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

Visitor Vehicle Emissions Study
Comparison of Traffic Data at Three California National Parks
Final Report

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EXECUTIVE SUMMARY

As part of a National Park Service (NPS) project to evaluate visitor vehicular emissions in the National Parks, a field study was performed from August 2002 to April 2003. The study was a joint effort between the NPS, the National Park Foundation, and the Volpe National Transportation Systems Center's Environmental Measurement and Modeling Division (Volpe Center). Three parks were studied: Point Reyes National Seashore, Joshua Tree National Park, and Yosemite National Park. This report compares the vehicular traffic and speed distribution data from each California park. Appendix A presents a user's guide describing how to model additional parks using a simplified modal emissions inventory meta-model. Appendix B presents an example vehicle count logsheet, and Appendix C presents a description of the Volpe Center's GPS system for vehicle speed sampling.

The Volpe Center collected vehicular traffic data over a period of four days[1] in each park. The measured data included vehicle counts, vehicle types (derived from vehicle registration records), and speed profiling (car chase) activities. The data were processed to obtain the necessary inputs for vehicular emissions modeling. One of the key data processing activities involved the development of representative driving cycles from the car chase data.

Representative vehicle distributions from Yosemite, Joshua Tree, and Pt. Reyes are compared to each other and the MOBILE6 default vehicle distribution in order to determine whether vehicle distributions in different parks are significantly different from each other and/or the MOBILE6 default. Representative driving cycles, or speed distributions, from the three parks are also compared to each other and the Federal Test Procedure (FTP) in order to determine whether driving cycles in different parks are significantly different from each other and the MOBILE6 default.

In Appendix A, instructions are presented on how park personnel with limited technical experience might construct emissions inventories in other parks. This simplified approach utilizes a CMEM-based Meta-Model described in Appendix A and is meant to guide the user through data collection and a simplified modeling process with minimal technical detail. A more detailed approach to measurement and modeling is presented in companion technical reports written up for each of the three California parks which may help supplement the simplified approach.

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. The sole purpose of the simplified approach is to provide park personnel with a useful emissions inventory tool to use in the generation of a generic park vehicular emissions inventory without committing the funding and time necessary to perform a more detailed measurement and analysis.

[1] Two weekdays and two weekend days.

1 INTRODUCTION

As part of a National Park Service (NPS) project to evaluate vehicular emissions in the National Parks, a visitor vehicle emissions study was conducted for Yosemite National Park, Joshua Tree National Park, and Point Reyes National Seashore. This study was a joint effort between the NPS, the National Park Foundation (NPF), and the Volpe National Transportation Systems Center's Environmental Measurement and Modeling Division (Volpe Center). The goal of this study was two-fold: (1) Develop a park-specific baseline vehicular emissions inventory of carbon monoxide (CO), the volatile organic compound (VOC) category of hydrocarbons (HC), and nitrogen oxides (NOx); and (2) develop a simplified methodology to produce vehicular emissions inventories for varying visitor traffic scenarios.

The development of the emissions inventories required the collection of three key datasets concerning visitor vehicles: (1) vehicle counts; (2) vehicle types; and (3) driving patterns within the park. These datasets were used with the Environmental Protection Agency's (EPA's) MOBILE6 (Version 6.2) vehicular emissions model to produce the baseline inventories. In addition to MOBILE6, alternative methods involving modal emissions models were used to generate refined 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[2] using only the speed and acceleration variables in CMEM was developed to simplify the use of CMEM.

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.

1.1 Objective

This summary report compares the data from the three California national parks measured and presents a simplified methodology for performing a generic emissions inventory on other parks. The specific objectives of this report include: 1. Compare the vehicle distributions from the three parks to determine whether vehicle distributions in different parks are significantly different from each other; 2. Compare the speed distributions from the three parks to determine whether driving cycles in different parks are significantly different from each other; and 3. Provide park personnel with a useful simplified emissions inventory tool to use in the generation of a generic park vehicular emissions inventory without committing the funding and time necessary to perform a more detailed measurement and analysis to be used for park planning purposes.

