissions as calculated by DPEC are summarized in Table 6. Apart from CO_2, emissions are dominated by NOx (which represents the sum of NO and NO_2 emissions) with relatively small amounts of other criteria pollutants. Table 7 lists separate emission subtotals for emissions released inside and outside of the State of Florida territorial limits. It is assumed that the only emissions occurring outside state waters are from the dredge vessel; all support (auxiliary) vessel emissions were assumed to occur within state waters because the specific operating locations of the support vessels are unknown and this provides a conservative estimate of in-state emissions. Total project NOx emissions within the State of Florida (15.3 tons) exceed the General Conformity *de minimus* emission thresholds in the conformity regulations (Table 1) for extreme ozone nonattainment areas, but are below the thresholds applicable to other locations. Emissions of other pollutants are below the *de minimus* thresholds. Although no extreme ozone nonattainment areas currently exist outside of California, comparisons with the *de minimus* emission thresholds are only presented here for informational purposes. As the location of the project activities within the State of Florida does not correspond to any Clean Air Act nonattainment area, it is not necessary in this case to perform a conformity determination under the conformity rules (40 CFR 93.153).

As is typically the case for projects of this type, the dredge vessel is the dominant source of total project emissions with the support vessels and on-shore construction equipment contributing a relatively small share to the total. The dredge vessel accounts for 91% of project total NOx

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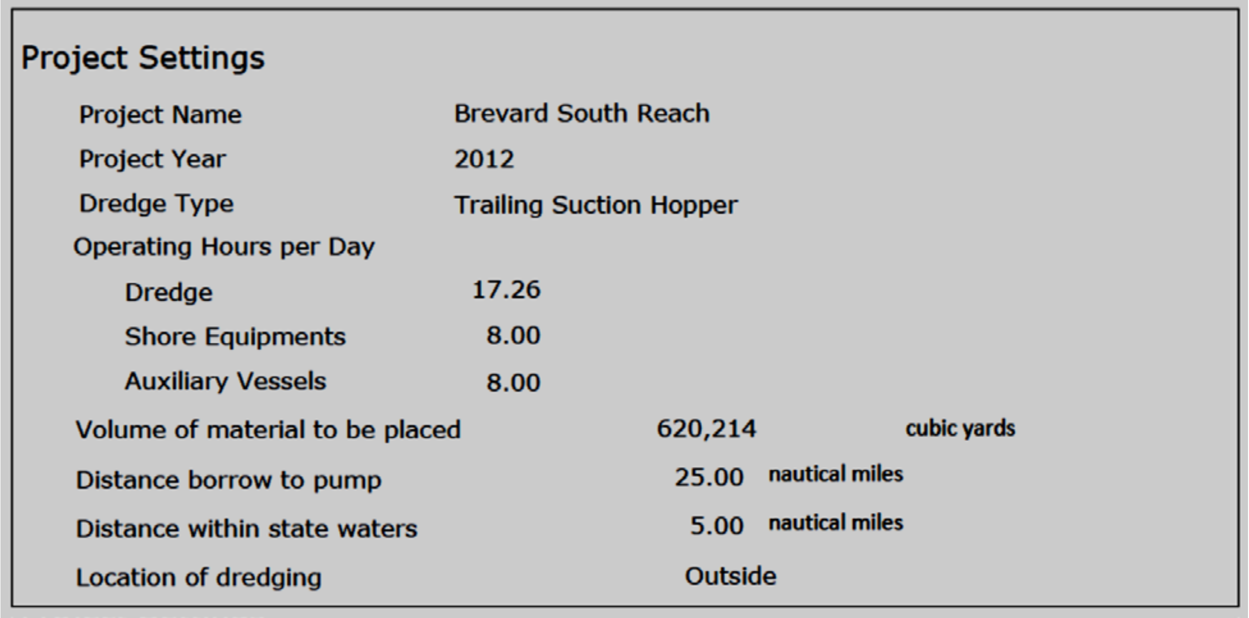
[7] Shah et al., 2012.

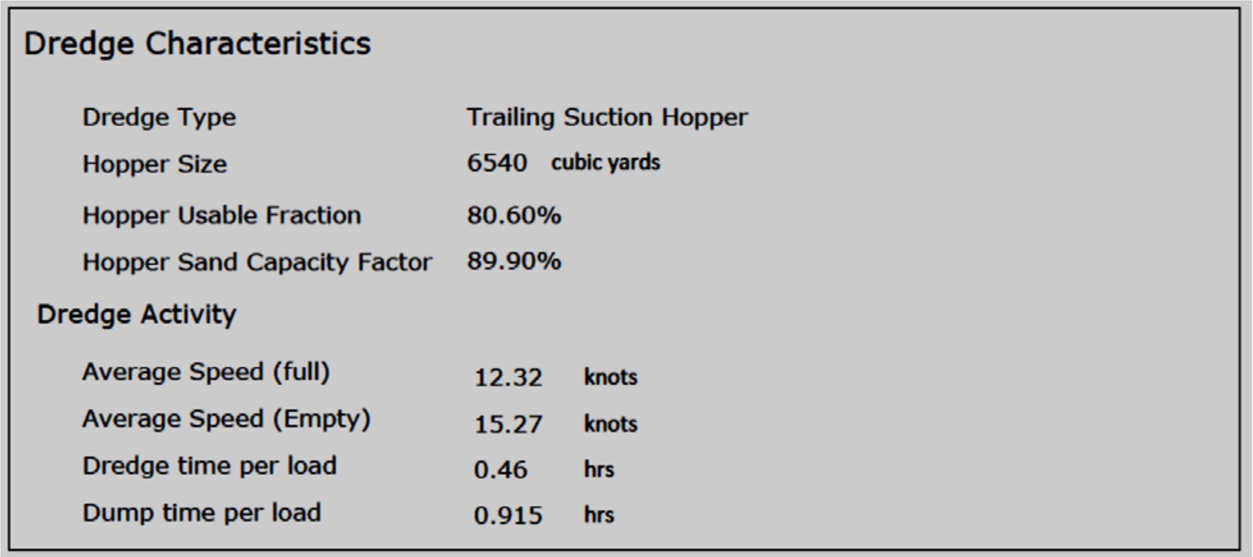
emissions. However, it must be kept in mind that both the location as well as the magnitude of emissions is important when estimating on-shore air quality impacts from the project. Thus, emissions from the on-shore equipment and near shore dredge operations (i.e., pump out) are relatively more important on a per ton basis than emissions released further off shore.



Project Settings

Project Name	Brevard South Reach	
Project Year	2012	
Dredge Type	Trailing Suction Hopper	
Operating Hours per Day		
Dredge	17.26	
Shore Equipments	8.00	
Auxiliary Vessels	8.00	
Volume of material to be placed	620,214	cubic yards
Distance borrow to pump	25.00	nautical miles
Distance within state waters	5.00	nautical miles
Location of dredging	Outside	

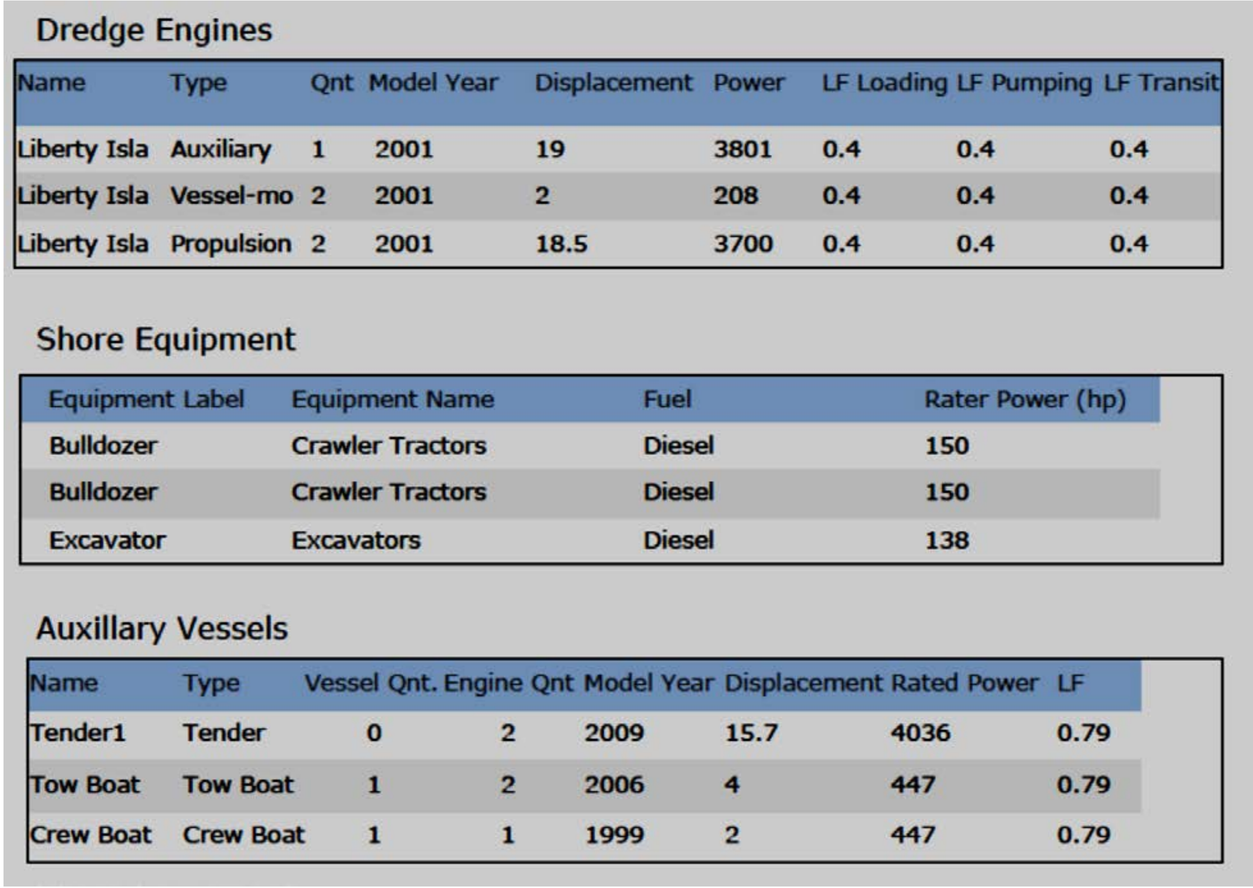
Figure 2. Project settings used in the DPEC run.



Dredge Characteristics

Dredge Type	Trailing Suction Hopper	
Hopper Size	6540	cubic yards
Hopper Usable Fraction	80.60%	
Hopper Sand Capacity Factor	89.90%	
Dredge Activity		
Average Speed (full)	12.32	knots
Average Speed (Empty)	15.27	knots
Dredge time per load	0.46	hrs
Dump time per load	0.915	hrs

Figure 3. Dredge characteristics specified in the DPEC run.



Dredge Engines

Name	Type	Qnt	Model Year	Displacement	Power	LF Loading	LF Pumping	LF Transit
Liberty Isla	Auxiliary	1	2001	19	3801	0.4	0.4	0.4
Liberty Isla	Vessel-mo	2	2001	2	208	0.4	0.4	0.4
Liberty Isla	Propulsion	2	2001	18.5	3700	0.4	0.4	0.4

Shore Equipment

Equipment Label	Equipment Name	Fuel	Rater Power (hp)
Bulldozer	Crawler Tractors	Diesel	150
Bulldozer	Crawler Tractors	Diesel	150
Excavator	Excavators	Diesel	138

Auxillary Vessels

Name	Type	Vessel Qnt.	Engine Qnt	Model Year	Displacement	Rated Power	LF
Tender1	Tender	0	2	2009	15.7	4036	0.79
Tow Boat	Tow Boat	1	2	2006	4	447	0.79
Crew Boat	Crew Boat	1	1	1999	2	447	0.79

Figure 4. Engine parameters input to the DPEC run (LF = engine load factor).

Table 6.

Summary of project emissions by source type and location.

		Emissions (short tons)						
Source Name	Type	HC	VOC	CO	NOx	PM$_{10}$	PM$_{2.5}$	CO$_2$
INSIDE STATE WATERS								
Bulldozer	Crawler Tractors	0.01	0.01	0.03	0.09	0.01	0.01	15
Bulldozer	Crawler Tractors	0.01	0.01	0.03	0.09	0.01	0.01	15
Crew Boat	Crew Boat	0.03	0.03	0.19	1.19	0.03	0.03	81
Excavator	Excavators	0.01	0.01	0.03	0.08	0.01	0.01	15
Liberty Island Aux.	Auxiliary	0.02	0.02	0.40	1.70	0.03	0.03	109
Liberty Island Aux.	Auxiliary	0.03	0.03	0.50	2.12	0.04	0.04	136
Liberty Island Generator	Vessel-mounted	0.00	0.01	0.03	0.17	0.00	0.00	12
Liberty Island Generator	Vessel-mounted	0.01	0.01	0.04	0.22	0.01	0.00	15
Liberty Island Main	Propulsion	0.05	0.06	0.97	4.12	0.08	0.08	265
Liberty Island Main	Propulsion	0.04	0.04	0.78	3.30	0.07	0.06	213
Tender1	Tender	0.00	0.00	0.00	0.00	0.00	0.00	0
Tow Boat	Tow Boat	0.06	0.07	0.43	2.19	0.05	0.04	162
TOTALS FOR EMISSIONS SOURCES INSIDE		0.27	0.28	3.43	15.26	0.33	0.32	1037
OUTSIDE STATE WATERS								
Liberty Island Aux.	Auxiliary	0.01	0.01	0.25	1.06	0.02	0.02	69
Liberty Island Aux.	Auxiliary	0.09	0.09	1.60	6.79	0.14	0.13	437
Liberty Island Generator	Vessel-mounted	0.00	0.00	0.02	0.11	0.00	0.00	8
Liberty Island Generator	Vessel-mounted	0.02	0.02	0.11	0.69	0.02	0.02	48
Liberty Island Main	Propulsion	0.17	0.18	3.11	13.21	0.26	0.26	851
Liberty Island Main	Propulsion	0.03	0.03	0.49	2.07	0.04	0.04	133
TOTALS FOR EMISSIONS SOURCES OUTSIDE		0.32	0.33	5.57	23.94	0.48	0.46	1545
ALL LOCATIONS AND SOURCES								
		HC	VOC	CO	NOx	PM$_{10}$	PM$_{2.5}$	CO$_2$
TOTALS FOR EMISSIONS AT ALL LOCATIONS		0.59	0.62	9.00	39.20	0.81	0.78	2583

4.3 DISPERSION MODELING

4.3.1 Model Selection and Modeling Approach

A variety of atmospheric dispersion models have been developed and are recommended for regulatory applications by EPA (40 CFR Appendix W). Federal land management agencies (National Park Service, U.S. Forest Service, Fish and Wildlife Service) have also developed modeling guidance in collaboration with EPA for evaluating emission impacts on lands they are responsible for managing (FLAG, 2010; IWAQM, 1998). Specific models are recommended based largely on the spatial scale over which model predictions are needed and the types of emission impacts that are being evaluated. Local scale (less than about 50 km) impacts of pollutants where in situ atmospheric chemical transformations are of little significance are typically modeled using EPA's guideline Gaussian plume model, AERMOD. For larger scale applications and where formation of secondary particulate matter is important, the CALPUFF Lagrangian puff model is frequently used. More complex and larger scale applications, including those involving simulation of ozone formation, require the use of a photochemical grid model such as CMAQ or CAMx.

