National Park Service
U.S. Department of the Interior
Joshua Tree National Park, Pt. Reyes National Seashore, Yosemite National Park
California

Visitor Vehicle Emissions Study
Summary Report
Final Report

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Background

The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center), Environmental Measurement and Modeling Division, provided technical support to the National Parks Foundation as a part of a National Park Service (NPS) project to evaluate vehicular emissions in the national parks. A Visitor Vehicular Emissions Study was performed in three California National Parks between August 2002 and April 2003 – Yosemite National Park, Joshua Tree National Park, and Point Reyes National Seashore – in order to collect traffic count, vehicle tracking, meteorological, Inspection and Maintenance Program, and fuel program data. This data was processed through the Environmental Protection Agency's (EPA) MOBILE6.2 modeling software to produce park-specific emission factors, and weekly traffic count data was used with these emission factors to produce a weekly emissions inventory for each park. Alternative methods involving modal emissions models were also investigated. This summary report presents the Visitor Vehicle Emissions Study results in a concise format and conveys, in simplified language, the recommendations of the Volpe Center for future related studies. These results and recommendations are explained in greater detail in the companion Volpe Center report, "Visitor Vehicle Emissions Study: Comparison of Traffic Data at Three California National Parks" and three companion technical reports produced for each of the California parks.

Objectives

The main objective of this study was to answer a series of important questions about predicting emissions in the National Parks.

1. **Are the defaults in the current emissions inventory model, MOBILE6, satisfactory for modeling emissions in the National Parks?**

2. **Do better alternatives exist for modeling emissions in the National Parks?**

3. **Can emissions inventories be modeled, and their results accepted as absolute?**

4. **Who would most benefit from a flexible emissions model?**

5. **What are some additional tools for monitoring environmental quality in the National Parks?**

A large body of data was collected and analyzed in various ways with the goal of answering these questions. This data and all pertinent data analysis processes are discussed at length in the companion report "Visitor Vehicle Emissions Study: Comparison of Traffic Data at Three California National Parks" and the companion technical reports produced for each of the California parks.

This document summarizes the findings of the study as they relate to each of the important questions mentioned above. The reader is frequently referred to the companion reports, but the concise, simplified language used in this summary should help parks personnel to better understand what was achieved through this study.

Results

<u>Question 1:</u> Are the defaults in the current emissions inventory model, MOBILE6, satisfactory for modeling emissions in the National Parks?

MOBILE Version 6.2 ("MOBILE6") is the latest version of the MOBILE-series vehicular emission factor modeling software promulgated by the EPA [EPA 2002]. Typically, states and various local/regional agencies use the model for developing vehicular emissions inventories as a requisite for state implementation plans and conformity analyses. This model is discussed in more detail in each of the companion technical reports produced for the California parks.

MOBILE6 predicts emission factors (e.g., g/vehicle-mile) for several pollutants such as several HC categories (including VOC), CO, and NOx. The model takes into account various parameters, including vehicle types, vehicle starts, traffic count, temperature, vehicle driving cycle (speeds and accelerations), inspection/maintenance (I/M) programs, etc., to generate current emission factors. Many of these parameters are provided as defaults within the model, and this study sought to examine how a few of these defaults compare to actual conditions measured within the three California parks.

<u>Speeds</u>

MOBILE6 was basically developed through emissions measurements using a Federal Test Procedure (FTP) driving cycle with a length of 7.5 miles and a speed averaged over one cycle of 19.6 miles per hour (mph). The default MOBILE6 speed distribution is presented in Figure 1.

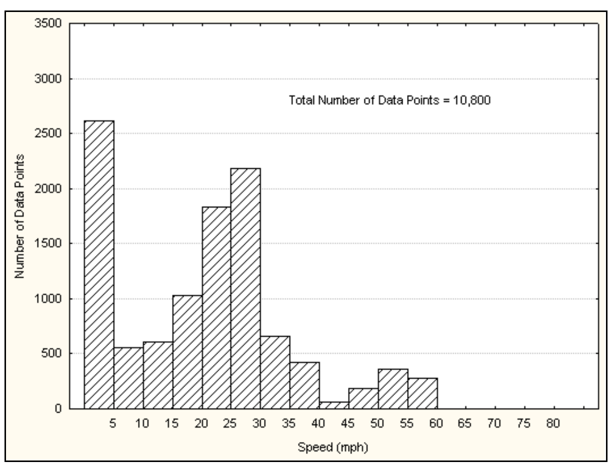


Figure 1. Default MOBILE6 speed distributions

The average representative speed distributions for Joshua Tree and Pt. Reyes are presented in Figures 2 and 3.

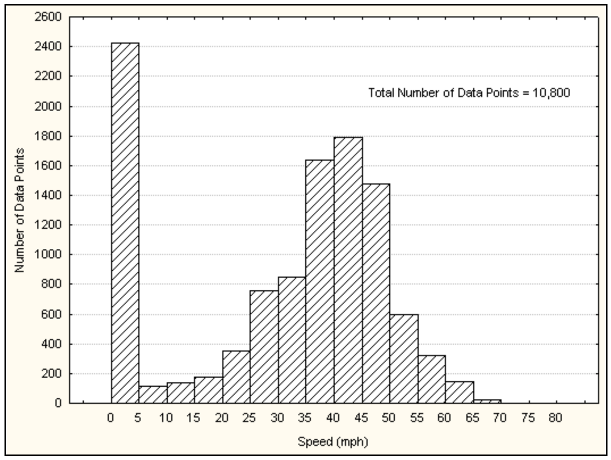


Figure 2. Speed distribution for Joshua Tree

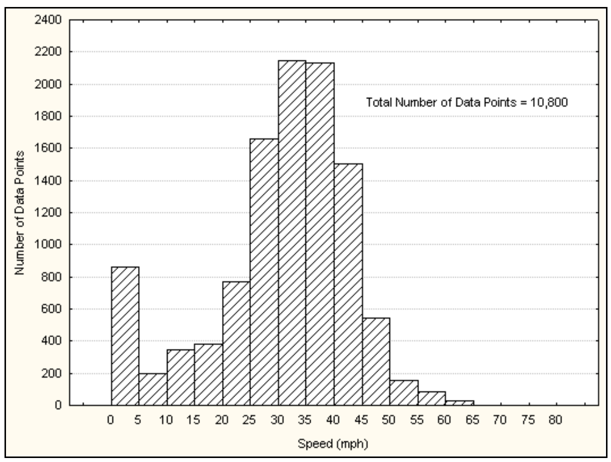


Figure 3. Speed distribution for Pt. Reyes

While all three speed distributions have considerable idling activity (speed = 0 – 5 mph), the MOBILE6 default speed distribution contains more lower-speed data points (20 – 30 mph) than either the Joshua Tree distribution, which contains many data points between 35 – 45 mph, or the Pt. Reyes distribution, which contains many data points between 30 – 40 mph. Utilizing the default MOBILE6 speed distribution to model Joshua Tree or Pt. Reyes, therefore, could possibly model a 50% to 75% slower speed distribution than those representative speeds which are actually occurring in these parks.