[2] 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.

2 Comparison of Vehicle Type Datasets

Detailed traffic counting at Yosemite National Park, Joshua Tree National Park, and Pt. Reyes National Seashore yielded vehicle distributions for each park. For detailed information on how the vehicle type distribution data was collected, see the companion technical reports produced for each of the three California parks.

The vehicle distributions discussed in this section divide all processed park vehicles into 26 vehicle categories used in CMEM, described in Table 1.

Table 1. CMEM's 26 vehicle categories.

Category #	Vehicle Technology Category
	Normal Emitting Cars
1	No Catalyst
2	2-way Catalyst
3	3-way Catalyst, Carbureted
4	3-way Catalyst, FI, >50K miles, low power/weight
5	3-way Catalyst, FI, >50K miles, high power/weight
6	3-way Catalyst, FI, <50K miles, low power/weight
7	3-way Catalyst, FI, <50K miles, high power/weight
8	Tier 1, >50K miles, low power/weight
9	Tier 1, >50K miles, high power/weight
10	Tier 1, <50K miles, low power/weight
11	Tier 1, <50K miles, high power/weight
24	Tier 1, >100K miles
	Normal Emitting Trucks
12	Pre-1979 (<=8500 GVW)
13	1979 to 1983 (<=8500 GVW)
14	1984 to 1987 (<=8500 GVW)
15	1988 to 1993, <=3750 LVW
16	1988 to 1993, >3750 LVW
17	Tier 1 LDT2/3 (3751-5750 LVW or Alt. LVW)
18	Tier 1 LDT4 (6001-8500 GVW, >5750 Alt. LVW)
25	Gasoline-powered, LDT (> 8500 GVW)
40 *	Diesel-powered, LDT (> 8500 GVW)
	High Emitting Vehicles
19	Runs lean
20	Runs rich
21	Misfire
22	Bad catalyst
23	Runs very rich

*What CMEM calls Category #40, this paper will hereafter refer to as Category #26.

Vehicle type distributions for each park were also developed using the 16 MOBILE6 vehicle categories. Because the recommendations for a simplified methodology are based on the use of the CMEM Meta-Model, the vehicle type distribution comparisons were conducted using CMEM vehicle types rather than MOBILE6 vehicle types.

2.1 Yosemite National Park

The representative weekly vehicle distribution for Yosemite National Park is presented in Figure 1.