While impacts of beach nourishment projects on all criteria pollutants must be addressed at some level under NEPA, and, on occasion, the CAA in non-attainment or maintenance areas, the main impacts of concern are peak 1-hour average NO_2 concentrations. This is due to the relatively large amounts of NOx emitted from diesel engines used in these projects and EPA's recent promulgation of a stringent 1-hour, 100 ppb (188 $\mu g/m^3$) NO_2 standard. Emissions from equipment used in the beach nourishment project are released fairly close to the surface: there are no tall stacks as might be found at a power plant or factory. As a result, peak 1-hour NO_2 impacts from the project can be expected to occur at locations along the immediate shoreline that are closest to the major project activity areas. Based on results of the emissions calculations presented in Section 4.2, peak concentrations can be expected at locations where the dredge vessel comes closest to shore and this occurs along the beach directly opposite the pump-out site. Thus, the dispersion model selected for this application should be able to predict near-source impacts (those within a few kilometers or less of the source) with reasonable accuracy.

In addition to NO_2 impacts, ozone impacts may become of increasing concern in many locations if EPA proceeds with promulgation of a new, more stringent ozone standard that results in many Gulf and East Coast locations being designated as ozone nonattainment areas. NOx emissions from beach nourishment projects can result in some ozone production as they are transported downwind and mixed with sufficient amounts of VOC emissions from either biogenic or other anthropogenic sources. On the other hand, locations close to concentrated dredge project NOx emission plumes may experience some local ozone reductions due to titration of ozone by NO and suppression of formation of atmospheric radicals that drive ozone production. Similarly, dredge project NOx emissions can result in downwind formation of secondary particulate matter as the NOx oxidizes and forms nitrates. While CALPUFF includes simplified algorithms for estimating nitrate formation, CALPUFF is not designed to simulate the complex chemical processes that govern the impacts of NOx on ozone. A detailed simulation of dredge project impacts on ozone and secondary PM would involve photochemical grid modeling, which is a more complex and expensive process than is typically feasible for all but the largest project (or groups of future projects such as may, for example, be evaluated in a programmatic environmental assessment). Photochemical modeling is thus beyond the scope of the example demonstration presented here. However, other examples of the use of photochemical models for assessing the contribution of offshore sources on ozone and PM are available (e.g., Yarwood et al., 2004).

A key concern with simulation of on-shore impacts from offshore pollutant sources is the proper treatment of over water transport and the effects on dispersion of the transition from a marine to a continental atmospheric boundary layer. This transition can lead to the shoreline fumigation phenomenon in which an elevated plume advected towards shore within a relatively stable marine boundary layer characterized by weak vertical mixing mixes to the ground shortly after crossing the coastline as a result of the greater surface roughness and thermally induced turbulence found during the day over the land surface. BOEM has long been concerned with this issue and developed a Gaussian-plume model named the Offshore and Coastal Dispersion (OCD) model in the early 1980s to address it. OCD was specifically designed to handle the off-shore to on-shore transition, and used Monin-Obukhov surface layer theory for the surface fluxes and profiles. Development of OCD essentially stopped in the mid-1990s, and in the last decade BOEM sponsored the development of a new model designed to replace OCD. This project culminated in 2006 with release of a three-volume report (Earth Tech, 2006) and a new version of the CALPUFF three-dimensional Lagrangian puff modeling system. CALPUFF has been adopted by the EPA as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas, and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. Nearly all of the MMS-sponsored CALPUFF developments have been incorporated into the current EPA regulatory-default version of CALPUFF (version 5.8). These developments include the use of the Coupled Ocean Atmosphere Response Experiment (COARE) form of Monin-Obukhov similarity theory, convective overwater boundary layer parameterizations, building downwash calculations suitable for elevated (platform) structures, the ability to use AERMOD turbulence profiles, and the use of buoy data. However, CALPUFF lacks a mechanism to limit NO to NO_2 conversion based on ambient ozone levels.

A comparison between OCD5 and CALPUFF was performed as part of the BOEM-sponsored enhancements to CALPUFF (Earth Tech, 2006). Tracer studies in Cameron, LA; Carpinteria, CA; Pismo Beach, CA; Ventura, CA; and the strait of Øresund, Denmark/Sweden were simulated with both OCD5 and CALPUFF. This model validation study showed that CALPUFF performed as well or better than OCD5 in all cases. Of particular interest is the Øresund case, where the wind direction was not fixed and the air mass passed through two land/water transitions. Source-to-receptor distances in all of the tracer studies were less than 50 km. The conclusion of this study was that CALPUFF performs as well or better then OCD5 in both near- and far-field dispersion modeling.

AERMOD, the AMS/EPA Regulatory MODeling system, is the regulatory-default model for industrial facilities under EPA's Modeling Guidelines (40 CFR Appendix W). AERMOD is a steady-state Gaussian plume model which incorporates state-of-the-art dispersion modeling concepts based on planetary boundary layer turbulence structure and scaling concepts and treats both surface and elevated sources including building and stack-tip downwash in both simple and complex terrain. AERMOD includes two algorithms (PVMRM and OLM) as options for using observed ambient ozone concentrations to limit the conversion of NO emissions to NO_2. However, AERMOD is not formulated to directly assess shoreline fumigation. The AERMET meteorological processor typically used with AERMOD contains its own internal model of the atmosphere which always includes the growth of a day-time mixed layer. This growth algorithm is designed to be most appropriate for over-land applications. In AERMET, the roughness length of the underlying surface is represented by fixed values based on land-use categories. In reality, the roughness length over water is a function of wind speed, as higher winds roughen the sea surface. For calculating short-term average pollutant concentrations, this shortcoming is typically not very profound, because the maximum predicted concentrations usually occur during periods of the lowest wind speeds when the sea surface is smoothest. Although some systematic error in long-term average predictions is expected due to this limitation, from a practical standpoint the biases introduced by this simplification are of little consequence; if a source can meet the 1-hour NO_2 NAAQS, it will likely meet the annual NO_2 standard by a wide margin.

Different dispersion models have varying levels of meteorological data input requirements. CALPUFF is designed to use gridded three-dimensional fields of temperature, winds and other parameters generated by the CALMET preprocessor program. BOEM previously developed CALMET data sets for the Gulf of Mexico region under the MMS 2009-029 "OCS" study (Douglas and Hudischewskyj, 2008). An updated meteorological data set for the Gulf of Mexico is currently in preparation.[8] A BOEM sponsored study to develop a similar set of gridded meteorological data for the Atlantic coast is also currently underway.[9]

As the gridded meteorological data required to run CALPUFF or other grid models are currently not available for the Brevard County beach nourishment project (or other projects for which sufficient data needed to estimate emissions are available), ENVIRON in consultation with BOEM, have elected to use AERMOD for this example application. AERMOD has the benefit of including a mechanism for limiting the rate of NO to NO_2 conversion based on ambient ozone level – a critical capability when estimating peak 1-hour NO_2 impacts from diesel engines. In recognition of the unique nature of coastal dispersion processes, the AERCOARE meteorological preprocessor was used in place of the standard AERMET preprocessor to develop the meteorological input data files needed to run AERMOD. AERMET is designed to simulate the diurnal fluctuations in boundary layer height typically observed over land, using an internal model for the growth of the daytime mixed layer. It is therefore not ideally suited for over-water dispersion. However, EPA recently sponsored the development of an alternative processer (AERCOARE) better suited to modeling over-water sources (Richmond and Morris, 2012a,b). AERCOARE implements the same COARE overwater flux model that was previously added to CALPUFF under BOEM sponsorship. AERCOARE/AERMOD model predictions were compared with tracer study data from Pismo Beach CA, Carpentaria CA, Cameron LA and Ventura CA by Richmond and Morris, (2012a). These tracer studies had previously been used to

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[8] *Meteorological and Wave Measurements for Improving Meteorological and Air Quality Modeling (GM-08-04),* (http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Gulf_of_Mexico_Region/Ongoing_Studies/GM-08-04.pdf)

[9] *Synthesis, Analysis, and Integration of Air Quality and Meteorological Data for the Atlantic Region* (http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/National/NT-AQ-Profile.pdf)

evaluate the OCD model and the reformulated CALMET/CALPUFF model. All four tracer studies used off-shore releases with on-shore model receptor points. Although the receptors were intentionally placed to minimize shoreline fumigation, some fumigation events were no doubt captured in the study data. Richmond and Morris (2012a) concluded from the model evaluation results that concentrations near the upper end of the concentration distribution predicted by AERCOARE/AERMOD (as measured by the robust highest concentration) were "not biased towards underestimates" which is typically the case with AERMOD evaluations (Brode, 2012). When averaging over all predicted values there was no significant bias: the geometric mean bias, i.e., the inverse log of the mean log predicted/observed ratios), was 0.99 (a value of 1 indicates no bias) with an approximate 95% confidence interval of (0.82, 1.19). Correlation between the observed and predicted values was 0.78 and 55 percent of observed/predicted pairs fell within a factor of 2 of each other.[10] This level of model performance is typical of Gaussian plume models (Brode 2012). The acceptable performance of models using the AERCOARE preprocessor obtained in the tracer studies suggests that AERCOARE/AERMOD provides a reasonably accurate simulation of the on-shore impact of offshore sources.

4.3.2 Model Inputs

Input data required to run AERMOD include hourly processed meteorological data, emission rates and physical source parameters and locations of model receptor points where predicted concentrations will be calculated. Procedures for developing these inputs are described in the following paragraphs.

Meteorological Data

Hourly meteorological data for use in AERMOD were developed using the AERCOARE preprocessor. Meteorological data inputs for AERCOARE were developed using five years of data for the period February 13th, 2010 through April 10th, 2010 (corresponding to the start and end date of the dredging project)[11] from two offshore buoys (buoys 41009 and 41113) and an onshore meteorological station (TRDF1) located in the vicinity of Brevard County (see Figure 5). AERCORE requires specification of convective mixing height values for hours with unstable boundary layer structures. Because mixing height values are not available from the buoy data, for the purposes of this example application we examined average morning mixing heights from maps compiled by Holzworth (1972) for a location near the project site. Morning mixing heights were used as the lower morning values will produce more conservative (i.e., higher) predicted concentrations. Mixing heights for winter and spring were averaged to roughly correspond with the February – April project period. This procedure resulted in a value of 750 m which was used for the convective mixing height value in AERCORE. During stable atmospheric conditions, AERCORE was configured to calculate mechanical mixing heights via the method of Venketram (1980). While use of the Holzworth average mixing heights was considered adequate for the purposes of this example application, use of hourly observed mixing heights representative of the specific project location and time period is strongly recommended in actual applications as predicted concentrations are sensitive to input mixing height values.

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[10] Details of the model performance calculations are provided by Richmond and Morris (2012a).

[11] Emissions were estimated assuming the project took place in 2012 for reasons noted in Sec. 4.2.

As buoy data generally may not be reliable at very low wind speeds, the a calm wind threshold setting of 0.5 m/s was considered appropriate. For simplicity, ENVIRON selected the default surface roughness calculation method based on friction velocity in AERCOARE as the best representation for surface roughness lengths over the near-shore waters rather than more complex forms based on wave heights which have not been evaluated in the near-shore environment. A copy of the AERCOARE Summary File is provided in Appendix D.

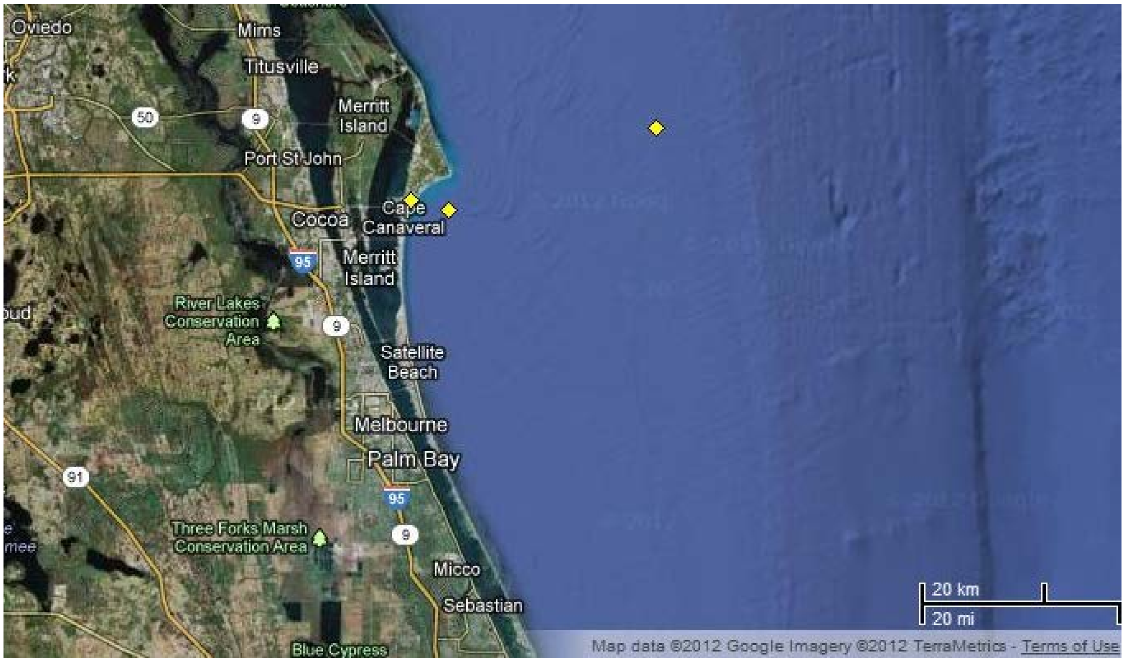

Figure 5. Locations of meteorological stations (yellow diamonds).

AERMOD Input Parameters and Receptor Locations

AERMOD inputs consist of the output of AERCOARE, the emissions data described in Section 4.2 and ancillary modeling parameters and option selections. Preparation of the project emissions data for input to AERMOD are described in the following section. Regulatory default options in AERMOD were specified as per EPA modeling guidance (40 CFR Appendix W). Full conversion of NO emissions to NO_2 was assumed at all times and receptor locations, resulting in conservative estimates of NO_2 concentrations. More refined estimates of NO to NO_2 conversion based on ambient ozone levels could be obtained by using either the OLM or PVMRM options, but this was determined not to be necessary in this case as the conservative approach yielded estimates below the level of the NO_2 NAAQS. A copy of the AERMOD input parameter file is provided in Appendix E.