This speed data and the comparisons are discussed in detail in the companion reports.

Vehicle Type

MOBILE6 utilizes a vehicle type distribution based on the 16 vehicle categories listed in Table 1.

Table 1. MOBILE6 vehicle categories

Number	Abbreviation	Description
1	LDV	Light-Duty Vehicles (Passenger Cars)
2	LDT1	Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3,750 lbs. LVW)
3	LDT2	Light-Duty Trucks 2 (0-6,000 lbs. GVWR, 3,751-5,750 lbs. LVW)
4	LDT3	Light-Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-5,750 lbs. ALVW*)
5	LDT4	Light-Duty Trucks 4 (6,001-8,500 lbs. GVWR, 5,751 lbs. and greater ALVW)
6	HDV2B	Class 2b Heavy-Duty Vehicles (8,501-10,000 lbs. GVWR)
7	HDV3	Class 3 Heavy-Duty Vehicles (10,001-14,000 lbs. GVWR)
8	HDV4	Class 4 Heavy-Duty Vehicles (14,001-16,000 lbs. GVWR)
9	HDV5	Class 5 Heavy-Duty Vehicles (16,001-19,500 lbs. GVWR)
10	HDV6	Class 6 Heavy-Duty Vehicles (19,501-26,000 lbs. GVWR)
11	HDV7	Class 7 Heavy-Duty Vehicles (26,001-33,000 lbs. GVWR)
12	HDV8A	Class 8a Heavy-Duty Vehicles (33,001-60,000 lbs. GVWR)
13	HDV8B	Class 8b Heavy-Duty Vehicles (>60,000 lbs. GVWR)
14	HDBS	School Buses
15	HDBT	Transit and Urban Buses
16	MC	Motorcycles (All)

* ALVW = Alternative Loaded Vehicle Weight: The adjusted loaded vehicle weight is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR)

The MOBILE6 default vehicle type distribution, shown in Figure 4, is developed from national EPA statistics.

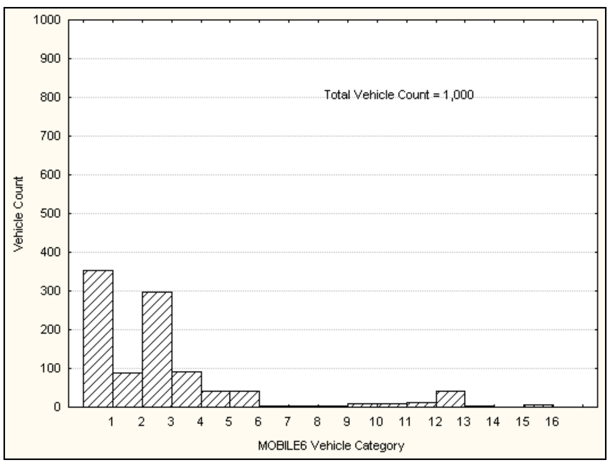


Figure 4. MOBILE6 default vehicle distribution

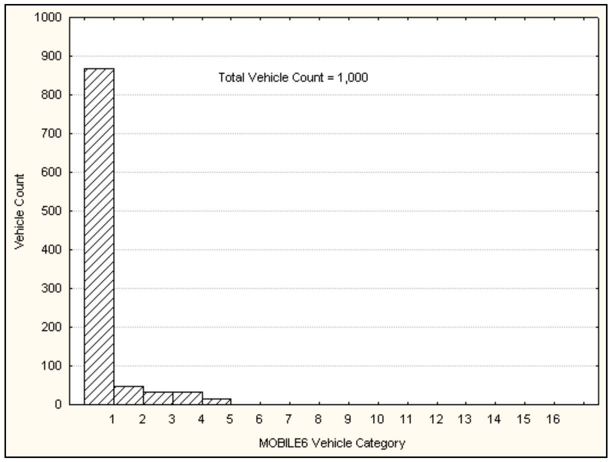


Figure 5. Average vehicle distribution from three California parks

The average vehicle distribution from the California parks, shown in Figure 5, was developed from vehicle counts at Yosemite, Joshua Tree, and Pt. Reyes. The MOBILE6 default distribution includes almost as many category #3 vehicles (light-duty trucks) as category #1 vehicles (passenger cars). This differs a great deal from the parks distribution, which is clearly dominated by passenger cars. Utilizing the MOBILE6 default vehicle distribution to model Yosemite, Joshua Tree, or Pt. Reyes, therefore, could possibly model a set of vehicle types unrepresentative of those which are actually visiting these parks.

This vehicle type data and the comparisons are discussed in detail in the companion reports.

Other

Other default information contained in MOBILE6 may not reflect what is happening in the park being modeled. *Vehicle counts*, for example, were very different among the three California parks (see companion technical report for each California park), and an emissions inventory modeled for these parks using the default MOBILE6 vehicle counts – based on national EPA statistics – could introduce large errors. Also, the *Inspection and Maintenance* (I/M) default in MOBILE6 assumes there is no I/M program of any kind, and this was not the case in the counties which contained the California parks.

Vehicle count and I/M data are discussed in detail in the companion technical reports for each park.

Question 2: Do better alternatives exist for modeling emissions in the National Parks?

In addition to MOBILE6, alternative methods using modal emissions models were developed to provide refined modeling capabilities and results. The University of

California at Riverside's (UCR) Comprehensive Modal Emissions Model (CMEM, Version 2.02) was used as the basis for this refined emissions modeling work. A derivative Meta-Model[1] using only the speed and acceleration variables in CMEM was developed to simplify the use of CMEM. The advantages and disadvantages to these models are discussed below.

<u>CMEM</u>

Modal emissions models provide the ability to directly model emissions that are specific to different vehicle operational modes. Depending on its intended use, a modal emissions model could provide emission factors on an aggregate level or on a second-by-second basis for the corresponding speed and acceleration values. One such model used to predict second-by-second emissions is CMEM.

There are several potential advantages to utilizing CMEM over other statistics-based modal emissions models such as MOBILE6. The micro-scale modeling approach employed in CMEM ensures that it can be used for varying scales of analysis whereas a statistical model like MOBILE6 may be constrained by the level of detail in the data on which it was developed. The micro-scale analysis capability allows for modeling a wide range of scales since the results can be aggregated for larger scales. CMEM also provides numerous parameters and variables that can be used to refine an analysis such as the addition of road grade information. In addition to these, the physical modeling approach employed in CMEM represents a more realistic and likely a more accurate model. *In using the model to develop an overall emissions inventory, CMEM has two potential advantages over MOBILE6: (1) the ability to explicitly model different driving cycles (i.e., speeds and acceleration other than the FTP cycle); and (2) the ability to take into account road grade data, a significant concern in many National Parks.*

A disadvantage to using a model of this type is the data requirement. The higher-fidelity nature requires a similarly higher level of input complexity and understanding from the user. Although default parameters can be used, refinements in analyses require the user to provide more data. Data used for other modal emissions analyses may need to be expanded using assumptions as necessary to develop speed, acceleration, road grade, etc. In addition, the model is also limited to light-duty vehicles. Large or heavy-duty vehicles are beyond the scope of the current model. This is not a concern when modeling visitor vehicular emissions at National Parks because of the negligible fractions of these visitor vehicle types at the parks (see Figure 5).