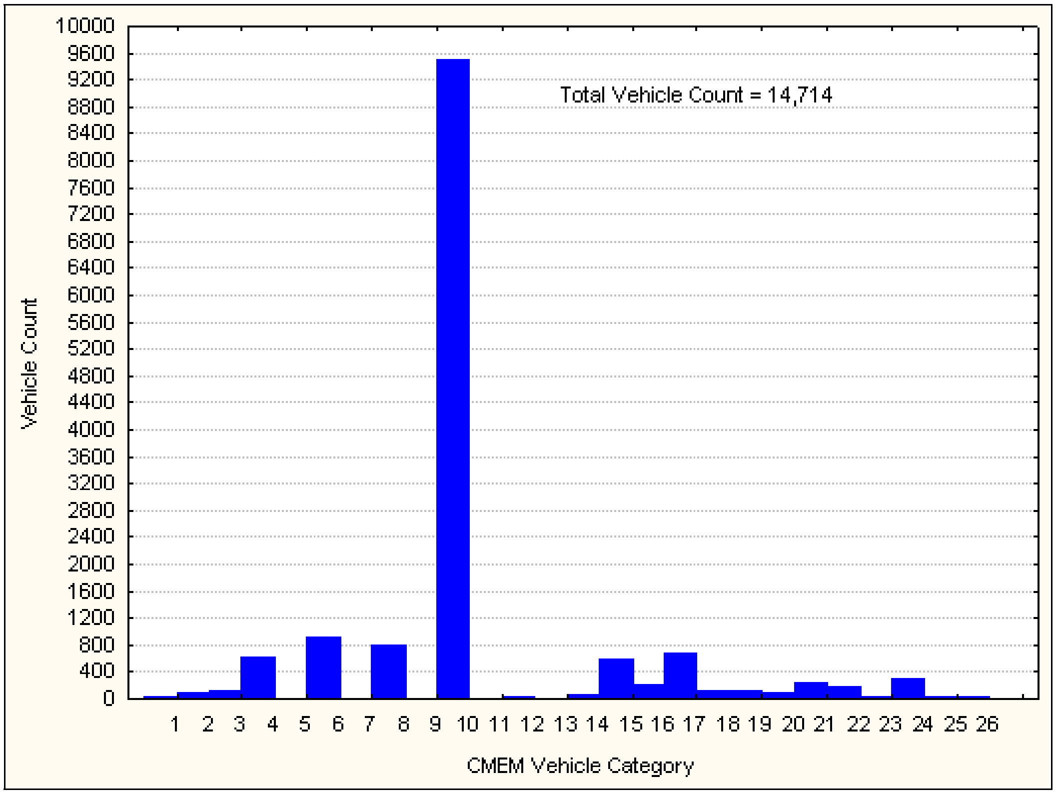


Figure 1. Weekly distribution of Yosemite vehicles among CMEM vehicle categories

This distribution is dominated by vehicle category #10 – normal emitting Tier 1 cars with under 50,000 miles, low in power and weight – which has a vehicle count of 9,488, 64.5% of the total vehicle count and more than a power of 10 higher than the next most common vehicle category, #6 – normal emitting 3-way catalyst fuel injection cars with over 50,000 miles, low in power and weight – which has a vehicle count of 926, 6.3% of the total vehicle count.

2.2 Joshua Tree National Park

The representative weekly vehicle distribution for Joshua Tree National Park is presented in Figure 2.