Three sets of AERMAP surface receptors were defined as regularly spaced grids with horizontal spacings of 500, 100, and 10 meters over the land surface as shown in Figure 6. While receptors were not placed over water surfaces for purposes of this example, the EPA or other reviewing authority may require evaluation of overwater concentrations depending on the specific application. In order to better illustrate the drop-off in concentration with distance from the dredge plant, a cross-sectional analysis which includes overwater concentration calculations was performed as described in Section 4.4 below. The finest (10 m) grid spacing was located along the beach opposite the pump-out location. In this configuration, the receptors are best equipped to capture peak impacts of emissions from the sources nearest to shore (the onshore sites located on the beach and the pumping station).

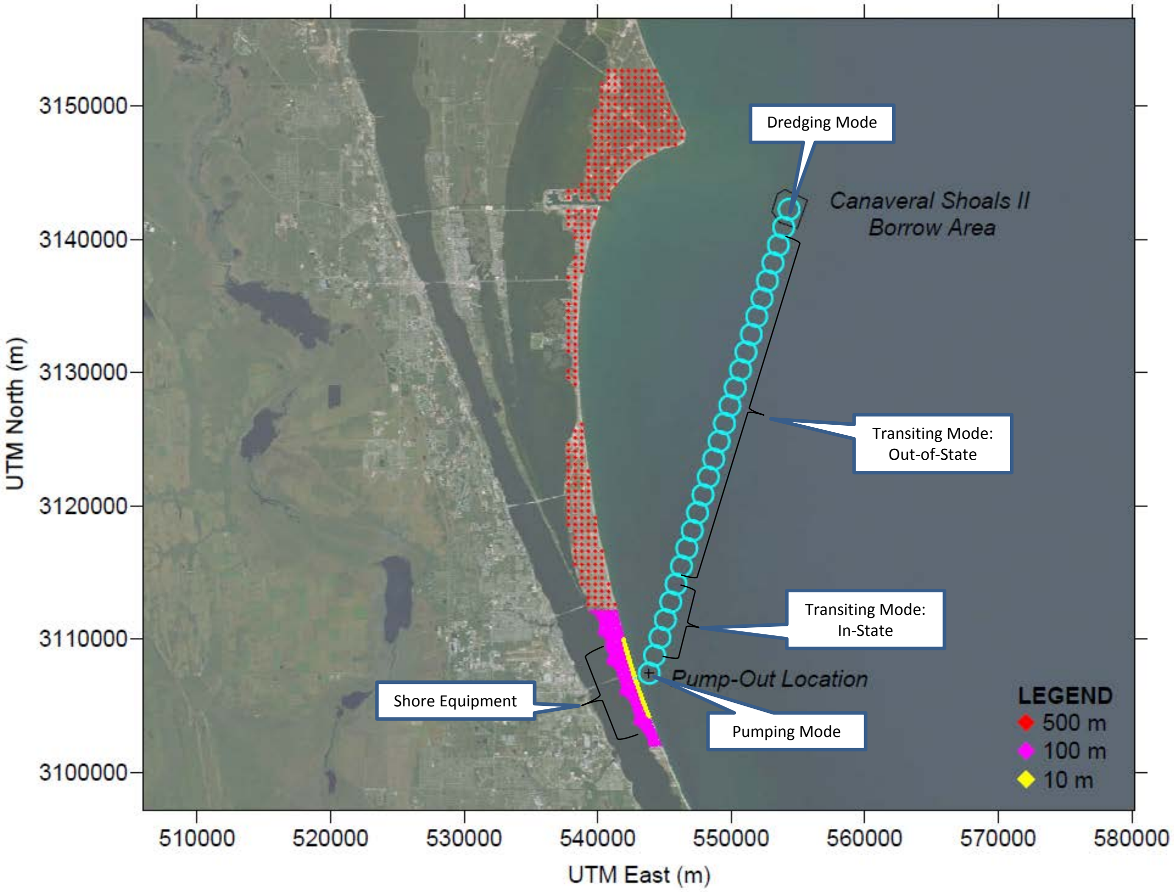

Figure 6. Receptor arrays with 500 m, 100 m and 10 m spacing (colored dots) and emission source (mode) locations; auxiliary vessel emissions were modeled alongside the dredge vessel but are not shown (see text).

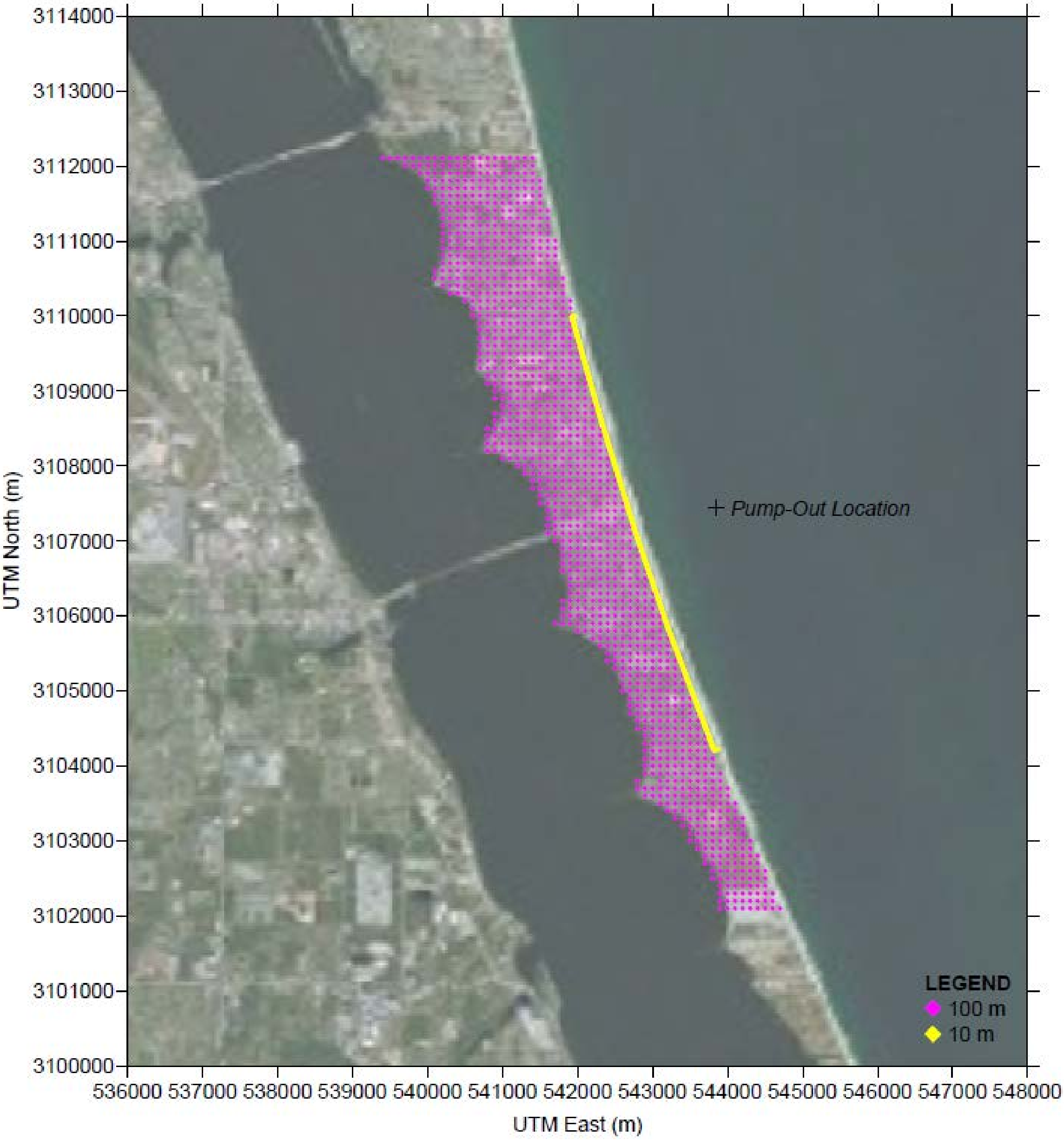

Figure 7. Detail area from Fig. 6 illustrating 100m (magenta), and 10m (yellow) spacing receptor grids used for AERMOD modeling.

Emissions

Project emissions described in Section 4.2 were spatially and temporally disaggregated in preparation for dispersion modeling. Dredge vessel emissions were modeled as occurring in four modes: dredging, pumping, transiting (outside of state waters) and transiting (within state waters). Dredging mode emissions were modeled as a volume source centered over the borrow area; pumping mode emissions were modeled as a volume source centered over the pump-out location. Transiting emissions were modeled as a set of 5 in-state and 20 out-of-state volume sources of equal emissions linearly arranged along the transit path between the pump-out location and borrow area (see Figure 6). Detailed data on auxiliary (support) vessel movements were not available. Auxiliary vessel emissions were modeled as a set of volume sources placed alongside the dredge vessel and offset 20 m to the east of the dredge volume sources. The exact positioning of auxiliary vessel emissions is not expected to have a significant impact on the model results as emissions from the support vessels are small compared to those from the dredge.

Shore equipment emissions were modeled as a volume source located on the beach centered at a point directly opposite the pump-out location. Source parameters used in the AERMOD run are listed in Table 7. Source locations are depicted in Figure 6. It is important to note that the source parameters used for this example application may or may not be appropriate for other specific applications. Predicted concentrations, especially at receptors located close to a source, can be sensitive to the choice of parameters used to define the physical characteristics of the emissions sources (release heights, exhaust stack configurations and locations relative to obstructions to airflow such as superstructures, buildings, etc.). In some cases it may be necessary to perform sensitivity analyses to evaluate the potential impact of alternative source parameter selections on predicted maximum concentrations. Volume sources were used to represent dredge plant emissions during each portion of the dredging cycle (mode) for this analysis. While use of volume sources is typically recommended for representing mobile sources such as trucks and locomotives while moving along a linear track (see, for example, Robinson and Daye, 2011), other source parameterizations have been used in some studies, including area sources for representing marine vessels while underway and point sources for representing vessel emissions while at dock (ARB, 2008).

Table 7.

Volume source parameters.

Source/Mode	UTM X (m)	UTM Y (m)	Release Height (m)	Sigma y (m)	Sigma z (m)
Shore Equipment	542819	3107088	10	35	20
Dredge/ Pumping	543851	3107449	10	651	20
Dredge/ Transiting	Various	Various	10	651	20
Auxiliary Vessels	Various	Various	5	651	10
Dredge/ Dredging	554326	3142227	10	651	20

Peak 1-hour pollutant impacts were calculated assuming each source was operating continuously at its maximum hourly emission rate as shown in Table 8. Daily average emission rates were also calculated (Table 9) and used to evaluate 24-hour average and annual average concentrations. Daily average emissions are lower than the peak 1-hour emissions because each piece of equipment does not operate continuously all day. Modeling with the peak 1-hour emission rates would result in overestimates of daily average concentrations. For example, the pumping operation is located close to shore and thus has a large impact on shore but pumping only happens at intervals throughout the day with an average total daily pumping time of 3 hours. Assuming continuous pumping emissions throughout the day would thus result in a significant overestimation of daily average concentrations.

Three separate AERMOD runs were executed to capture all of the possible configurations of sources at different times in the dredging cycle (each run included the shore equipment emissions source):

1. Dredge and auxiliary vessels located at the pump-out buoy,
2. Dredge and auxiliary vessels transiting between the pump-out buoy and the borrow area, and
3. Dredge and auxiliary vessels located in the borrow area.

Outputs from each run were processed as described below, and the maximum value predicted over the three runs tabulated. Results are presented in Section 4.4.

Table 8.

Source emission rates for 1-hour impact analysis.

Source/Mode	NOx (lb/hr)	CO (lb/hr)	PM_{10} (lb/hr)	$PM_{2.5}$ (lb/hr)
Shore Equipment	1.7	0.7	0.2	0.2
Dredge/ pumping	107.8	25.1	2.2	2.1
Dredge/ transiting in-state	107.8	25.1	2.2	2.1
Dredge/ transiting out-of-state	107.8	25.1	2.2	2.1
Dredge/ dredging	107.8	25.1	2.2	2.1
Auxiliary Vessels[a]	7.4	1.3	0.2	0.2

[a] As detailed data on auxiliary vessel movements were not available, auxiliary vessel emissions were assumed to be evenly split between operations alongside the dredge during pumping, transiting and dredging.

Table 9.

Source emission rates for daily average impact analysis.

	NOx (lb/day)	CO (lb/day)	PM_{10} (lb/day)	$PM_{2.5}$ (lb/day)
Shore Equipment	13.4	5.5	1.3	1.2
Dredge: Pumping	339.7	79.0	6.8	6.6
Dredge: Transiting In-State	272.3	63.3	5.5	5.3
Dredge: Transiting Out-of-State	1089.1	253.4	21.8	21.2
Dredge: Dredging	170.8	39.7	3.4	3.3
Auxiliary Vessels[a]	59.3	10.9	1.3	1.2

[a] As detailed data on auxiliary vessel movements were not available, auxiliary vessel emissions were assumed to be evenly split between operations alongside the dredge during pumping, transiting and dredging.

4.4 RESULTS

Predicted concentrations from AERMOD runs with the 1-hour peak emissions and the 24-hour average emissions were examined to determine the magnitudes and locations of peak impacts. Maximum 1-hour NO_2 concentrations were predicted to occur along the edge of the beach at a location opposite of the pump out site as shown in Figures 8 and 9. A secondary 1-hour NO_2 peak is located along the coast to the north at a location directly opposite the borrow area. Impacts from the other pollutants modeled follow this same spatial pattern. Comparisons of the model results to the Significance Levels referenced in 30 CFR 250.303(e) and to the NAAQS are presented in the following subsections.