CMEM is discussed in much more detail in the companion technical reports for each California park.

[1] As used in this context, a "meta-model" is a model developed from the outputs of a parent model (e.g., CMEM) by varying a subset of all the parameters within the parent model.

CMEM Meta-Model

Since CMEM is a relatively complicated model to run, a simplified method was developed to create a meta-model based on CMEM outputs. Specifically, combinations of speed and acceleration ranges were modeled in CMEM to produce corresponding second-by-second modal emission rates. The speed values ranged from 0 to 80 mph and the acceleration values ranged from –6 to 6 mph/s. Each combination of speed and acceleration were fed into CMEM as a set of three records with speed differences that corresponded to the acceleration rate. The resulting matrix of emission factors is based on speed, acceleration, and vehicle type.

The CMEM Meta-Model uses this emission factor matrix and user-defined speed and acceleration input to provide one-second emission factors, in g/vehicle. Since the emission factors and cycle data points are both based on a one-second interval, the emission factors are summed and then multiplied by the total number of vehicles to obtain total emissions per week.

An advantage to using the CMEM Meta-Model is its ease of use. Since the model already takes into account a representative park vehicle distribution and other parameters such as weather, altitude, I/M, and road grade, the only required input is a user-defined speed and acceleration dataset. Anyone able to operate a computer and process simple data in an Excel spreadsheet could use the model.

A disadvantage to using the CMEM Meta-Model is the inability to change many of the input parameters. In order to change vehicle distribution, weather, I/M, etc., the user would need to run CMEM and develop a new matrix of emission factors for use with the Meta-Model.

The CMEM Meta-Model software is included on the CD-ROM accompanying this summary report. A tutorial on simplified data collection and use of the CMEM Meta-Model is provided in Appendix A of this summary report. The CMEM Meta-Model is discussed in much more detail in the companion technical reports for each California park.

Question 3: Can emissions inventories be modeled reliably, and their results accepted as accurate?

Answering this question would require additional study. While this study did result in emissions inventories for the three California national parks, modeled in MOBILE6, CMEM, and the CMEM Meta-Model, there are no validation emissions data available for comparison with the modeled results. An example one-week emissions inventory is presented for Joshua Tree National Park in Figures 6, 7, and 8 below.

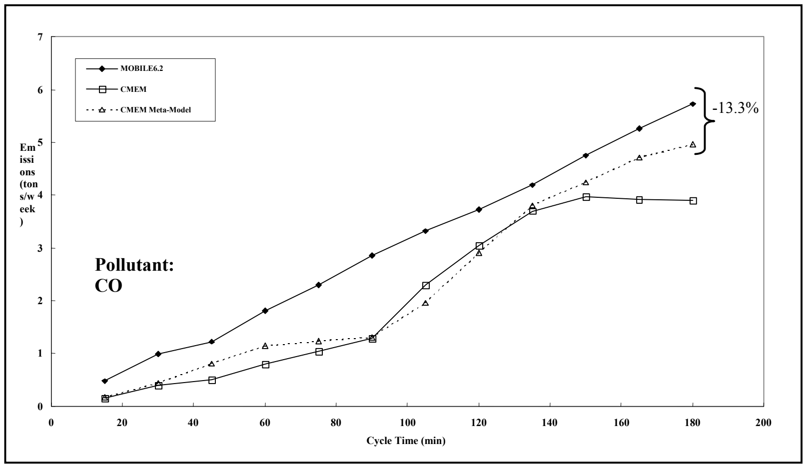


Figure 6. Joshua Tree carbon monoxide (CO) emissions

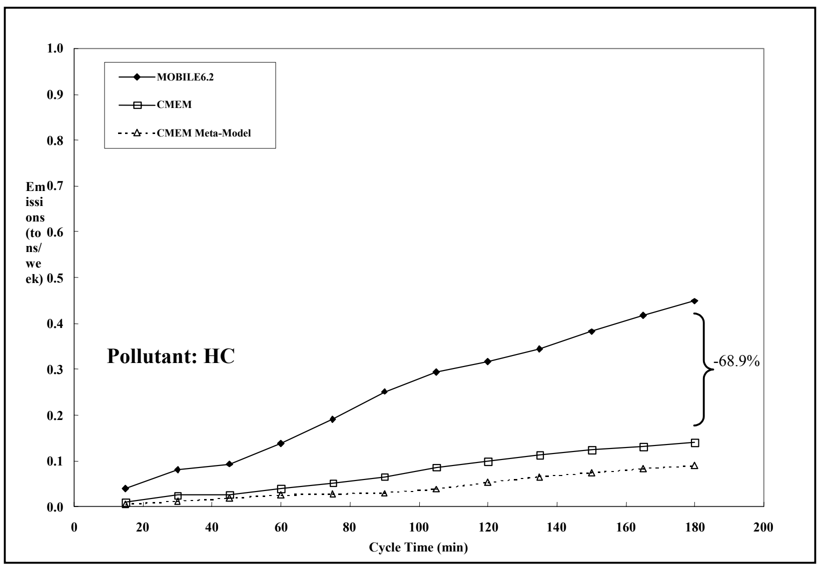


Figure 7. Joshua Tree hydrocarbons (HC) emissions

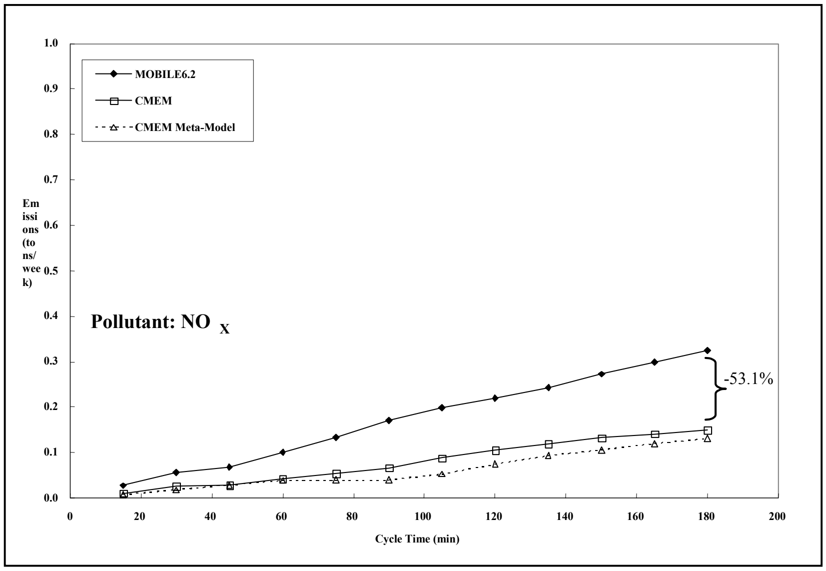


Figure 8. Joshua Tree nitrogen oxide (NO_x) emissions

These graphs show that the MOBILE6 emissions predictions are consistently higher and more conservative than both CMEM and the CMEM Meta-Model for the same general data inputs: For CO, MOBILE6 predicts 13.3% higher emissions than the CMEM Meta Model and 31.8% higher than CMEM; for HC, MOBILE6 predicts 68.9% higher than CMEM and 80.0% higher than the CMEM Meta Model; for NO_x, MOBILE6 predicts 53.1% higher than CMEM and 59.4% higher than the CMEM Meta Model. It is difficult to tell which model's results are exactly right without any validation data available for comparison. The companion technical reports do compare each park's emissions inventory with emissions inventories modeled at other parks, but *the only real way to gauge the absolute accuracy of MOBILE6, CMEM, or the CMEM Meta-Model would be to conduct a thorough air quality validation study in one of the California parks then compare that absolute data to the modeled results.*

Complete emissions inventories for Yosemite, Joshua Tree, and Pt. Reyes are presented in the companion technical reports, as well as all model inputs and outputs.