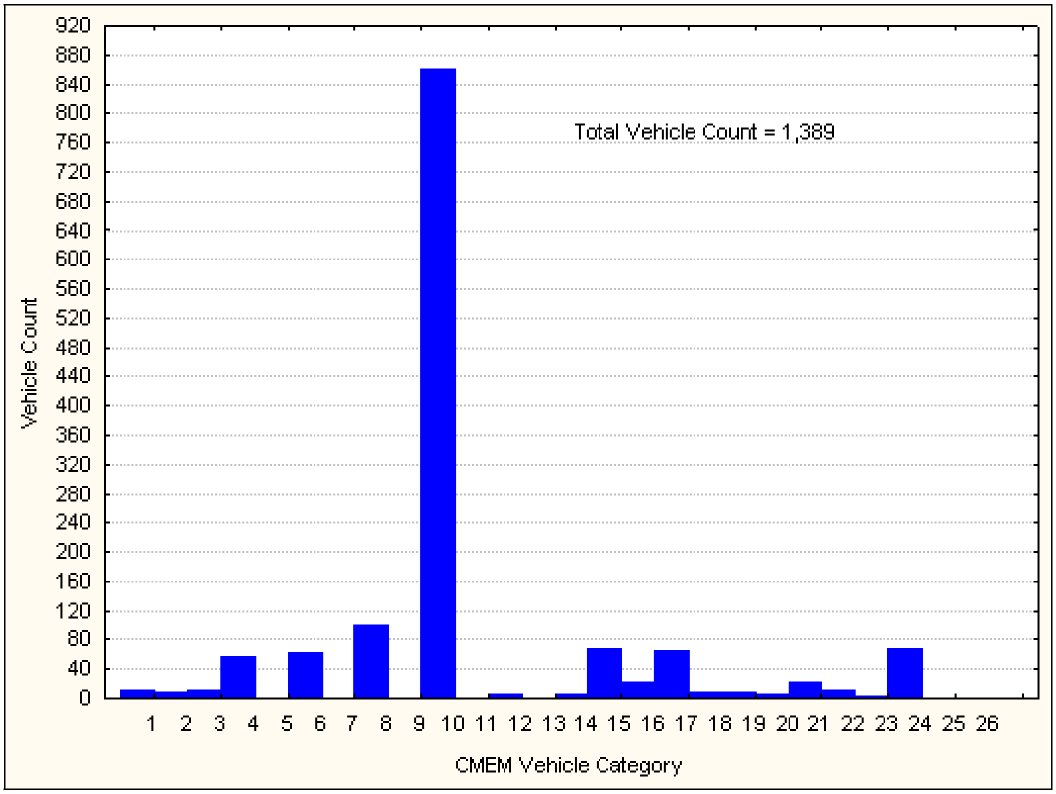


Figure 2. Weekly distribution of Joshua Tree vehicles among CMEM vehicle categories

The Joshua Tree distribution is also dominated by vehicle category #10, which has a vehicle count of 859, 61.8% of the total vehicle count and almost a power of 10 higher than the next most common vehicle category, #8 – normal emitting Tier 1 cars with over 50,000 miles, low in power and weight – which has a vehicle count of 99, 7.1% of the total vehicle count.

2.3 Point Reyes National Seashore

The representative weekly vehicle distribution for Pt. Reyes National Seashore is presented in Figure 3.

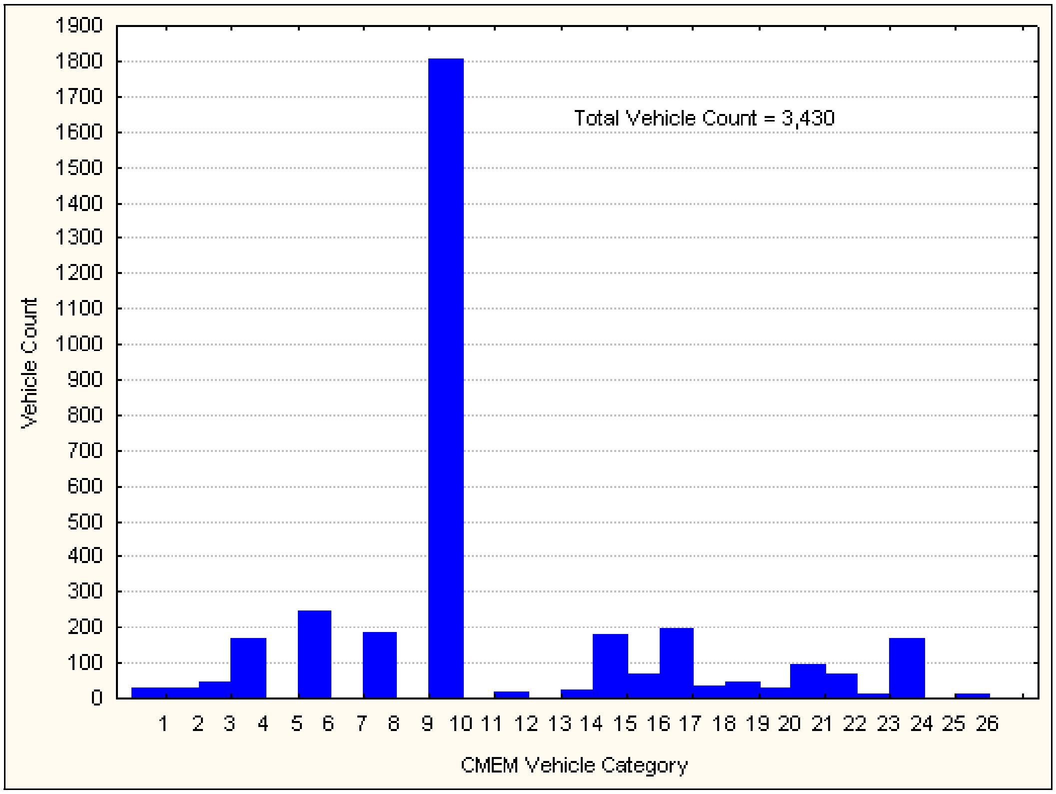


Figure 3. Weekly distribution of Pt. Reyes vehicles among CMEM vehicle categories