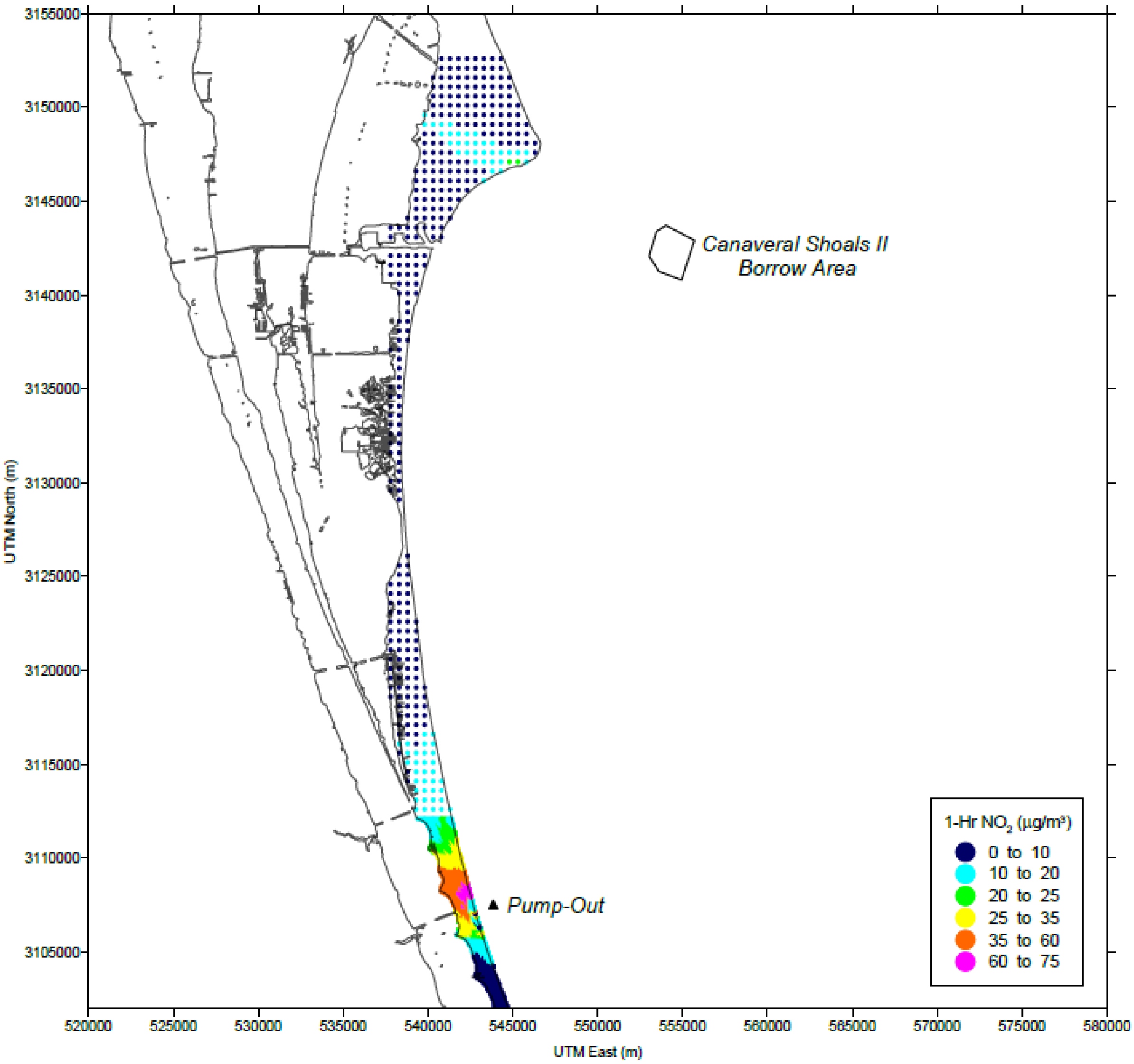

Figure 8. Spatial distribution of maximum 8th highest 1-hour NO$_2$ concentrations (refer to Fig. 6 for geographic orientation).

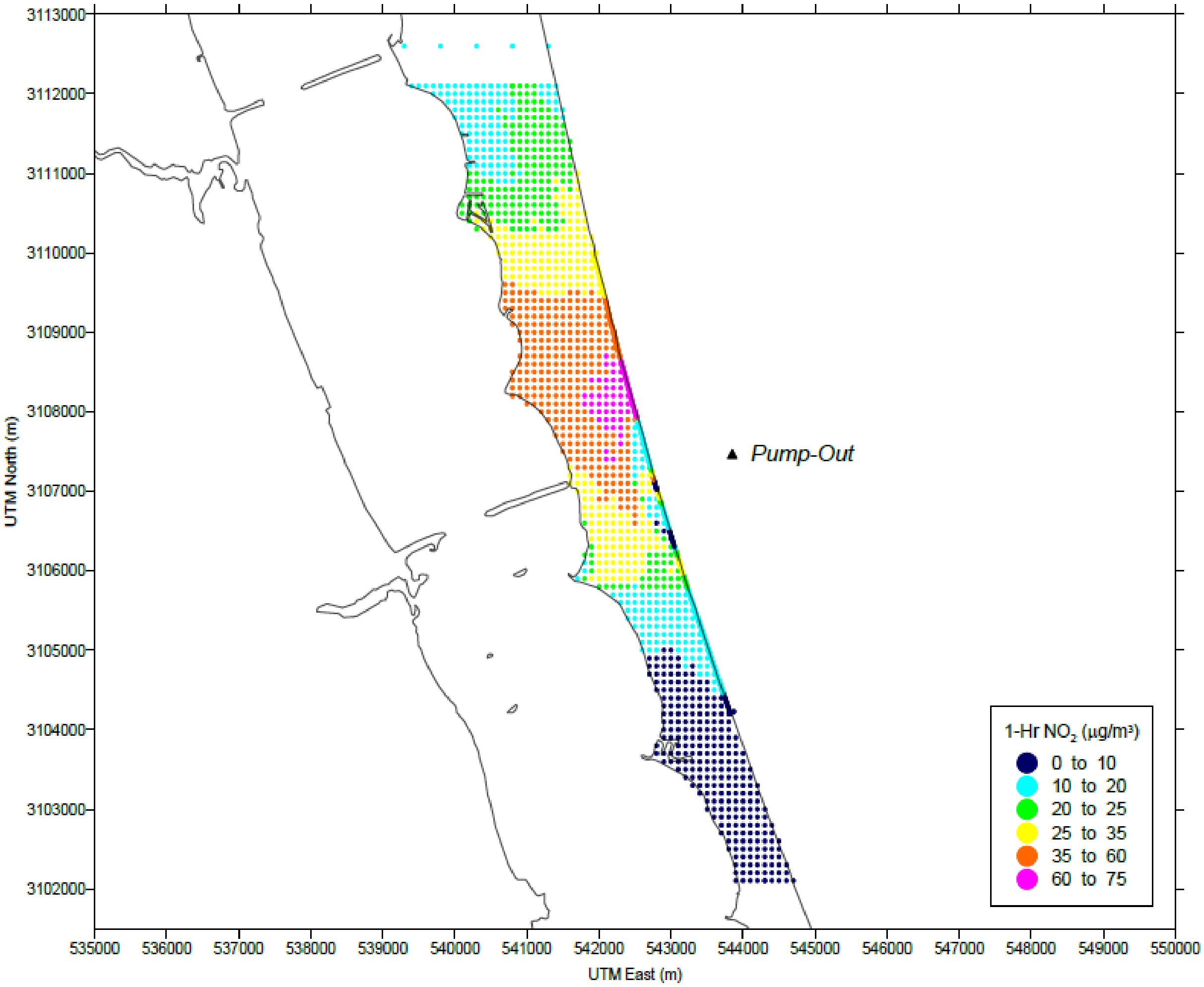

Figure 9. Spatial distribution of maximum 8th highest 1-hour NO_2 concentrations: detail of area with maximum concentrations (refer to Fig. 7 for geographic orientation).

4.4.1 Significance Levels

As a point of reference, predicted maximum PM, NO_2 and CO concentrations were compared to the Significance Levels defined in 30 CFR 250.303(e). Results are shown in Table 10. All predicted impacts from the project are less than their respective Significance Levels. It is worth noting that the highest average NO_2 concentration (average taken over the 38 day dredging project period) was predicted to be 1.1 µg/m³, which just exceeds the annual average Significance Level. However, the actual highest annual average NO_2 impact from the project would be much lower since emissions during the remainder of the year are zero. Thus the annual average NO_2 concentration is 1.1 x (38/365) = 0.1 µg/m³ which is less than the Significance Level. If the project had continued on at the same working rate for a period of more than 331 days, the annual average NO_2 Significance Level would have been exceeded.

Table 10.

Maximum predicted concentrations and corresponding Significance Levels as per 30 CFR 250.303(e).

Pollutant	Averaging time (hours)	Significance Level (µg/m³)	Max. Predicted Conc. (µg/m³)
PM_{10}	Annual	1	0.01[a]
	24-Hour	5	0.6
NO_2	Annual	1	0.1[a]
CO	8-Hour	500	15.8
	1-Hour	2,000	66.9

[a]Based on average concentration (AvgConc) predicted over 38 project days and zero emissions during reminder of one year period, i.e., Annual Average = AvgConc x (38/365).

4.4.2 NAAQS Analysis

For demonstration purposes, predicted criteria pollutant NAAQS design values were determined from the AERMOD results and compared to the NAAQS to determine if the project could contribute to any NAAQS violations. Modeled design values were extracted using procedures consistent with the definition of each NAAQS and EPA modeling guidance (40 CFR Appendix W; Fox, 2010a,b; Fox, 2011). Conservative procedures were used to extract the design values corresponding to each NAAQS from the model results. These procedures are summarized in Table 11.

For the annual average NAAQS, average predicted concentrations over the modeled period are used to represent the modeled design values for ease of interpretation and to provide the reader with additional information about average concentrations predicted to occur during the project period. As noted above, actual annual average impacts from this particular project will be lower than these values by a factor of 38/365 = 0.104 since project emissions occur over a period of 38 days and project-related emissions for the remaining days of the year are zero.

Cumulative project impacts were calculated by adding modeled design values from project emissions (i.e., the project incremental impacts) to observed background concentrations which represent the impacts of existing sources on air quality within the vicinity of the project. Background concentrations were obtained from nearest available air quality monitoring sites with sufficient data as shown in Table 12. These background concentrations are added to the predicted design values from the beach nourishment project to determine the final design values for comparison with the NAAQS. Results are summarized in Table 13.

Cumulative project impacts are less than the NAAQS for all pollutants. For 1-hour NO_2, the cumulative project impact (143.4 µg/m³) is 76% of the level of the NAAQS; impacts from all other pollutants are much smaller percentages of their respective NAAQS. For projects such as dredging projects which involve significant diesel engine emissions, the 1-hour NAAQS will typically be the most notable impact relative to the NAAQS. In fact, the maximum 1-hour NO_2 concentration in this case is 270 µg/m³ (assuming all NOx is NO_2) which exceeds the NAAQS. Although in this case the NO_2 design value for the cumulative project impact is below the NAAQS, these results suggest that analyses of other dredging projects with different configurations may lead to estimated 1-hour NO_2 NAAQS violations and require implementation of mitigation measures such as use of cleaner diesel engines.

Table 11.

Procedures for calculation of modeled design values.

Pollutant	Averaging Time	NAAQS Formulation	Modeled Design Value
NO_2	Annual	Annual average	Average over modeling period[a]
	1-hour	3-year average of annual 98th percentile of daily maximum 1-hour values	8th highest daily maximum 1-hour average
CO	8-hour	Not to be exceeded more than once per year	Maximum 8-hour average
	1-hour	Not to be exceeded more than once per year	Maximum 1-hour average
$PM_{2.5}$	Annual	Annual averge	Average over modeling period[a]
	24-hour	3-year average of annual 98th percentile of daily maximum 24-hour values	8th highest daily average
PM_{10}	24-hour	Not to be exceeded more than once per year	Maximum daily average

[a] Represents conservative estimate of the annual average as project duration is just 38 days (see text).

Table 12.

Criteria pollutant NAAQS design values measured at nearest available ambient air quality monitoring sites.

Pollutant	Averaging Time	Data Source	Concentration	Monitoring Station or Reference
NO_2	Annual	Annual mean	5 ppb (9.4 µg/m³)	Morris Blvd., Orange Co. (12-095-2002)
	1-hour	3-yr average of 98th percentile daily max	37 ppb (69.6 µg/m³)	Morris Blvd., Orange Co. (12-095-2002)
PM_{10}	24-hour	Highest 2nd high in 3 years	51 µg/m³	Port St. John (12-009-0011)
$PM_{2.5}$	Annual	Annual mean	6.6 µg/m³	Brevard Co. (12-009-0007)
	24-hour	3-yr average of 98th percentile daily mean	15 µg/m³	Brevard Co. (12-009-0007)
CO	8-hour	2nd Max	1,400 ppb (1,603 µg/m³)	Morris Blvd., Orange Co. (12-095-2002)
	1-hour	2nd Max	2,600 ppb (2,977 µg/m³)	Morris Blvd., Orangbe Co. (12-095-2002)

[a] Seasonal average diurnal profiles used for modeling background contribution to predicted 1-hour NO2 design value as per Fox (2011).

Table 13.

Modeled design values and NAAQS.

Pollutant	Averaging Time	Modeled Design Value (µg/m³)	Background Conc. (ug/m^3)	Total	NAAQS (ug/m^3)	NAAQS Exceeded?
NO_2	Annual	1.1[a]	9.4	10.5	100	No
	1-hour	73.8[b]	69.6	143.4	188	No
CO	8-hour	15.8[c]	1,603	1618.8	10,000	No
	1-hour	66.9[d]	2,977	3043.9	40,000	No
$PM_{2.5}$	Annual	0.1[a]	6.6	6.7	15	No
	24-hour	0.3[e]	15	15.3	35	No
PM_{10}	24-hour	0.6[f]	51	51.6	150	No

[a] Average over modeling period; [b] 8th highest predicted daily maximum 1-hour average; [c] Maximum 8-hour average; [d] Maximum 1-hour average; [e] 8th highest daily average; [f] Maximum daily average.

4.5 MODELING UNCERTAINTY

4.5.1 Uncertainties Associated with Source Parameterizations

To better illustrate the dependence of peak concentrations with downwind distance from the dredge plant, AERMOD was rerun for two scenarios:

1. The hour during dredging operations at the borrow area which produced the maximum onshore concentration over the Cape Canaveral area shown in Figure 8, and
2. The hour during pump-out operations which produced the maximum onshore impact along the adjacent beach illustrated in Figure 9.

Predicted surface level NOx concentrations along a line extending from the source (i.e., the dredge plant) in the downwind direction under these two scenarios are shown in Figures 10 and 11, respectively. As noted above, the emissions from the dredge plant are represented as a volume source, i.e., a three dimensional “cloud” of emissions centered over the dredge plant with a Gaussian concentration distribution in the horizontal (with standard deviation specified by the “initial sigma-y” parameter) and the vertical (standard deviation specified by the “initial sigma-z” parameter). AERMOD does not calculate predicted concentrations within a distance from the source equal to 2.14 times the initial sigma-y value (in this case equal to 2.14 x 651 = 1,393 m) as concentration predictions within this radius are unreliable. The outer edge of this exclusion zone happens to coincide approximately with the downwind distance from the dredge plant to the beach under the pump-out scenario illustrated in Figure 10, so the predicted maximum concentration occurs approximately at the beach. When the dredge is at the borrow area (Figure 11), the maximum concentration occurs over the ocean; maximum concentrations at the coastline are approximately one-third of the over-water maximum value.