Question 4: Who would most benefit from a flexible emissions tool?

Given enough resources, engineers and other technical personnel could measure a park's emissions characteristics and learn to use MOBILE6 and CMEM well enough to produce an emissions inventory, as described in the companion technical reports. However, time and funds for data collection studies and expertise for competent emissions model operation may not be available to the parks personnel, including superintendents and rangers, who make decisions about vehicle travel in the parks and who therefore require access to updated emissions data.

While MOBILE6 is the current standard model for all Federal, state, and local emissions policymaking, its use is beyond the technical capabilities of many parks personnel, and, as shown in some of the findings mentioned above, its defaults often do not reflect actual park conditions.

An unofficial but easy-to-use tool such as the CMEM Meta-Model may provide parks personnel with an efficient method of identifying the impacts of major changes in park emissions characteristics, such as driving behavior (speed limits and access) and traffic counts (gate limits). A tutorial on simplified data collection and use of the CMEM Meta-Model is provided in Appendix A of this summary report. The CMEM Meta-Model is discussed in much more detail in the companion technical reports for each California park.

Question 5: What are some additional tools for modeling environmental quality in the National Parks?

In addition to visitor vehicle emissions, other sources of park visitor environmental pollution can be monitored and modeled.

CLIPP

As part of the National Park Service's (NPS) Climate Leadership in Public Places (CLIPP) program, the NPS' Air Resources Division in Ft. Collins, Colorado, is funding ICF Consultants in Washington, DC, to develop a tool for estimating emissions inventories in the parks. The intent is that this tool, called the CLIPP Tool, will be distributed to and used by National Park personnel.

The CLIPP Tool was developed using MS Excel 2000. Users with an understanding of this spreadsheet tool should be able to use the CLIPP Tool.

TNM

Traffic noise, for example, can be modeled in the Federal Highway Administration's (FHWA) Traffic Noise Model. Using this FHWA tool, supported by the Volpe Center Acoustics Facility (VCAF), users can model the "directivity" of a noise source, that is, the distance and angle of the sound emitted as well as its interaction with objects in the environment, and its "level", that is, the sound's intensity as it reaches a receiver such as a park visitor.

During the Yosemite measurement, VCAF performed a noise measurement of the Ford Th!nk vehicle and one of the park's shuttle buses. The data from this noise measurement has since been analyzed and processed according to FHWA standards, and the results from this measurement can be found in Appendix H of the companion technical report for Yosemite National Park. Conceivably, the sound level data from these two vehicles could now be entered into the TNM, along with traffic volume and speed data, park geometry information, and receiver information, and the model would predict sound level information for the modeled receivers. This could prove quite a useful exercise for a park like Yosemite which has so much traffic flow and a vested interest in predicting what the noise would be if traffic volume was reduced.

Particulate Matter

The Volpe Center's Air Quality Facility (VCAQF) are experienced managers of EPA- and Federal Aviation Administration (FAA)-approved particulate matter emissions measurement and analysis studies. VCAQF's expertise makes it possible for them to design and perform particulate matter emissions studies like the visitor vehicle emissions validation study necessary to prove or disprove the accuracy of MOBILE6, CMEM, and the CMEM Meta-Model.

Conclusion

It remains in the parks' best interests to use and accept MOBILE6 results in the development of environmental policy with the EPA. However, for internal purposes, the CMEM Meta-Model may prove a very useful tool for parks interested in examining the effects of various park traffic and driving cycle scenarios while avoiding the cost of hiring a MOBILE6 expert. In addition, distribution of the CLIPP Tool may demonstrate that it is another viable option for parks interested in estimating emissions inventories.

Appendix A: User's Manual for the CMEM Meta-Model

The sole purpose of this simplified approach to calculating a park-specific emissions inventory is to provide park personnel with a useful tool for the generation of a generic vehicular emissions inventory for a park without committing the funding and time necessary to perform a more detailed measurement and analysis. If a park employee feels comfortable performing the following tasks: 1. Count traffic using a pencil and paper; 2. Follow visitor vehicles in a car and call out speeds into a tape recorder; and 3. Use the rudimentary functions of Microsoft Windows Explorer and Microsoft Excel, then that employee can generate an emissions inventory using the tools described in this appendix and contained on the CD-ROM included with this paper.

The instructions and recommendations contained herein are not meant to be substituted for any certification procedure or policy utilized by any local, state, or federal government in the generation of any data necessary for the formation of environmental policy.

A.1 Measurements

When utilizing the CMEM Meta-Model to calculate an emissions inventory for a park, the user must first determine a representative, park-specific traffic count for the park and a representative, park-specific driving cycle.

A.1.1 Traffic Count

The key to assembling a representative traffic count for a park is recording a reliable count of the number of vehicles which enter the park in a representative period of time. Only vehicles entering the park at distinct park entrances should be counted, and it can be assumed that a week is a fairly representative period of time, since a week includes both weekdays and weekend days, which in some parks result in completely different traffic counts.

In setting up to count vehicles for a week, several logistical options are available for the designated observer(s) stationed at all distinct park entrances.

Logsheet The simplest way to count vehicles is to station a human observer at a park entrance during the park's hours of operation for a week and equip that observer with pencils and paper logsheets. The observer should make a checkmark as each vehicle enters the park, and these checkmarks can be tallied later to determine the traffic count for that time period. An example logsheet is included in Appendix B.

Palmtop Computer The paper logsheet may be replaced by a palmtop computer, as utilized by the Volpe Center in much of its traffic counting in Yosemite National Park and Pt. Reyes National Seashore California National Parks. If the park has access to a palmtop computer equipped with a simple text editor, it can count traffic by typing in observer, date, and site information followed by a 1 typed in for each vehicle. This method saves paper and makes tallying up the total traffic count much easier when the data are imported into a spreadsheet.

Video Camera Human observers may be replaced with video cameras mounted at park entrances, as utilized by the Volpe Center in much of its traffic counting in Joshua Tree National Park and Pt. Reyes National Seashore. This method allows one person to perform the traffic counting at several entrances, so long as the tapes and batteries are changed regularly. Tapes may be replayed later, and reliable traffic counts tallied from them onto paper or directly into a text editor or spreadsheet.