The Pt. Reyes distribution is also dominated by vehicle category #10, which has a vehicle count of 1,804, 52.6% of the total vehicle count and almost a power of 10 higher than the next most common vehicle category, #6, which has a vehicle count of 245, 7.1% of the total vehicle count.

2.4 Default Distribution of MOBILE6 Vehicles

The default vehicle distribution in MOBILE6 consists of 16 vehicle categories. For comparative purposes, the 16 MOBILE6 vehicle categories have been converted into 26 CMEM vehicle categories. This default distribution of MOBILE6 vehicle types among the CMEM vehicle categories is presented in Figure 4.

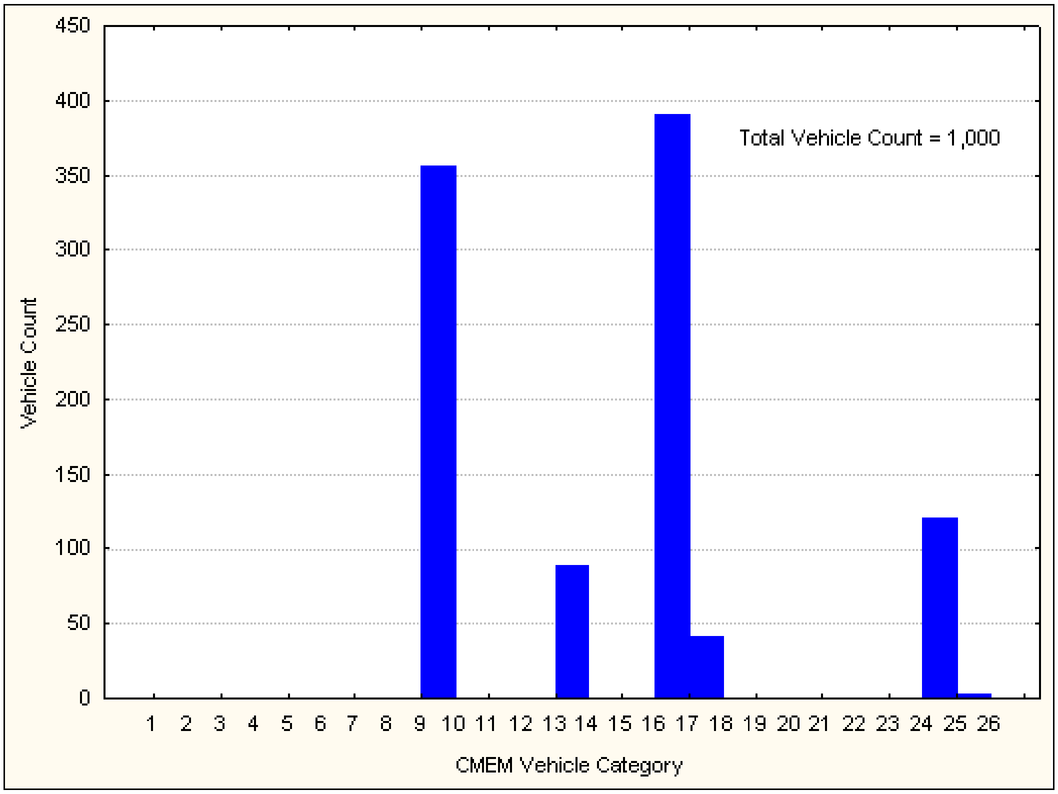


Figure 4. Default distribution of MOBILE6 vehicles among CMEM vehicle categories

The MOBILE6 default distribution is dominated by vehicle categories #17, that is, light trucks, and #10, that is, passenger cars. This distribution is markedly different from the distributions in the California parks, which were dominated only by vehicle category #10, that is, passenger cars.