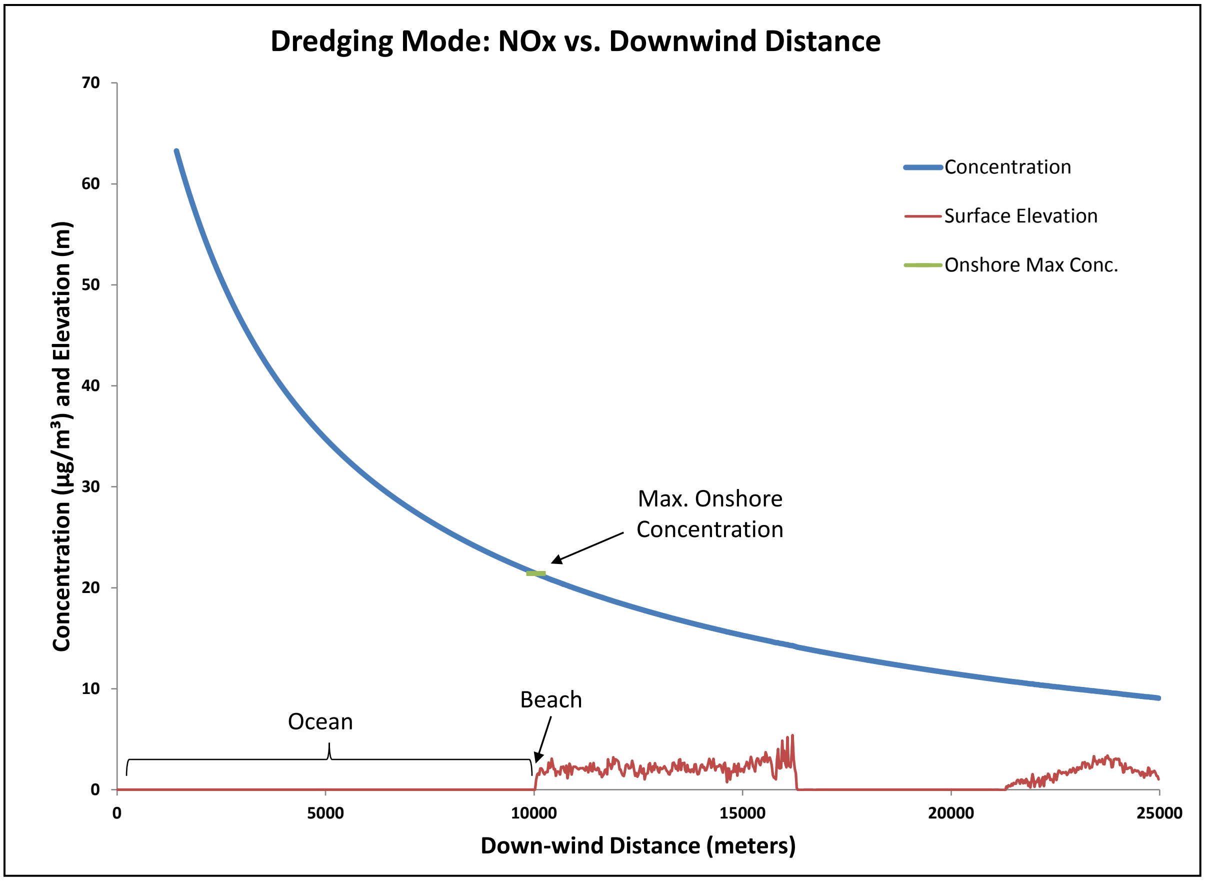

Figure 10. Maximum surface NOx concentration as function of downwind distance from the dredge plant during dredging mode operations at the borrow area during hour that produced the highest predicted NOx value (no concentration values are calculated within 1,400 m of the source for reasons explained in the text).

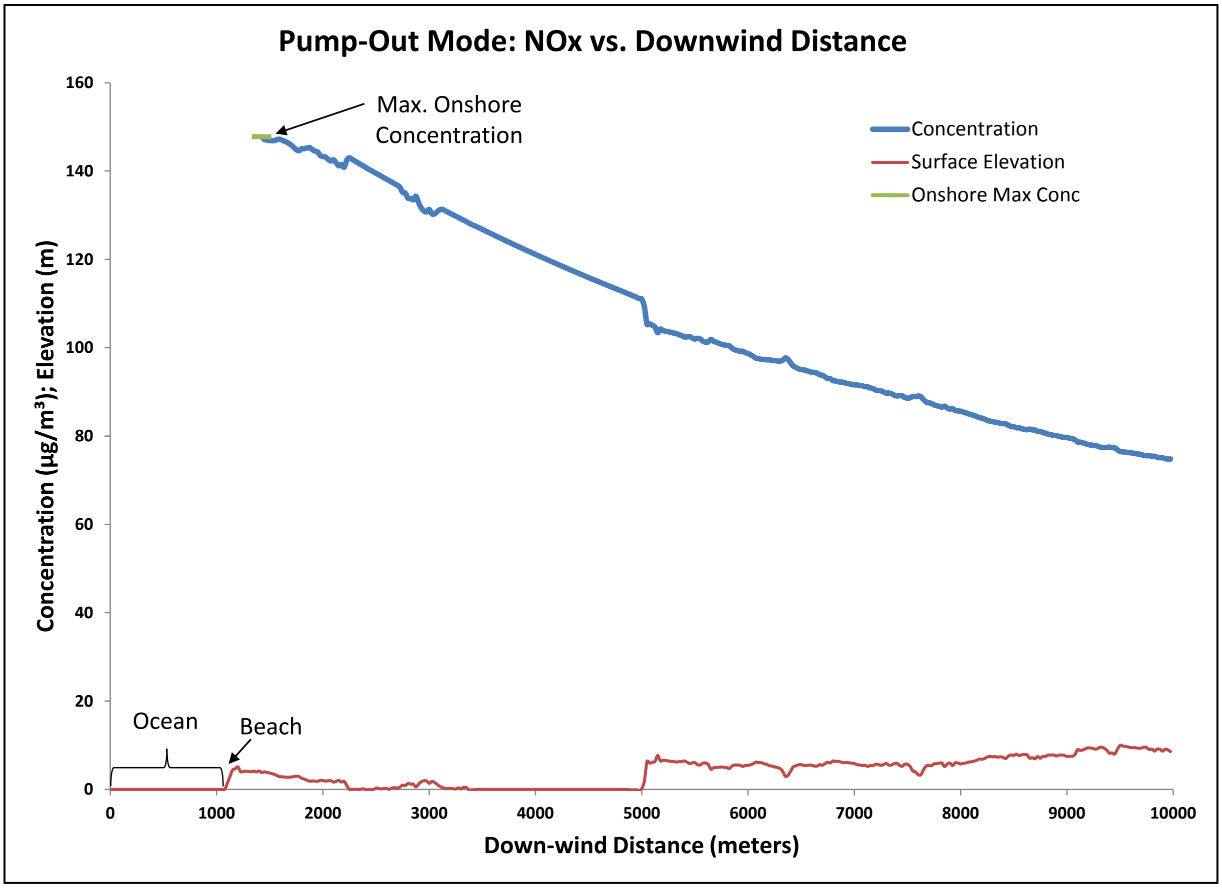

Figure 11. Maximum surface NOx concentration as a function of downwind distance from the dredge plant during pump-out mode operations during hour that produced the highest predicted NOx value (no concentration values are calculated within 1,400 m of the source for reasons explained in the text).

Given the proximity of the dredge plant to the beach while at the pump-out location, it is reasonable to expect that resulting peak onshore concentrations will be sensitive to the choice of source parameters as discussed in Section 4.3. To illustrate this, a sensitivity analysis was conducted in which the dredge plant was modeled while at the pump-out location as in Figure 11 but with the emissions source represented in AERMOD as either a volume source with two different choices for the initial horizontal (sigma-y) dimension (10 m and 651 m) or as a point source (i.e., a small stack treated in AERMOD as a geometric point with no significant horizontal dimension located at a height 20 m above the surface with a stack gas exit volumetric flux of 0.04 m^3/s and a stack gas exit temperature of 400 K.)[12] Results of this analysis are shown in Figure 12. For the 1-hour average concentrations depicted in this example, predicted concentrations within 10 km of the source are very sensitive to the choice of source parameters. Note that surface level concentrations under the point source scenario drop off close to the

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[12] These point source stack parameters were selected for illustration purposes only and were designed to insure that the plume would not penetrate above the top of the boundary layer and therefore remain in the mixed layer. Plumes penetrating above the boundary layer would tend to remain aloft and not impact the surface along the immediate coast, resulting in lower predicted surface concentrations. Information on actual stack parameters for the modeled dredge plant was not available for this example application.

source as all or most of the plume remains elevated above the surface out to a distance of approximately 1,500 m. One would expect that results for locations off of the centerline of the plume (i.e., not directly downwind of the source) and for multi-hour average (e.g., daily or annual average) concentrations will differ from those shown in Figure 12, both in terms of which source parameterization results in the most conservative predictions and in the degree of sensitivity to the choice of parameters. It is therefore important to carefully consider the range of source parameterizations which might be appropriate for a given application and perform sensitivity analyses as necessary to identify the uncertainties in model results arising from alternative parameterizations.

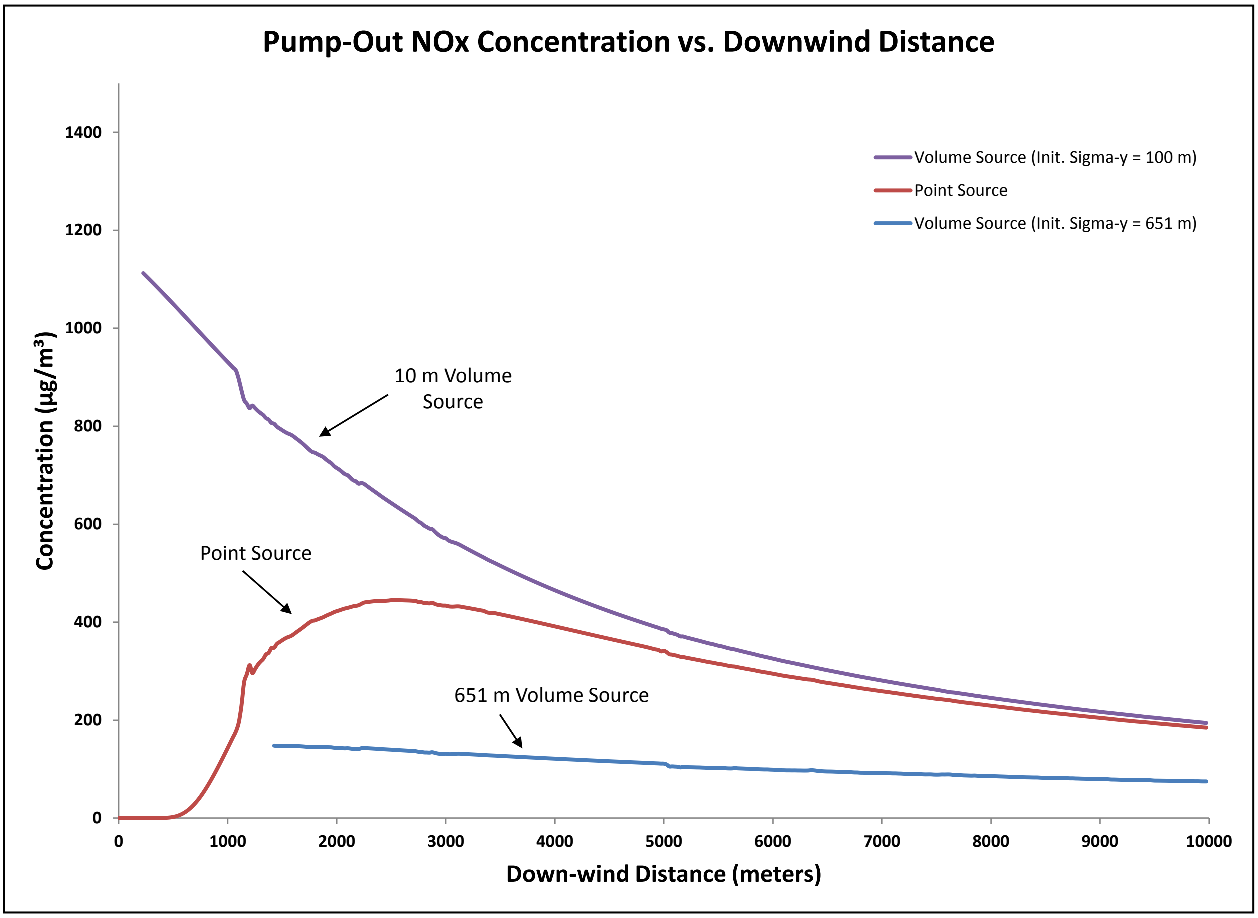

Figure 12. As in Figure 11 but for different choices of the source parameterization (see text).

4.5.2 Other Sources of Uncertainties

Apart from the effects of potential errors in emission estimates and uncertainties introduced by source parameterizations as described above, the performance of atmospheric dispersion models in accurately predicting downwind pollutant concentrations depends on numerous factors such as terrain and land cover characteristics, meteorological conditions and their spatial and temporal variability, and the degree to which meteorological data used to drive the model is representative of the source locations. It is therefore not possible to obtain *a priori* estimates of uncertainties (i.e., bias and precision) in model results for any specific application. Steady-state Gaussian plume models such as AERMOD are particularly sensitive to deviations from the underlying assumptions of spatially homogeneous, steady-state hourly meteorological conditions. For this particular application, the main concern in this regard is proper treatment of the transition zone between the over water and over land boundary layers as described in Sec. 4.3.1 and the most directly relevant information on model uncertainties is the model performance evaluation results from the coastal tracer studies described in that section. Overall, these results are consistent with other AERMOD evaluation studies in that rank ordered AERMOD predictions are generally well within a factor of two of rank-ordered observations (i.e., observations and predictions are compared by rank order and are not necessarily paired in space or time). As with most dispersion models, AERMOD demonstrates little skill when predictions are compared with observations matched by time and location.

A particular difficulty involved in applying a steady-state model such as AERMOD to a moving source of emissions such as a marine vessel is that the model is not able to replicate the time-dependent behavior of the source. For the example application described above, a separate model run was created for each mode of the dredging cycle (with the dredge in a different position during each mode)and the mode producing the maximum onshore impacts for each averaging time of interest (1-hour, 24-hour and annual) was identified. This process could introduce errors in cases in which overlapping plumes from different modes lead to higher concentrations. Use of a non-steady state dispersion model such as CALPUFF with time varying emission inputs would avoid this problem. As noted in Section 4.3.1, however, there are also some disadvantages to using CALPUFF instead AERMOD.

5. SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

BOEM identified the need for a standardized and technically defensible method for estimating criteria pollutant and GHG emissions associated with beach nourishment projects to ease the burden of preparing the required environmental reviews. BOEM commissioned the development of a method capable of calculating project emissions based on project design parameters, such as the amount of material to be placed on shore, location of the borrow area(s) and pump-out location(s) relative to the beach construction zone and specifications of the dredge vessel and other equipment to be used for the project. ENVIRON and Woods Hole Group reviewed historical dredging projects and consulted with dredging contractors to develop a method for translating these project design parameters into estimates of the amount of work (hp-hours) performed by the dredge vessels, support vessels and other project equipment. These activity estimates are in turn used to calculate engine emissions based on standard EPA procedures and assumptions. A Microsoft ACCESS database program, the DPEC, was developed to facilitate these calculations. DPEC stores all of the required information, provides a simple user interface for input of project design parameters, performs all of the necessary calculations and provides results via a suite of reports and a spreadsheet compatible data export.

To illustrate how the DPEC might be used in practice, a demonstration for a “typical” beach nourishment project (the Brevard South Reach project located along the east coast of Florida) was described. This project involved the use of 650,000 cubic yards of sand from a borrow area located beyond the 3 nm state territorial limits. Results from the demonstration application confirmed that the dredge vessel is the major source of emissions from the project, accounting for 91% of total NOx emissions with the remainder coming from auxiliary (support) vessels and on-shore construction equipment. Emissions estimated using DPEC were compared to the General Conformity *de minimus* thresholds to determine if a project of this size and type would exceed the thresholds and require a more detailed analysis for its potential to cause violations of the NAAQS. Total project emissions were found to be less than the General Conformity *de minimus* levels for all pollutants except that total NOx emissions calculated to be released within Florida territorial limits (15 tons out of a project total of 39 tons) exceeded the *de minimus* level for areas classified as extreme nonattainment for ozone (however, no such areas currently exist outside of California). The project total NOx emissions (39 tons) exceed the *de minimus* thresholds for severe and extreme ozone nonattainment areas only (such areas currently exist only in California and Houston, TX). Thus, even if the physical layout of the project had been different so as to result in most of the project emissions having been released within the Florida territorial limits, the *de minimus* thresholds would not be exceeded. These results suggest that dredging projects of this size would only require a detailed dispersion modeling analysis of their potential to cause violations of the NAAQS under the conformity rules if they were located offshore of a severe or extreme ozone nonattainment area.

Application of DPEC provides a standardized, scientifically sound and defensible approach to estimating emissions from planned future beach nourishment/coastal restoration projects. DPEC can provide reasonable emission estimates given only basic information about a proposed project. However, DPEC users can easily modify the calculations to include more refined project information when available.

To illustrate how an analysis of the ambient air quality impacts of a typical beach nourishment project might be performed, a modeling analysis of the Brevard County South Reach Shore Protection Project was conducted. Personnel responsible for preparing air quality impact analyses of future beach nourishment/restoration projects may find the emission calculation and dispersion modeling procedures described in this example application instructive. Model results from this example can also be used to evaluate the likely scale of ambient air quality impacts from future beach nourishment projects similar to the typical example project analyzed here and thus help guide future beach nourishment project designs so as to avoid, to the maximum possible extent, potential adverse air quality impacts which might delay or complicate necessary permit approvals.

Dispersion modeling results showed that peak short-term (1-hour) impacts occur when the dredge is located closest to shore and stationary, in other words during periods when the dredge is discharging its load. During this portion of the dredging cycle, peak 1-hour NO_2 concentrations reached levels exceeding the 188 µg/m³ level of the 1-hour NO_2 NAAQS. However, the predicted 8^{th} highest daily maximum 1-hour NO_2 concentration (which is the design value that is compared with the 1-hour NO_2 NAAQS) was less than half the level of the NAAQS in this case because conditions producing the peak 1-hour level (onshore winds while the dredge is at the pump-out location) occurred on fewer than 8 days during the project. Concentrations of all other criteria pollutants were well below their applicable NAAQS.

It is reasonable to assume that the most significant concern from an air quality perspective for most beach nourishment and coastal restoration projects will be on possible violations of the 1-hour NO_2 standard. It is not unreasonable to expect that NO_2 violations are possible from projects in which the dredge vessel operates close to shore for significant periods of time and meteorological conditions are frequently unfavorable (i.e., light on-shore winds under limited vertical mixing). Readers should keep in mind, however, that each situation is unique, and modeling procedures will vary from one project to the next depending on project design, location of activities and concerns raised by local residents and governments.

5.2 RECOMMENDATIONS

Given the limited number of historical projects for which sufficient activity data was available for this study, it is recommended that data from additional projects relating project-level parameters to engine usage and fuel consumption be collected and used to update the DPEC. These additional data could be used to refine the DPEC and reduce uncertainties in calculated emissions. As noted above, the historical projects with data suitable for analysis identified in this study only included projects involving hopper dredges. Additional data from projects involving other types of dredges, particularly those involving cutterhead (pipeline) dredges, are needed, especially if pipeline dredge projects become more common in the future. Several projects were constructed in 2012 using cutterhead dredges including Pinellas Co., FL and Pelican Island, LA. Data from these projects (specifically fuel consumption data for each engine or group of similar engines along with engine operating hours or average load factors and project design parameters such as amount of material dredged and placed, distance to beach and daily operating schedules) can provide the basis for extensions of the DPEC to allow for estimation of cutterhead dredge project emissions based on project parameters.

Given potentially large future demand for sand in certain locations (e.g., Gulf Coast), it is conceivable that in some cases offshore federal sand resources may be hopper dredged and stockpiled at a temporary near-shore site for subsequent transport to the beach via a pipeline dredge. Emissions from these types of potential future projects can be estimated by combining separate DPEC calculations for the hopper and pipeline dredge portions of the project. Extensions of the DPEC could be made to streamline these calculations. It is also recommended that engine and operating parameters for additional dredges from the available US dredge vessel fleet be added to the DPEC so that users of the calculator do not have to look up and enter these data.

AERMOD evaluation studies suggest that peak concentration predictions tend to be reasonably accurate when emissions are accurately specified (including an appropriate specification of the source type [area, volume or point] and dimensions) and meteorological conditions representative of the project area are used. However, AERMOD does not explicitly account for the differences in boundary layer dispersion parameters between the over water and over land portions of the modeling domain and this could lead to more significant errors in some cases. Further evaluation of AERMOD predictions and comparisons of AERMOD with other models such as CALPUFF in dredging project applications is needed. These studies should include further evaluations of the impact of alternative source parameterizations on predicted peak concentrations.

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Appendix A

Sample Projects

Sandbridge Beach Erosion and Hurricane Protection Project, Sandbridge Beach, VA (Weeks Marine) 2007

Two hopper dredges were used on the Sandbridge Beach project; the RN Weeks and BE Lindholm were used for different phases of the project. The project activity statistics were provided in the production reports. Based on this data and the installed power for each dredge plant, the average engine load factor was 38.7% for the RN Weeks and 35.8% for the BE Lindholm. The load factor was determined from the ratio of the actual fuel consumption to the estimated fuel consumption at full load for all installed engines assuming each dredge was used for the entire project. Dredge specifications are given below (https://www.dredgepoint.org/dredging-database/owners/weeks-marine-inc):

Vessel	Engines	Total Installed Power	Hopper Size	Loaded Speed
RN Weeks	6 Caterpillar engines (diesel-electric)	9,843 kW	3058 m^3	8 knots
BE Lindholm	2 propulsion engines, and 4 auxiliary engines	10,955 kW	3075 m^3	12.75 knots

Table A-1. Sandbridge project activity factors.

Dredge Activity	Production Statistics	Inferred Rate
Fuel (gal)	597,765	
Distance from Borrow to Pump (nm)	4	
Theoretical (Hopper volume x loads) (yd3)	3,683,631	
Gross hauled volume (yd3)	2,609,036	
Discharged (yd3)	2,231,458	
Survey placed volume (yd3)	2,110,975	
Dredge time per load (hrs)	0.51	5,555 (Gross cy/hr)
Sail to pump per load (hrs)	0.58	6.9 knots
Hookup/unhook and dump per load (hrs)	0.34	
Dump time per load (hrs)	0.59	3,885 (Placed cy/hr)
Sail to cut per load (hrs)	0.46	8.7 knots
Loads	921	
Percent Run Time	82%	
CALCULATED FACTORS		
Useable Hopper Fraction (Gross/(Hopper Size x Loads)) (Discharged/(Hopper Size x Loads))	70.8% 60.6%	
Sand Capacity Factor (Survey Placed / Gross Hauled)	80.9%	
Avg. Placed volume per load (yd3)	2,292	

U.S. Army Corps of Engineers, 2007, “Sandbridge Beach Nourishment Virginia Beach, Virginia,” USACE, Norfolk District.

Brevard County Shore Protection Project (South Reach), FL (Great Lakes Dredge and Dock) 2010

The hopper dredge used on the Brevard County project was the *Liberty Island*. The average engine load factor was of 49.4%. Specifications for the *Liberty Island* are (http://www.dredgepoint.org/dredging-database/owners/great-lakes-dredge-dock-co):[13]

Rated power: 15,566 hp total with 9920 hp propulsion,
Loaded speed: 14 knots,
Hopper size: 5000 m^3.

Table A-2. Brevard 2010 project activity factors.

Dredge Activity	Production Statistics	Inferred Rate
Fuel (gal)	251,811	
Distance from Borrow to Pump (nm)	25	
Theoretical (Hopper volume x loads)	856,740	
Gross hauled volume (yd3)	690,270	
Discharged volume (yd3)	N/A	
Survey placed volume (yd3)	620,214	
Dredge time per load (hrs)	0.46	11,455 (Gross cy/hr)
Sail to pump per load (hrs)	2.03	12.3 knots
Hookup/unhook time per load (hrs)	Included in dump	
Dump time per load (hrs)	0.89	5,320 (Placed cy/hr)
Sail to cut time (hrs)	1.64	15.3 knots
Loads	131	
Percent Run Time	72%	
CALCULATED FACTORS		
Useable Hopper Fraction (Gross/(Hopper Size x Loads))	80.6%	
Sand Capacity Factor (Survey Placed / Gross Hauled)	89.9%	
Avg. Load (yd3)	4,734	

Olsen Associates, Inc. 2010. "Brevard County, Florida, Federal Shore Protection Project South Reach - 2010 Renourishment, Project Completion Report," Prepared for the Minerals Management Service of the U. S. Department of the Interior on behalf of Brevard County, Florida and the U. S. Army Corps of Engineers by Olsen Associates, Inc., July 9, 2010. (including separate load tracking data files provided by Weeks Marine)

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[13] Note that slightly different engine hp and average load factors as well as an average loaded speed less than the 14 kt specification (to account for accelerations/deceleration) were assumed for purposes of the example application presented in Section 4.

Surf City Beach Nourishment, Topsail Island, NC (Weeks Marine) 2011

The hopper dredge used on this project was the R.N. Weeks (see specifications given above). The hopper dredge excavated sediment for the New River Inlet in an inlet realignment and beach nourishment project. The average engine load factor was 37.1%. There was an extra screening for this project (2 inch screen) for ordnance removal.

Table A-3. Surf City project activity factors.

Dredge Activity	Production Statistics	Inferred Rate
Fuel (gal)	89,310	
Distance from Borrow to Pump (nm)	2.5	
Theoretical (Hopper volume x loads) (yd3)	544,000	
Gross hauled volume (yd3)	N/A	
Discharged volume (yd3)	329,533	
Survey placed volume (yd3)	268,894	
Dredge time per load (hrs)	0.87	2,785 (Discharge cy/hr)
Sail to pump per load (hrs)	0.68	3.7 knots
Hookup/unhook and dump per load (hrs)	Included in dump time	
Dump time per load (hrs)	0.57	3,468 (Placed cy/hr)
Sail to cut per load (hrs)	0.57	4.6 knots
Loads	136	
Percent Run Time	76%	
CALCULATED FACTORS		
Useable Hopper Fraction (Discharge/(Hopper Size x Loads))	60.6%	
Sand Capacity Factor (Survey Placed / Discharge)	81.6%	
Avg. Placed volume per load (yd3)	1,977	

Load tracking data provided by Weeks Marine

Patrick Air Force Base, FL (Weeks Marine) 2005

The hopper dredge used on this project was the R.N. Weeks (see specifications given above). The average engine load factor was 40.9%.

Table A-4. Patrick Air Force Base project activity factors.

Dredge Activity	Production Statistics	Inferred Rate
Fuel (gal)	68,045	
Distance from Borrow to Pump (nm)	12.4	
Theoretical (Hopper volume x loads) (yd3)	264,000	
Gross hauled volume (yd3)	N/A	
Discharged volume (yd3)	162,843	
Survey placed volume (yd3)	119,223	
Dredge time per load (hrs)	0.39	6,326 (Discharge cy/hr)
Sail to pump per load (hrs)	1.52	8.2 knots
Hookup/unhook and dump per load (hrs)	Included in dump time	
Dump time per load (hrs)	0.59	3,061

Dredge Activity	**Production Statistics**	**Inferred Rate**
		(Placed cy/hr)
Sail to cut per load (hrs)	1.21	9.6 knots
Loads	66	
Percent Run Time	78%	
CALCULATED FACTORS		
Useable Hopper Fraction (Discharge/(Hopper Size x Loads))	61.7%	
Sand Capacity Factor (Survey Placed / Discharged)	73.2%	
Avg. Placed volume per load (yd3)	1,806	

Load tracking data provided by Weeks Marine

Engine load factors vary depending on the work being done, but data on loads under different work scenarios are not available. Average engine load factors were estimated based on the dredge vessel installed power, hours of activity and fuel consumption provided by the production reports for each project. As fuel consumption is only reported on a daily or weekly basis and may have been computed via reconciliation against fuel purchases, there is significant uncertainty in the day to day or week to week fuel consumption estimates. Therefore, only one average load factor for the entire project was estimated using the ratio of the actual total fuel consumption divided by the theoretical (full load) maximum fuel consumption for all engines on the dredge combined based on EPA's specific fuel consumption values for marine engines via the equation below. Specific fuel consumption is a measure of the fuel efficiency for the diesel engine in units of grams per kilowatt-hour (or pounds/hp-hr) and is sometimes referred to as the specific fuel oil consumption (SFOC) or brake-specific fuel consumption (BSFC).

Load Factor = Actual Fuel Consumption / [(Sum of all engines' power) x (hours of operation) x BSFC]

Appendix B

Marine Engine Emission Factors

Table B-1. Emission factors for diesel marine engines (sources: 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-08-001, March; reviewed via personal communication with Penny Carey, EPA 2011.)