A.1.2 Driving Cycle

The key to assembling a representative driving cycle for a park is recording a reliable sample of speeds and accelerations of different types of vehicles traveling in different places inside the park. Only vehicles traveling inside the park should be sampled.

In setting up to record a sample of vehicle speeds and accelerations, several logistical options are available for the designated observer(s) stationed within the park.

Video camera Observers interested in sampling the speeds of cars on a road videotape the travel of cars on that road between two cones placed a known distance apart on the side of that road. From the videotape, collect the time it takes for a car to travel the known distance between the cones. Since velocity = distance/time, velocities can be calculated for every vehicle which passes by.

Radar equipment Some observers interested in sampling the speeds of cars on a road position a radar device near that road with a data recorder. This method is well known to local traffic law enforcement agencies, and most agencies will know how to buy or rent and use the proper equipment.

Chase car and tape recorder An observer equipped with a chase car may imitate the speed of another vehicle traveling on a random trip through the park by driving after it at a reasonable distance (~100 ft). The crucial element to this sampling strategy is the recording of the chase car speeds and accelerations during the trip. The simplest recording method is a tape recorder placed near the observer's voice: As the chase car changes speeds, the observer may note these speeds on the chase car's speedometer and call them out at a regular rate, perhaps once every two seconds, into the microphone of the tape recorder. This method was utilized by the Volpe Center in its sampling of speeds and accelerations in Yosemite National Park. These tape-recorded speed data were replayed later and typed into a spreadsheet, where accelerations were calculated. Advantages to this method are simplicity and cost effectiveness; a disadvantage is the potential for unreliable data, as the speedometer of the chase car will only reflect rough estimates of the speed, and as the rate of sampling may become irregular.

Chase car and GPS system A far more sophisticated and reliable recording method is a Global Positioning System (GPS), as utilized by the Volpe Center in all three California

National Parks. A GPS system allows the recording of second-by-second, accurate location data onto an electronic media as the chase car follows another vehicle on a random trip through the park. The Volpe Center's GPS system is described in some detail in Appendix C. There are many types of GPS systems available, some of them inexpensive and simple to operate. If a park wishes to build a sample of GPS speeds and accelerations but does not wish to invest in a GPS system, it may consider hiring a consultant who specializes in GPS measurements. An advantage to the GPS method is the reliability of the data; disadvantages include cost, complexity, and the risk that a good GPS satellite signal may not be available in a particular park, as was the case much of the time in Yosemite National Park.

A.2 Emission Factor Modeling

This section presents an overview of the CMEM Meta-Model. A more detailed overview of the model is presented in each of the three California park companion technical reports.

Model Requirements The CMEM Meta-Model should be installed on a computer equipped with a Windows 98 or above operating system. To check the operating system of a computer, go to Windows Explorer, My Computer. Right click on My Computer and select Properties. Select the General tab; the operating system will be identified under the header System.

The only data necessary to run the CMEM Meta-Model is a sample of representative speed and acceleration data. Before running the CMEM Meta-Model, create a data directory on the computer's hard drive, for example, **C:\CMEM_META_MODEL**.

This tutorial uses the file ***Sample-Input.txt***, which can be found on the CD-ROM included with this report under the ***Tutorial*** directory. Copy this file onto the hard drive and remember where it was placed. Microsoft Excel also needs to be installed for this tutorial.

Speed/Acceleration Data A park's representative speed and acceleration data should be contained in a text file, as pictured in Figure A-1. A blank text file can be opened in Notepad, standard with Microsoft Windows operating systems, and the data entered there, line-by-line. A text file will end with the "TXT" extension. Using the Windows browser feature, give the file an appropriate name, for example, **PORE_speeds.TXT**, and save it to a folder on the computer's hard drive, for example, **C:\CMEM_META_MODEL**.

The example speed/acceleration input text file provided in the ***Tutorial*** directory and pictured in Figure A-1 contains 51 seconds' worth of speed/ acceleration data, starting at speed 1 = 0 mph and acceleration 1 = 0 mph/s. Note:

- **One second of data is assigned to each line in the text file.**
- For each second of data, the speed and acceleration are separated by a comma.

- Data should be limited to one decimal place.
- Processing is easier if speed data are limited to units of miles per hour (mph): If the speeds are collected at a rate of something other than mph, convert the speeds to mph.
- Processing is easier if acceleration data are limited to units of mph per second (mph/s): If the accelerations are collected at a rate other than mph/s, convert the accelerations to mph/s.
- Accelerations, in mph/s, may be calculated from the one-second speed data by using the following formulas:
    - acceleration 1 = 0
    - acceleration 2 = speed 2 – speed 1
    - acceleration 3 = speed 3 – speed 2
    - acceleration 4 = speed 4 – speed 3, etc.
- Negative acceleration values represent decelerations

```
0,0
2.3,2.3
3.6,1.3
4.1,0.5
5.2,1.1
6.9,1.7
7.2,0.3
8.8,1.6
8.2,-0.6
9.7,1.5
8.5,-1.2
10.3,1.8
12.4,2.1
15.1,2.7
17,1.9
20.1,3.1
21.4,1.3
24.5,3.1
23.5,-1
22.4,-1.1
24.3,1.9
25.9,1.6
23.5,-2.4
23.4,-0.1
22.3,-1.1
25.7,3.4
24.7,-1
23.2,-1.5
21.3,-1.9
23.4,2.1
22.3,-1.1
20.9,-1.4
18.5,-2.4
16.4,-2.1
15.7,-0.7
13.4,-2.3
12.3,-1.1
10.1,-2.2
10.4,0.3
11.4,1
10,-1.4
9.8,-0.2
8.1,-1.7
8.9,0.8
7.3,-1.6
5.6,-1.7
4.5,-1.1
3.4,-1.1
2.1,-1.3
1.2,-0.9
0,-1.2
```

Figure A-1. An example speed/acceleration input text file, 1 s data per line

For each of these speed and acceleration combinations, the CMEM Meta-Model will calculate emission factors in grams per second (g/s) for Hydrocarbons (HC), Carbon Monoxide (CO), and Nitrogen Oxides (NOx).

Setting Up the Model In the "CMEM-Meta-Model-Interpolation-Program" directory on the CD-ROM, a set of instructions and a ***Setup.exe*** program has been provided. Double-click the ***Setup.exe*** program and follow the instructions until the setup is finished. Running the program will result in the portal screen shown in Figure A-2.