2.5 Kolmogorov-Smirnov Test of Vehicle Type Distributions

A Kolmogorov-Smirnov test was used to compare the distribution characteristics of the vehicle type distribution data from the three California national parks and the default MOBILE6 distribution. The Kolmogorov-Smirnov one-sample test for normality is based on the maximum difference between the sample cumulative distribution and the hypothesized cumulative distribution and produces three main statistics, D, p, and Lilliefors p. A commercial software package, STATISTICA, was used to perform these tests [Statsoft].

If the D (difference) statistic is significant, then the hypothesis that the respective distribution is normal should be rejected.

Two probability (significance) values will be reported for each Kolmogorov-Smirnov D statistic: The first, p, is based on the probability values as tabulated by Massey [Statsoft]; those probability values pertain to cases when the mean and standard deviation of the normal distribution are known a-priori and not estimated from the data. However, these parameters are typically computed from the actual data. In this case, the test for normality involves a complex conditional hypothesis ("how likely is it to obtain a D statistic of this magnitude or greater, contingent upon the mean and standard deviation computed from the data"), and the Lilliefors p statistic should be interpreted in determining whether the Kolmogorov-Smirnov D statistic is significant [Statsoft].

The Kolmogorov-Smirnov test was run on the three California parks and default MOBILE6 vehicle type datasets, and distribution characteristics of the data are presented in Table 2.

Table 2. A comparison of the Kolmogorov-Smirnov test characteristics for vehicle types

Dataset	N	Confidence -95%	Confidence +95%	p	Lilliefors-p	Mean	Standard Deviation	Variance	D
Yosemite Vehicle Type Distribution	14714	10.71106	10.84569	< 0.0100	< 0.00999999978	10.7783743	4.1659346	17.35501	0.392308358
Joshua Tree Vehicle Type Distribution	1389	10.85014	11.33848	< 0.0100	< 0.00999999978	11.0943125	4.63887882	21.51920	0.380861935
Pt. Reyes Vehicle Type Distribution	3430	11.32247	11.67229	< 0.0100	< 0.00999999978	11.4973761	5.22471069	27.29760	0.3393194
MOBILE6 Vehicle Type Distribution	1000	14.96987	15.56813	< 0.0100	< 0.00999999978	15.2690000	4.82036	23.23587	0.218818858

California Parks The D statistics for the park distributions, all between 0.3393194 and 0.392308358, have an arithmetic mean of 0.37083 and a standard deviation of 0.022766, which is 6.1% of the mean. This statistic and the very similar shape of the three distributions show that the vehicle type datasets from the three California national parks are similar.

California Parks and MOBILE6 Default When the MOBILE6 statistics are factored in, the D statistics have an arithmetic mean of 0.332827 and a standard deviation of 0.068712071, which is 20.6% of the mean. Since including the MOBILE6 distribution increases the variance of the distribution statistics, it may be concluded that the MOBILE6 default vehicle type distribution is not similar to the California park vehicle type distribution. This dissimilarity is mainly caused by the fact that the MOBILE6 distribution is dominated by both light trucks and passenger cars, whereas the California parks distributions are clearly dominated by passenger cars alone.

Since the vehicle type distributions in the three California National Parks are indeed similar, it is recommended that modelers use an average vehicle type distribution, built by averaging the distributions from the three California National Parks together, in modeling other California National Parks. This average vehicle type distribution is presented in Table 3.

Table 3. Average CMEM vehicle type distribution.