		Displacement (l/cyl)		Power (kW)		Power Density	Emission Factor (g/kW-h)[a]					BSFC	Cert Fuel S
Tier	Year Last Applied	≥	<	≥	<	kW/l	HC	CO	NOx	PM10 Cert. Fuel	PM10 15 ppm S	g/kW-h	ppm
0	1999	0	0.9	0	8		2.01	6.71	13.41	1.341	1.21	248.3961	3300
0	1999	0	0.9	8	19		2.28	6.71	11.4	1.207	1.08	248.3961	3300
0	1999	0	0.9	19	37		2.41	6.71	9.25	1.073	0.94	248.3961	3300
0	1999	0	0.9	37	100000		0.41	1.6	10	0.54	0.43	213.0849	3300
0	1999	0.9	1.2	0	100000		0.32	1.6	10	0.47	0.36	213.0849	3300
0	1999	1.2	2.5	0	100000		0.27	1.6	10	0.34	0.23	213.0849	3300
0	1999	2.5	3.5	0	100000		0.27	1.6	10	0.3	0.19	213.0849	3300
0	1999	3.5	5	0	100000		0.27	1.8	11	0.3	0.19	216.4091	3300
0	1999	5	15	0	100000		0.134	2.48	13.36	0.32	0.21	213.0849	3300
0	1999	15	20	0	100000		0.134	2.48	13.36	0.32	0.21	213.0849	3300
0	1999	20	25	0	100000		0.134	2.48	13.36	0.32	0.21	213.0849	3300
0	1999	25	30	0	100000		0.134	2.48	13.36	0.32	0.21	213.0849	3300
1	2004	0	0.9	0	8		1.02	5.51	7.013	0.603	0.47	248.3961	3300
1	2004	0	0.9	8	19		0.59	2.9	5.95	0.362	0.23	248.3961	3300
1	2003	0	0.9	19	37		0.375	2.05	6.34	0.456	0.33	248.3961	3300
1	2004	0	0.9	37	100000		0.41	1.6	9.8	0.54	0.43	213.0849	3300
1	2003	0.9	1.2	0	100000		0.32	1.6	9.8	0.47	0.36	213.0849	3300
1	2003	1.2	2.5	0	100000		0.27	1.6	9.8	0.34	0.23	213.0849	3300
1	2006	2.5	3.5	0	100000		0.27	1.6	9.1	0.3	0.19	213.0849	3300
1	2006	3.5	5	0	100000		0.27	1.8	9.2	0.3	0.19	213.0849	3300
1	2006	5	15	0	100000		0.134	2.48	10.55	0.32	0.21	213.0849	3300
1	2006	15	20	0	100000		0.134	2.48	10.55	0.32	0.21	213.0849	3300
1	2006	20	25	0	100000		0.134	2.48	10.55	0.32	0.21	213.0849	3300
1	2006	25	30	0	100000		0.134	2.48	10.55	0.32	0.21	213.0849	3300
2	2008	0	0.9	0	8		0.91	5.51	5.89	0.51	0.50	248.3961	350
2	2008	0	0.9	8	19		0.28	2.9	4.87	0.255	0.24	248.3961	350
2	2008	0	0.9	19	37		0.724	2.05	4.98	0.308	0.29	248.3961	350
2	2008	0	0.9	37	75		0.41	1.6	5.7	0.23	0.22	213.0849	350
2	2011	0	0.9	75	100000		0.41	1.6	5.7	0.23	0.22	213.0849	350

		Displacement (l/cyl)		Power (kW)		Power Density	Emission Factor (g/kW-h)[a]					BSFC	Cert Fuel S
Tier	Year Last Applied	≥	<	≥	<	kW/l	HC	CO	NOx	PM10 Cert. Fuel	PM10 15 ppm S	g/kW-h	ppm
2	2012	0.9	1.2	0	100000		0.32	0.9	6.1	0.12	0.11	213.0849	350
2	2013	1.2	2.5	0	100000		0.19	1.1	6	0.13	0.12	213.0849	350
2	2012	2.5	3.5	0	100000		0.19	1.1	6	0.13	0.12	213.0849	350
2	2011	3.5	5	0	100000		0.19	1.1	6	0.13	0.12	213.0849	350
2	2011	5	7	0	100000		0.134	2	8.33	0.32	0.31	213.0849	350
2	2012	7	15	0	3700		0.134	2	8.33	0.32	0.31	213.0849	350
2	2013	7	15	3700	100000		0.134	2	8.33	0.32	0.31	213.0849	350
2	2013	15	20	0	100000		0.134	2	8.33	0.32	0.31	213.0849	350
2	2013	20	25	0	100000		0.134	2	8.33	0.32	0.31	213.0849	350
2	2013	25	30	0	100000		0.134	2	8.33	0.32	0.31	213.0849	350
3	2050	0	0.9	0	8		0.58	5.51	5.89	0.322	0.32	213.0849	no adj
3	2013	0	0.9	8	19		0.282	2.9	4.87	0.255	0.26	213.0849	no adj
3.1	2050	0	0.9	8	19		0.282	2.9	3.11	0.255	0.26	213.0849	no adj
3	2013	0	0.9	19	37		0.55	2.05	4.975	0.241	0.24	213.0849	no adj
3.1	2050	0	0.9	19	37		0.55	2.05	3.11	0.241	0.24	213.0849	no adj
3	2013	0	0.9	37	75		0.3	1.6	5.7	0.17	0.17	213.0849	no adj
3.1	2050	0	0.9	37	75		0.3	1.6	3.56	0.17	0.17	213.0849	no adj
3	2050	0	0.9	75	100000	35	0.14	1.6	4.08	0.08	0.08	213.0849	no adj
3	2050	0.9	1.2	0	100000	35	0.13	0.9	4.54	0.05	0.05	213.0849	no adj
3	2017	1.2	2.5	0	600	35	0.1	1.1	4.69	0.07	0.07	213.0849	no adj
3.1	2050	1.2	2.5	0	600	35	0.1	1.1	4.69	0.061	0.06	213.0849	no adj
3	2050	0	0.9	75	100000	1000	0.15	1.6	4.38	0.08	0.08	213.0849	no adj
3	2016	0.9	1.2	0	100000	1000	0.14	0.9	4.89	0.05	0.05	213.0849	no adj
3	2050	1.2	2.5	0	600	1000	0.11	1.1	4.81	0.08	0.08	213.0849	no adj
3	2017	1.2	2.5	601	1000		0.1	1.1	4.69	0.07	0.07	213.0849	no adj
4	2050	1.2	2.5	601	1000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2016	1.2	2.5	1001	100000		0.1	1.1	4.69	0.07	0.07	213.0849	no adj
4	2050	1.2	2.5	1001	100000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2017	2.5	3.5	0	600		0.1	1.1	4.69	0.07	0.07	213.0849	no adj
3.1	2050	2.5	3.5	0	600		0.1	1.1	4.69	0.061	0.06	213.0849	no adj
3	2017	2.5	3.5	600	1000		0.1	1.1	4.69	0.07	0.07	213.0849	no adj

		Displacement (l/cyl)		Power (kW)		Power Density	Emission Factor (g/kW-h)[a]					BSFC	Cert Fuel S
Tier	Year Last Applied	≥	<	≥	<	kW/l	HC	CO	NOx	PM10 Cert. Fuel	PM10 15 ppm S	g/kW-h	ppm
4	2050	2.5	3.5	600	1000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2016	2.5	3.5	1000	100000		0.1	1.1	4.69	0.07	0.07	213.0849	no adj
4	2050	2.5	3.5	1000	100000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2017	3.5	5	0	600		0.1	1.1	4.81	0.07	0.07	213.0849	no adj
3.1	2050	3.5	5	0	600		0.1	1.1	4.81	0.061	0.06	213.0849	no adj
3	2017	3.5	5	600	1000		0.1	1.1	4.81	0.07	0.07	213.0849	no adj
4	2050	3.5	5	600	1000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2016	3.5	5	1000	1400		0.1	1.1	4.81	0.07	0.07	213.0849	no adj
4	2050	3.5	5	1000	1400		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2015	3.5	5	1400	100000		0.1	1.1	4.81	0.07	0.07	213.0849	no adj
4	2050	3.5	5	1400	100000		0.04	1.1	1.3	0.03	0.03	213.0849	no adj
3	2050	5	15	0	600		0.07	1.1	5.97	0.11	0.11	213.0849	no adj
3	2017	5	15	600	1000		0.07	2	5.97	0.11	0.11	213.0849	no adj
4	2050	5	15	600	1000		0.02	2	1.3	0.03	0.03	213.0849	no adj
3	2016	5	15	1000	1400		0.07	2	5.97	0.11	0.11	213.0849	no adj
4	2050	5	15	1000	1400		0.02	2	1.3	0.03	0.03	213.0849	no adj
3	2015	5	15	1400	2000		0.07	2	5.97	0.11	0.11	213.0849	no adj
4	2050	5	15	1400	2000		0.02	2	1.3	0.03	0.03	213.0849	no adj
3	2013	5	15	2000	3700		0.134	2	8.33	0.11	0.11	213.0849	no adj
3.1	2015	5	15	2000	3700		0.02	2	1.3	0.11	0.11	213.0849	no adj
4	2050	5	15	2000	3700		0.02	2	1.3	0.03	0.03	213.0849	no adj
3.9	2016	5	15	3700	100000		0.06	2	1.3	0.1	0.10	213.0849	no adj
4	2050	5	15	3700	100000		0.03	2	1.3	0.04	0.04	213.0849	no adj
3	2015	15	20	0	2000		0.09	2	6.77	0.3	0.30	213.0849	no adj
4	2050	15	20	0	2000		0.01	2	1.3	0.04	0.04	213.0849	no adj
3	2015	15	20	2000	3700		0.01	2	1.3	0.3	0.30	213.0849	no adj
4	2050	15	20	2000	3700		0.01	2	1.3	0.04	0.04	213.0849	no adj
3.9	2016	15	20	3700	100000		0.07	2	1.3	0.23	0.23	213.0849	no adj
4	2050	15	20	3700	100000		0.01	2	1.3	0.05	0.05	213.0849	no adj
3	2016	20	30	0	100000		0.07	2	1.3	0.23	0.23	213.0849	no adj
3	2050	20	30	0	100000		0.01	2	1.3	0.05	0.05	213.0849	no adj

[a] VOC and PM2.5 emissions are derived from HC and PM10 emissions as per NONROAD model (http://www.epa.gov/otaq/nonrdmdl.htm)

Appendix C

Shore Based Equipment

Table C-1. All construction, commercial and industrial equipment. (SCC is the Source Category Code used by EPA in emission inventory reporting)

SCC	Fuel	Description
2270002003	Diesel	Pavers
2270002006	Diesel	Tampers/Rammers
2270002009	Diesel	Plate Compactors
2270002012	Diesel	Concrete Pavers
2270002015	Diesel	Rollers
2270002018	Diesel	Scrapers
2270002021	Diesel	Paving Equipment
2270002024	Diesel	Surfacing Equipment
2270002027	Diesel	Signal Boards
2270002030	Diesel	Trenchers
2270002033	Diesel	Bore/Drill Rigs
2270002036	Diesel	Excavators
2270002039	Diesel	Concrete/Industrial Saws
2270002042	Diesel	Cement & Mortar Mixers
2270002045	Diesel	Cranes
2270002048	Diesel	Graders
2270002051	Diesel	Off-highway Trucks
2270002054	Diesel	Crushing/Proc. Equipment
2270002057	Diesel	Rough Terrain Forklifts
2270002060	Diesel	Rubber Tire Loaders
2270002063	Diesel	Rubber Tire Dozers
2270002066	Diesel	Tractors/Loaders/Backhoes
2270002069	Diesel	Crawler Tractors
2270002072	Diesel	Skid Steer Loaders
2270002075	Diesel	Off-Highway Tractors
2270002078	Diesel	Dumpers/Tenders
2270002081	Diesel	Other Construction Equipment
2270003010	Diesel	Aerial Lifts
2270003020	Diesel	Forklifts
2270003030	Diesel	Sweepers/Scrubbers
2270003040	Diesel	Other General Industrial Equipment
2270003050	Diesel	Other Material Handling Equipment
2270006005	Diesel	Light Commercial Generator Sets
2270006010	Diesel	Light Commercial Pumps
2270006015	Diesel	Light Commercial Air Compressors
2270006020	Diesel	Light Commercial Gas Compressors
2270006025	Diesel	Light Commercial Welders
2270006030	Diesel	Light Commercial Pressure Washer
2270006035	Diesel	Hydro Power Units

Appendix D

AERCOARE Summary File

```
------------------------------ ----------
 AERCOARE Version            : D11244

 Run Date                    : 20121127
 Run Time (hour:min:sec)      : 15:14:46.645
 Run Time Zone               : -0800
 Control/Option file         : canaveral.inp
 Overwater meteorological file: canaveral_wayoff.csv
 Output SFC file for AERMOD   : canaveral_wayoff.sfc
 Output PFL file for AERMOD   : canaveral_wayoff.pfl

Control File Options
------------------------------- ----------
 Latitude (degN)             :    28.5190
 Longitude (degW)            :    80.1660
 Time Zone (5-EST.. 8-PST)    :          0
 COARE Gust Mix Ht (m)        :      511.0
 Mininum Overwater Mix Ht (m) :       25.0
 Min Abs(L) allowed          :        5.0
 Calm Threshold (m/s)         :       0.50
 Default VPTG (degC/m)        :      0.006
 Default Wind Meas. Ht (m)    :       5.00
 Default Temp Meas. Ht (m)    :       4.00
 Default RelH Meas. Ht (m)    :       4.00
 Default Sea Temp Depth (m)   :      1.000
 Mix Ht Option (-2 to 2)      :          1
 COARE Warm Layer Option (0-1):          0
 COARE Cool Skin Option (0-1) :          0
 COARE Wave Option (0-2)      :          0

Overwater Input File Variables and Limits
  n name column     scale       min       max
 -- ---- ------ --------- --------- ---------
  1 wspd      6  1.00      0.00      50.0
  2 wdir      5  1.00      0.00      360.
  3 tsea      9  1.00     -3.00      50.0
  4 tair      8  1.00     -30.0      50.0
  5 relh     10  1.00      0.00      100.
  6 pres      7  1.00      900.     0.110E+04
 17 hwav     11  1.00      0.00      80.0
 18 twav     12  1.00      0.00      40.0
 20 mixh     13  1.00      0.00     0.500E+04
```

```
Missing Data Summary by Variable (1)

 Vname   No. Miss
 ----- ----------
  wspd       352
  wdir       352
  tsea       352
  tair       352
  relh       361
  pres       352
  hwav       352
  twav       390
  mixh         0

(1) - does not include whole missing hours caused
      by non-sequential data.


 AERCOARE processed          7776  records
 number of records with insufficient data :          361
 number of calm records                    :          31
```