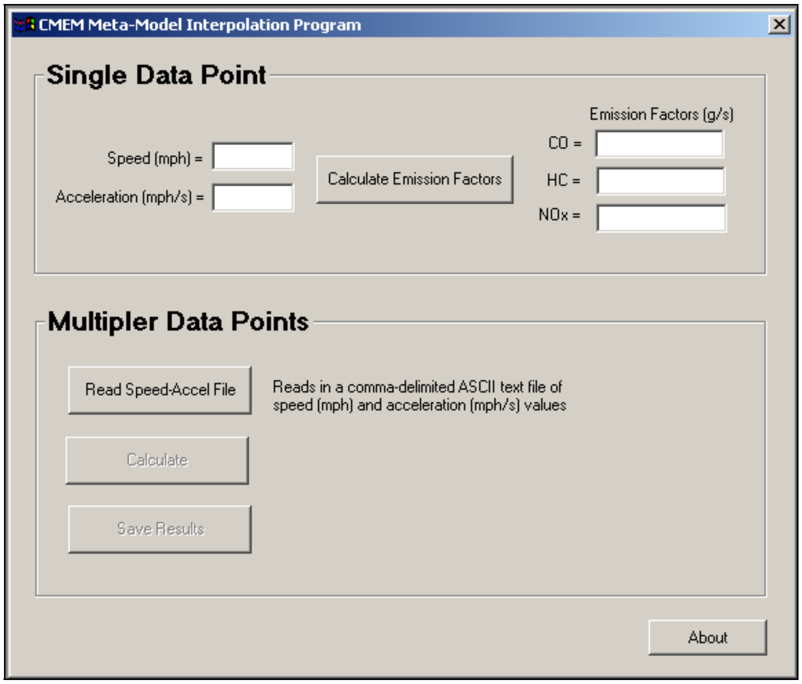


Figure A-2. Portal screen of CMEM Meta-Model

This screen represents the only portal screen in the CMEM Meta-Model: All data entry and software commands are executed from here.

Running the Model

The CMEM Meta-Model calculates emission factors in g/s for different speed/acceleration combinations. The model allows the user to calculate emission factors for a single speed/acceleration data point and multiple speed/acceleration data points.

- ***Single Data Point*** In the "Single Data Point" section of the input screen, enter the desired speed in the "Speed (mph) =" box. Enter the desired acceleration in the "Acceleration (mph/s) =" box. Click the ***Calculate Emission Factors*** button. The CO, HC, and NOx emission factors will appear in the "Emission Factors (g/s)" windows.

- ***Multiple Data Points*** The bottom "Multiple Data Points" section is used to read in multiple speed/acceleration data points, stored in the lines of a text file like the one pictured in Figure A-1. At program startup, note that all of the input screen buttons are disabled (grayed-out) except for the ***Read Speed-Accel File*** button.

Also note that the textual indicator to the right of the ***Read Speed-Accel File*** button reads: "Reads in a comma-delimited ASCII text file of speed (mph) and acceleration (mph/s) values." This is to remind the user of the format that the input data needs to be in, as discussed in the ***Speed/Acceleration Data*** paragraph of Section A.2 and Figure A-1. Press this ***Read Speed-Accel File*** button, and a "Read Data" dialog box will open. Using the Windows file browser feature, find the desired speed/acceleration data input file on the hard drive, for example, **C:\CMEM_META_MODEL\PORE_speeds.TXT**, and click ***Open***. The dialog box will disappear, and the program will have read in the data contained in the selected text file. The textual indicator to the right of the ***Read Speed-Accel File*** button should have changed to read:

"Number of records (data points) = 51*"

This indicates that the data was read in successfully. Note also that the ***Read Speed-Accel File*** button is now disabled (grayed-out) while the ***Calculate*** button is now active. Press the ***Calculate*** button, and the program will automatically conduct the interpolation calculations for each data point contained in the text file. The textual indicator to the right of the ***Calculate*** button indicates which record the interpolations are currently being conducted for. The final reading on the textual indicator should read:

PROGRESS = 51*

This means that record 51* was the last record for which the interpolations were conducted. This should always equal the total number of records that were read in. The ***Calculate*** button should now be disabled and the ***Save Results*** button should be active.

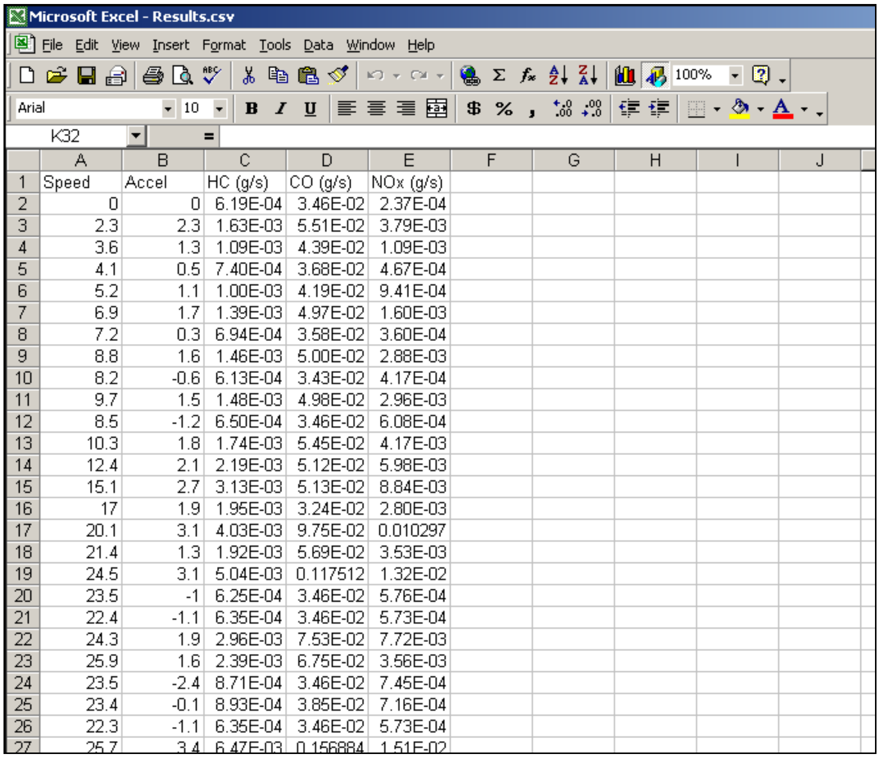
Saving Results Press the ***Save Results*** button, and a ***Save Data*** dialog box will open. Navigate to a suitable location on the hard drive, for example, **C:\CMEM_META_MODEL**, and save the results, using a "CSV" extension and an appropriate filename, for example, **PORE_emissionfactors.CSV**. Click the ***Save*** button, and the dialog box will disappear. The program has saved the CO, HC, and NOx emission factor results in the "CSV" file in a comma-delimited ASCII text format. All of the buttons and textual indicators should have reverted back to their original conditions. This allows the user to process more data as necessary. This ends the use of the "CMEM Meta-Model Interpolation Program."

A.3 Emissions Inventory

Tabulating Emission Factors Find the "CSV" results file on the hard drive, for example, **C:\CMEM_META_MODEL\PORE_emissionfactors.CSV**. Double-click this file, and it should open in Microsoft Excel. Even though it is a comma-delimited

* For however many lines of data there are in the speed/acceleration data input file

file, its "CSV" extension will be automatically recognized by Excel. In Excel, the data should appear as follows:



	A	B	C	D	E	F	G	H	I	J
1	Speed	Accel	HC (g/s)	CO (g/s)	NOx (g/s)					
2	0	0	6.19E-04	3.46E-02	2.37E-04					
3	2.3	2.3	1.63E-03	5.51E-02	3.79E-03					
4	3.6	1.3	1.09E-03	4.39E-02	1.09E-03					
5	4.1	0.5	7.40E-04	3.68E-02	4.67E-04					
6	5.2	1.1	1.00E-03	4.19E-02	9.41E-04					
7	6.9	1.7	1.39E-03	4.97E-02	1.60E-03					
8	7.2	0.3	6.94E-04	3.58E-02	3.60E-04					
9	8.8	1.6	1.46E-03	5.00E-02	2.88E-03					
10	8.2	-0.6	6.13E-04	3.43E-02	4.17E-04					
11	9.7	1.5	1.48E-03	4.98E-02	2.96E-03					
12	8.5	-1.2	6.50E-04	3.46E-02	6.08E-04					
13	10.3	1.8	1.74E-03	5.45E-02	4.17E-03					
14	12.4	2.1	2.19E-03	5.12E-02	5.98E-03					
15	15.1	2.7	3.13E-03	5.13E-02	8.84E-03					
16	17	1.9	1.95E-03	3.24E-02	2.80E-03					
17	20.1	3.1	4.03E-03	9.75E-02	0.010297					
18	21.4	1.3	1.92E-03	5.69E-02	3.53E-03					
19	24.5	3.1	5.04E-03	0.117512	1.32E-02					
20	23.5	-1	6.25E-04	3.46E-02	5.76E-04					
21	22.4	-1.1	6.35E-04	3.46E-02	5.73E-04					
22	24.3	1.9	2.96E-03	7.53E-02	7.72E-03					
23	25.9	1.6	2.39E-03	6.75E-02	3.56E-03					
24	23.5	-2.4	8.71E-04	3.46E-02	7.45E-04					
25	23.4	-0.1	8.93E-04	3.85E-02	7.16E-04					
26	22.3	-1.1	6.35E-04	3.46E-02	5.73E-04					
27	25.7	3.4	6.47E-03	0.156884	1.51E-02					

Figure A-3. The **PORE_emissionfactors.CSV** file loaded into Microsoft Excel

Within Excel, immediately save this "CSV" file as an Excel file on the hard drive, for example, **C:\CMEM_META_MODEL\PORE_emissionfactors.xls**. As indicated by the headers, each of the values under the HC, CO, and NOx columns represent emission factors, in g/s. Total emissions for this fictitious driving cycle of 51 speeds and accelerations can be obtained by simply adding each of these individual emission factors as follows:

HC: 6.19E-04 + 1.63E-03 + 1.09E-03 + … + 6.50E-04 = 6.76E-02 g
CO: 3.46E-02 + 5.51E-02 + 4.39E-02 + … + 3.46E-02 = 2.21 g
NOx: 2.37E-04 +3.79E-03 + 1.09E-03 + … + 2.37E-04 = 1.18E-01 g

In Excel, this corresponds to the following formulas:

=sum(C2:C43)
=sum(D2:D43)
=sum(E2:E43)

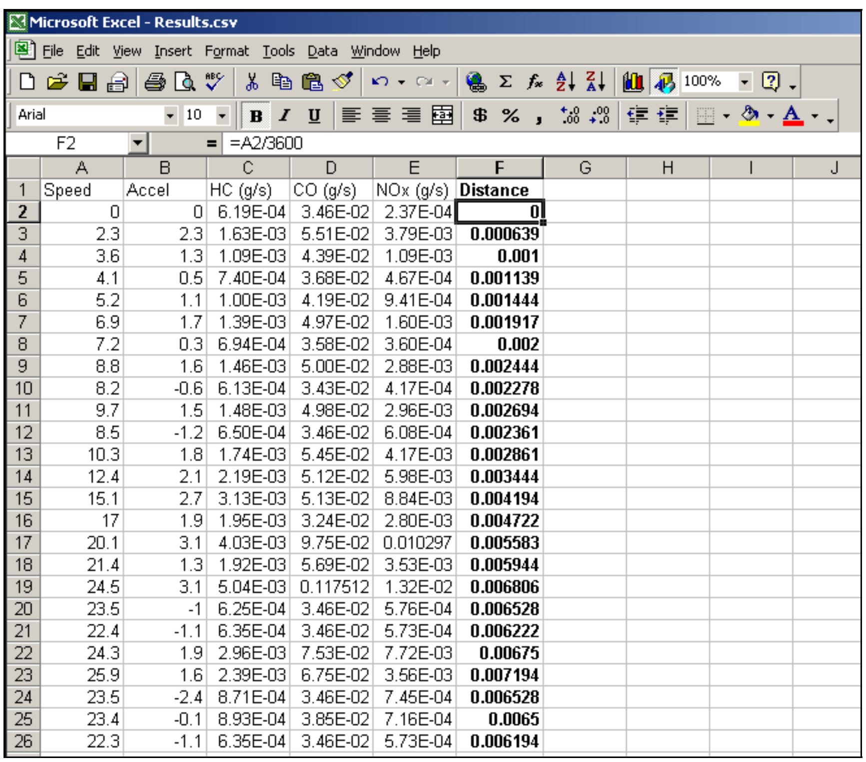
If emissions per mile are necessary (e.g., g/vehicle-mile), then the total distance must be determined. Add an additional "Distance" column to the spreadsheet, and use the following formula to calculate distance for each 1-second time interval in cells ***F2, F3, F4, etc.***:

Distance (mile) = Speed (mph) * (1 hr / 3600 seconds) * 1 second

In Excel, this corresponds to the following formulas:

=A2/3600
=A3/3600
=A4/3600, etc.

The resulting values are shown in Figure A-4.



Microsoft Excel - Results.csv

F2 = =A2/3600

	A	B	C	D	E	F	G	H	I	J
1	Speed	Accel	HC (g/s)	CO (g/s)	NOx (g/s)	**Distance**				
2	0	0	6.19E-04	3.46E-02	2.37E-04	0				
3	2.3	2.3	1.63E-03	5.51E-02	3.79E-03	**0.000639**				
4	3.6	1.3	1.09E-03	4.39E-02	1.09E-03	**0.001**				
5	4.1	0.5	7.40E-04	3.68E-02	4.67E-04	**0.001139**				
6	5.2	1.1	1.00E-03	4.19E-02	9.41E-04	**0.001444**				
7	6.9	1.7	1.39E-03	4.97E-02	1.60E-03	**0.001917**				
8	7.2	0.3	6.94E-04	3.58E-02	3.60E-04	**0.002**				
9	8.8	1.6	1.46E-03	5.00E-02	2.88E-03	**0.002444**				
10	8.2	-0.6	6.13E-04	3.43E-02	4.17E-04	**0.002278**				
11	9.7	1.5	1.48E-03	4.98E-02	2.96E-03	**0.002694**				
12	8.5	-1.2	6.50E-04	3.46E-02	6.08E-04	**0.002361**				
13	10.3	1.8	1.74E-03	5.45E-02	4.17E-03	**0.002861**				
14	12.4	2.1	2.19E-03	5.12E-02	5.98E-03	**0.003444**				
15	15.1	2.7	3.13E-03	5.13E-02	8.84E-03	**0.004194**				
16	17	1.9	1.95E-03	3.24E-02	2.80E-03	**0.004722**				
17	20.1	3.1	4.03E-03	9.75E-02	0.010297	**0.005583**				
18	21.4	1.3	1.92E-03	5.69E-02	3.53E-03	**0.005944**				
19	24.5	3.1	5.04E-03	0.117512	1.32E-02	**0.006806**				
20	23.5	-1	6.25E-04	3.46E-02	5.76E-04	**0.006528**				
21	22.4	-1.1	6.35E-04	3.46E-02	5.73E-04	**0.006222**				
22	24.3	1.9	2.96E-03	7.53E-02	7.72E-03	**0.00675**				
23	25.9	1.6	2.39E-03	6.75E-02	3.56E-03	**0.007194**				
24	23.5	-2.4	8.71E-04	3.46E-02	7.45E-04	**0.006528**				
25	23.4	-0.1	8.93E-04	3.85E-02	7.16E-04	**0.0065**				
26	22.3	-1.1	6.35E-04	3.46E-02	5.73E-04	**0.006194**				