Appendix E

AERMOD Control File for NOx Run.

```
CO STARTING
CO TITLEONE BOEM DREDGE
CO TITLETWO NOV 2012
CO MODELOPT CONC
CO AVERTIME 1 24 PERIOD
CO POLLUTID NOX
CO RUNORNOT RUN
CO ERRORFIL nox.2010.st.errors
CO FINISHED

SO STARTING
SO ELEVUNIT METERS
**          Name  Type    X        Y     Elev
SO LOCATION SHORE VOLUME 542819 3107088 1
SO LOCATION PUMP VOLUME 543851.2 3107448.68 0
SO LOCATION TRIN01 VOLUME 544254.0769 3108786.307 0
SO LOCATION TRIN02 VOLUME 544656.9538 3110123.934 0
SO LOCATION TRIN03 VOLUME 545059.8308 3111461.561 0
SO LOCATION TRIN04 VOLUME 545462.7077 3112799.188 0
SO LOCATION TRIN05 VOLUME 545865.5846 3114136.815 0
SO LOCATION TRIN06 VOLUME 546268.4615 3115474.442 0
SO LOCATION TRIN07 VOLUME 546671.3385 3116812.069 0
SO LOCATION TRIN08 VOLUME 547074.2154 3118149.696 0
SO LOCATION TRIN09 VOLUME 547477.0923 3119487.323 0
SO LOCATION TRIN10 VOLUME 547879.9692 3120824.95 0
SO LOCATION TRIN11 VOLUME 548282.8462 3122162.577 0
SO LOCATION TRIN12 VOLUME 548685.7231 3123500.204 0
SO LOCATION TRIN13 VOLUME 549088.6 3124837.831 0
SO LOCATION TRIN14 VOLUME 549491.4769 3126175.458 0
SO LOCATION TROU15 VOLUME 549894.3538 3127513.085 0
SO LOCATION TROU16 VOLUME 550297.2308 3128850.712 0
SO LOCATION TROU17 VOLUME 550700.1077 3130188.339 0
SO LOCATION TROU18 VOLUME 551102.9846 3131525.966 0
SO LOCATION TROU19 VOLUME 551505.8615 3132863.593 0
SO LOCATION TROU20 VOLUME 551908.7385 3134201.22 0
SO LOCATION TROU21 VOLUME 552311.6154 3135538.847 0
SO LOCATION TROU22 VOLUME 552714.4923 3136876.474 0
SO LOCATION TROU23 VOLUME 553117.3692 3138214.101 0
SO LOCATION TRIN24 VOLUME 553520.2462 3139551.728 0
SO LOCATION TRIN25 VOLUME 553923.1231 3140889.355 0
SO LOCATION DREDGE VOLUME 554326 3142227 0
SO LOCATION AUXPUMP VOLUME 543871.2 3107448.68 0
SO LOCATION AUXDRE VOLUME 554346 3142227 0
SO LOCATION AUXIN01 VOLUME 544274.0769 3108786.307 0
SO LOCATION AUXIN02 VOLUME 544676.9538 3110123.934 0
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SO LOCATION AUXIN03 VOLUME 545079.8308 3111461.561 0
SO LOCATION AUXIN04 VOLUME 545482.7077 3112799.188 0
SO LOCATION AUXIN05 VOLUME 545885.5846 3114136.815 0
SO LOCATION AUXIN06 VOLUME 546288.4615 3115474.442 0
SO LOCATION AUXIN07 VOLUME 546691.3385 3116812.069 0
SO LOCATION AUXIN08 VOLUME 547094.2154 3118149.696 0
SO LOCATION AUXIN09 VOLUME 547497.0923 3119487.323 0
SO LOCATION AUXIN10 VOLUME 547899.9692 3120824.95 0
SO LOCATION AUXIN11 VOLUME 548302.8462 3122162.577 0
SO LOCATION AUXIN12 VOLUME 548705.7231 3123500.204 0
SO LOCATION AUXIN13 VOLUME 549108.6 3124837.831 0
SO LOCATION AUXIN14 VOLUME 549511.4769 3126175.458 0
SO LOCATION AUXOU15 VOLUME 549914.3538 3127513.085 0
SO LOCATION AUXOU16 VOLUME 550317.2308 3128850.712 0
SO LOCATION AUXOU17 VOLUME 550720.1077 3130188.339 0
SO LOCATION AUXOU18 VOLUME 551122.9846 3131525.966 0
SO LOCATION AUXOU19 VOLUME 551525.8615 3132863.593 0
SO LOCATION AUXOU20 VOLUME 551928.7385 3134201.22 0
SO LOCATION AUXOU21 VOLUME 552331.6154 3135538.847 0
SO LOCATION AUXOU22 VOLUME 552734.4923 3136876.474 0
SO LOCATION AUXOU23 VOLUME 553137.3692 3138214.101 0
SO LOCATION AUXIN24 VOLUME 553540.2462 3139551.728 0
SO LOCATION AUXIN25 VOLUME 553943.1231 3140889.355 0

**         Name  Q(g/s)  Ht(m)  Temp(K)  Vel(m/s) Diam(m)
SO SRCPARAM SHORE 0.209577578 10 35 20
SO SRCPARAM PUMP 13.58304188 10 651 20
SO SRCPARAM TRIN01 0.181107225 10 651 20
SO SRCPARAM TRIN02 0.181107225 10 651 20
SO SRCPARAM TRIN03 0.181107225 10 651 20
SO SRCPARAM TRIN04 0.181107225 10 651 20
SO SRCPARAM TRIN05 0.181107225 10 651 20
SO SRCPARAM TRIN06 0.181107225 10 651 20
SO SRCPARAM TRIN07 0.181107225 10 651 20
SO SRCPARAM TRIN08 0.181107225 10 651 20
SO SRCPARAM TRIN09 0.181107225 10 651 20
SO SRCPARAM TRIN10 0.181107225 10 651 20
SO SRCPARAM TRIN11 0.181107225 10 651 20
SO SRCPARAM TRIN12 0.181107225 10 651 20
SO SRCPARAM TRIN13 0.181107225 10 651 20
SO SRCPARAM TRIN14 0.181107225 10 651 20
SO SRCPARAM TROU15 0.037144053 10 651 20
SO SRCPARAM TROU16 0.037144053 10 651 20
SO SRCPARAM TROU17 0.037144053 10 651 20
SO SRCPARAM TROU18 0.037144053 10 651 20
SO SRCPARAM TROU19 0.037144053 10 651 20
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SO SRCPARAM TROU20 0.037144053 10 651 20
SO SRCPARAM TROU21 0.037144053 10 651 20
SO SRCPARAM TROU22 0.037144053 10 651 20
SO SRCPARAM TROU23 0.037144053 10 651 20
SO SRCPARAM TRIN24 0.181107225 10 651 20
SO SRCPARAM TRIN25 0.181107225 10 651 20
SO SRCPARAM DREDGE 13.58304188 10 651 20
SO SRCPARAM AUXPUMP 0.928601316 5 651 10
SO SRCPARAM AUXDRE 0.928601316 5 651 10
SO SRCPARAM AUXIN01 0.037144053 5 651 10
SO SRCPARAM AUXIN02 0.037144053 5 651 10
SO SRCPARAM AUXIN03 0.037144053 5 651 10
SO SRCPARAM AUXIN04 0.037144053 5 651 10
SO SRCPARAM AUXIN05 0.037144053 5 651 10
SO SRCPARAM AUXIN06 0.037144053 5 651 10
SO SRCPARAM AUXIN07 0.037144053 5 651 10
SO SRCPARAM AUXIN08 0.037144053 5 651 10
SO SRCPARAM AUXIN09 0.037144053 5 651 10
SO SRCPARAM AUXIN10 0.037144053 5 651 10
SO SRCPARAM AUXIN11 0.037144053 5 651 10
SO SRCPARAM AUXIN12 0.037144053 5 651 10
SO SRCPARAM AUXIN13 0.037144053 5 651 10
SO SRCPARAM AUXIN14 0.037144053 5 651 10
SO SRCPARAM AUXOU15 0.181107225 5 651 10
SO SRCPARAM AUXOU16 0.181107225 5 651 10
SO SRCPARAM AUXOU17 0.181107225 5 651 10
SO SRCPARAM AUXOU18 0.181107225 5 651 10
SO SRCPARAM AUXOU19 0.181107225 5 651 10
SO SRCPARAM AUXOU20 0.181107225 5 651 10
SO SRCPARAM AUXOU21 0.181107225 5 651 10
SO SRCPARAM AUXOU22 0.181107225 5 651 10
SO SRCPARAM AUXOU23 0.181107225 5 651 10
SO SRCPARAM AUXIN24 0.037144053 5 651 10
SO SRCPARAM AUXIN25 0.037144053 5 651 10

** Included BPIP output sections


** Source Groups
SO SRCGROUP SHOREGR SHORE
SO SRCGROUP PUMPGR PUMP AUXPUMP
SO SRCGROUP DREDGEGR DREDGE AUXDRE
SO SRCGROUP TRANSGR TRIN01 TRIN02 TRIN03 TRIN04 TRIN05 TRIN06 TRIN07
TRIN08 TRIN09 TRIN10 TRIN11 TRIN12 TRIN13 TRIN14 TROU15 TROU16 TROU17
TROU18 TROU19 TROU20 TROU21 TROU22 TROU23 TRIN24 TRIN25 AUXIN01
```

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AUXIN02 AUXIN03 AUXIN04 AUXIN05 AUXIN06 AUXIN07 AUXIN08 AUXIN09
AUXIN10 AUXIN11 AUXIN12 AUXIN13 AUXIN14 AUXOU15 AUXOU16 AUXOU17
AUXOU18 AUXOU19 AUXOU20 AUXOU21 AUXOU22 AUXOU23 AUXIN24 AUXIN25
SO SRCGROUP ALL_PUMP SHORE PUMP AUXPUMP
SO SRCGROUP ALL_DRE SHORE DREDGE AUXDRE
SO SRCGROUP ALL_TRAN SHORE TRIN01 TRIN02 TRIN03 TRIN04 TRIN05 TRIN06
TRIN07 TRIN08 TRIN09 TRIN10 TRIN11 TRIN12 TRIN13 TRIN14 TROU15 TROU16
TROU17 TROU18 TROU19 TROU20 TROU21 TROU22 TROU23 TRIN24 TRIN25
AUXIN01 AUXIN02 AUXIN03 AUXIN04 AUXIN05 AUXIN06 AUXIN07 AUXIN08
AUXIN09 AUXIN10 AUXIN11 AUXIN12 AUXIN13 AUXIN14 AUXOU15 AUXOU16
AUXOU17 AUXOU18 AUXOU19 AUXOU20 AUXOU21 AUXOU22 AUXOU23 AUXIN24
AUXIN25
SO FINISHED

** Receptors
RE STARTING
RE ELEVUNIT METERS
RE INCLUDED ../../aermap/100m.rec
RE INCLUDED ../../aermap/500m.rec
RE INCLUDED ../../aermap/beach.rec
RE FINISHED

** Meteorology
ME STARTING
ME STARTEND 10 02 13 01 10 04 10 24
ME SURFFILE ../../aercoare_nov27/canaveral_wayoff.feb-apr_new.sfc
ME PROFFILE ../../aercoare_nov27/canaveral_wayoff.feb-apr_new.pfl
ME PROFBASE 55.0 METERS
ME SURFDATA 99999 2010
ME UAIRDATA 99999 2010
ME FINISHED

NO ECHO

** Output files
OU STARTING
OU SUMMFILE nox.2010.st.summary
OU RECTABLE 1 1 8
OU PLOTFILE 1 SHOREGR 8 nox.2010.st.SHOREGR.8th.1hr.plot
OU PLOTFILE 1 SHOREGR 1 nox.2010.st.SHOREGR.1st.1hr.plot
OU PLOTFILE 1 PUMPGR 8 nox.2010.st.PUMPGR.8th.1hr.plot
OU PLOTFILE 1 PUMPGR 1 nox.2010.st.PUMPGR.1st.1hr.plot
OU PLOTFILE 1 DREDGEGR 8 nox.2010.st.DREDGEGR.8th.1hr.plot
OU PLOTFILE 1 DREDGEGR 1 nox.2010.st.DREDGEGR.1st.1hr.plot
OU PLOTFILE 1 TRANSGR 8 nox.2010.st.TRANSGR.8th.1hr.plot
OU PLOTFILE 1 TRANSGR 1 nox.2010.st.TRANSGR.1st.1hr.plot
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OU PLOTFILE 1 ALL_PUMP 8 nox.2010.st.ALL_PUMP.8th.1hr.plot
OU PLOTFILE 1 ALL_PUMP 1 nox.2010.st.ALL_PUMP.1st.1hr.plot
OU PLOTFILE 1 ALL_DRE 8 nox.2010.st.ALL_DRE.8th.1hr.plot
OU PLOTFILE 1 ALL_DRE 1 nox.2010.st.ALL_DRE.1st.1hr.plot
OU PLOTFILE 1 ALL_TRAN 8 nox.2010.st.ALL_TRAN.8th.1hr.plot
OU PLOTFILE 1 ALL_TRAN 1 nox.2010.st.ALL_TRAN.1st.1hr.plot
OU RECTABLE 24 1
OU PLOTFILE 24 SHOREGR 1 nox.2010.st.SHOREGR.1st.24hr.plot
OU PLOTFILE 24 PUMPGR 1 nox.2010.st.PUMPGR.1st.24hr.plot
OU PLOTFILE 24 DREDGEGR 1 nox.2010.st.DREDGEGR.1st.24hr.plot
OU PLOTFILE 24 TRANSGR 1 nox.2010.st.TRANSGR.1st.24hr.plot
OU PLOTFILE 24 ALL_PUMP 1 nox.2010.st.ALL_PUMP.1st.24hr.plot
OU PLOTFILE 24 ALL_DRE 1 nox.2010.st.ALL_DRE.1st.24hr.plot
OU PLOTFILE 24 ALL_TRAN 1 nox.2010.st.ALL_TRAN.1st.24hr.plot
OU PLOTFILE PERIOD SHOREGR nox.2010.st.SHOREGR.1st.PERIODhr.plot
OU PLOTFILE PERIOD PUMPGR nox.2010.st.PUMPGR.1st.PERIODhr.plot
OU PLOTFILE PERIOD DREDGEGR nox.2010.st.DREDGEGR.1st.PERIODhr.plot
OU PLOTFILE PERIOD TRANSGR nox.2010.st.TRANSGR.1st.PERIODhr.plot
OU PLOTFILE PERIOD ALL_PUMP nox.2010.st.ALL_PUMP.1st.PERIODhr.plot
OU PLOTFILE PERIOD ALL_DRE nox.2010.st.ALL_DRE.1st.PERIODhr.plot
OU PLOTFILE PERIOD ALL_TRAN nox.2010.st.ALL_TRAN.1st.PERIODhr.plot
OU FINISHED
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The Department of the Interior Mission

As the Nation’s principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.