Figure A-4. The modified **PORE_emissionfactors.xls** file

Summing the distances will provide the following result:

Total distance = 0 + 0.000639 + 0.001 + … + 0 = 1.89E-01 mile

In Excel, this corresponds to the following formula:

=sum(F2:F43)

Dividing the total emissions by total distance will provide emissions per distance for an average vehicle type:

HC: 6.76E-02 g / 1.89E-01 mile = 0.36 g/vehicle-mile
CO: 2.21 g / 1.89E-01 mile = 11.69 g/vehicle-mile
NOx: 1.18E-01 g / 1.89E-01 mile = 0.62 g/vehicle-mile

In Excel, this corresponds to the following formulas:

=sum(C2:C43)/(sum(F2:F43))
=sum(D2:D43)/(sum(F2:F43))
=sum(D2:D43)/(sum(F2:F43))

Calculating the Emissions Inventory Thus far, complete, representative emission factors have been calculated, in units of g/vehicle-mile. In order to calculate a complete, representative emissions inventory, the emission factors must be multiplied by the representative, park-specific vehicle miles traveled (VMT) and the representative park-specific traffic count.

- ***Representative Vehicle Miles Traveled*** A VMT figure must be calculated for each separate trip length, in miles. The most representative trip length may be the average length of all vehicle trips measured. In its calculation of representative VMT for different trip lengths in each California National Park, the Volpe Center randomly pared individual smaller trips' one-second speed data end-to-end until it had a longer total trip (see companion technical reports for the California parks). For example, for a 3-hour trip, 10,800 seconds' worth of speed data, in mph, were randomly combined to form the larger trip. The average speed, in units of mph, was found for these 10,800 pieces of speed data. Multiplying this average speed by three hours gave the VMT figure, in miles, traveled over the course of that three hours. Suppose the average trip length for a small park is 90 minutes, and the average speed is 24.3 mph. Since 90 minutes is actually 1.5 hours, the VMT is 24.3 mph x 1.5 hours = 36.5 miles. The representative VMT for a trip of 90 minutes is 36.5 miles.

- ***Representative Traffic Count*** A tabulation of all traffic count data for a given number of days yields a total traffic count figure for a park. The Volpe Center counted traffic for two weekdays and two weekend days in each California National Park. The actual traffic count data can be extrapolated to fit a larger or smaller time period. For example, the Volpe Center wanted a traffic count for a representative week in each park, so it extrapolated the four days out to seven days using the following formula:

Representative weekly traffic count =
(2 weekdays traffic count)*2.5 + (2 weekend days traffic count)

This representative weekly traffic count assumes that each vehicle traveled for the amount of time, miles, and at the speed found as part of the calculation of the representative VMT.

- ***Representative Emissions Inventory*** Once the representative VMT and traffic count are found, a park-specific emissions inventory can be calculated. Simply multiply the total emission factor for a given pollutant, in g/vehicle-mile, by the VMT and by the traffic count, and the resulting emissions, in g, will give the user an idea of the emissions over a representative time period in the park being measured. The representative emissions inventory for CO, HC, and NOx, if calculated in the Excel spreadsheet pictured in Figure A-4, should utilize the following formulas:

=(sum(C2:C43)/(sum(F2:F43)))*(cell containing VMT)*(cell containing Traffic Count)
=sum(D2:D43)/(sum(F2:F43))* (cell containing VMT)*(cell containing Traffic Count)
=sum(D2:D43)/(sum(F2:F43))* (cell containing VMT)*(cell containing Traffic Count)

Appendix B: Vehicle Count Logsheet

VEHICLE COUNT LOGSHEET																			
Observer Name:									Date:				Park Entrance:						
Hour1:																			
Hour2:																			
Hour3:																			
Hour4:																			
Hour5:																			
Hour6:																			
Hour7:																			
Hour8:																			

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13. SUPPLEMENTARY NOTES
This Visitor Vehicle Emissions Study was made possible in part by a grant from the National Park Foundation through the generous support of the Ford Motor Company, A Proud Partner of America's National Parks. This report is part of a series of reports which describes measurements at Yosemite National Park, Joshua Tree National Park, and Pt. Reyes National Seashore and culminates in a comparison of the data measured and air quality results found at the three California parks.

14. ABSTRACT (Maximum 200 words)

The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center), Environmental Measurement and Modeling Division, provided technical support to the National Parks Foundation as a part of a National Park Service (NPS) project to evaluate vehicular emissions in the national parks. A Visitor Vehicular Emissions Study was performed in three California National Parks between August 2002 and April 2003 – Yosemite National Park, Joshua Tree National Park, and Point Reyes National Seashore – in order to collect traffic count, vehicle tracking, meteorological, Inspection and Maintenance Program, and fuel program data. This data was processed through the Environmental Protection Agency's (EPA) MOBILE6.2 modeling software to produce park-specific emission factors, and weekly traffic count data was used with these emission factors to produce a weekly emissions inventory for each park. Alternative methods involving modal emissions models were also investigated. This summary report presents the Visitor Vehicle Emissions Study results in a concise format and conveys, in simplified language, the recommendations of the Volpe Center for future related studies. These results and recommendations are explained in greater detail in the companion Volpe Center report, "Visitor Vehicle Emissions Study: Comparison of Traffic Data at Three California National Parks" and three companion technical reports produced for each of the California parks.

15. SUBJECT TERMS

national parks, emissions, emissions inventory, MOBILE6, traffic impact, National Park Service, CMEM, modal, modal emissions, Point Reyes, Yosemite, Joshua Tree

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NONE	NONE	NONE			(617) 494-6341

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS – WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup ©	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS – WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

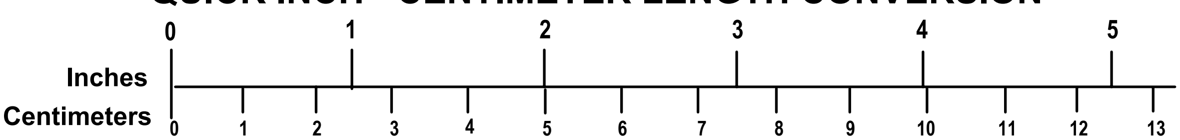
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our parks and historic 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 territories under U.S. administration.

NPS D-2113 / January 2005