CMEM Vehicle Category	Percentage (%)
1	0.59
2	0.58
3	0.92
4	4.34
5	0.00
6	5.94
7	0.00
8	5.96
9	0.00
10	59.63
11	0.00
12	0.35
13	0.06
14	0.43
15	4.68
16	1.59
17	4.96
18	0.80
19	0.89
20	0.57
21	2.02
22	1.30
23	0.22
24	3.90
25	0.07
26	0.20

More studies may be necessary before it can be recommended that this average vehicle type distribution be used for all US National Parks.

The average vehicle type distribution shown in Table 3 was used as the basis in developing the CMEM Meta-Model. Details concerning the development of this simplified model are provided in each of the companion technical reports for the three California parks.

3 Comparison of Speed Datasets

Vehicle profiling at Yosemite National Park, Joshua Tree National Park, and Pt. Reyes National Seashore yielded representative vehicle speed distributions for each park. For detailed information on how the vehicle speed distribution data was collected, see the companion technical report produced for each of the California parks. For these comparisons, the speed distributions were based on 3-hour driving cycles.

3.1 Yosemite National Park

The representative speed distribution for Yosemite National Park is presented in Figure 5.

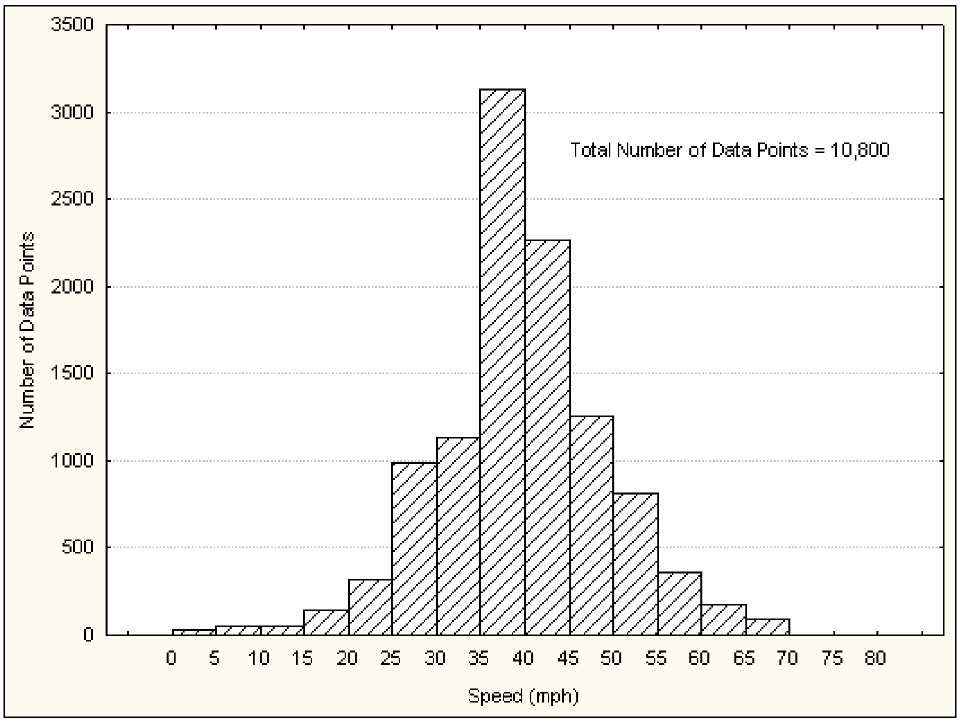


Figure 5. Distribution of speeds at Yosemite

This distribution is dominated by speeds ranging from 30 to 35 mph. There are very few speeds between 0 and 5 mph for two reasons: 1. The great size of Yosemite National Park calls for longer drive times in getting to any attraction; and 2. Due to intermittent GPS reception in the Park, speed data were recorded almost exclusively by the voice of the chase-car operator on a DAT recorder, and this resulted in a limited capture of idle mode.

3.2 Joshua Tree National Park

The representative speed distribution for Joshua Tree National Park is presented in Figure 6.

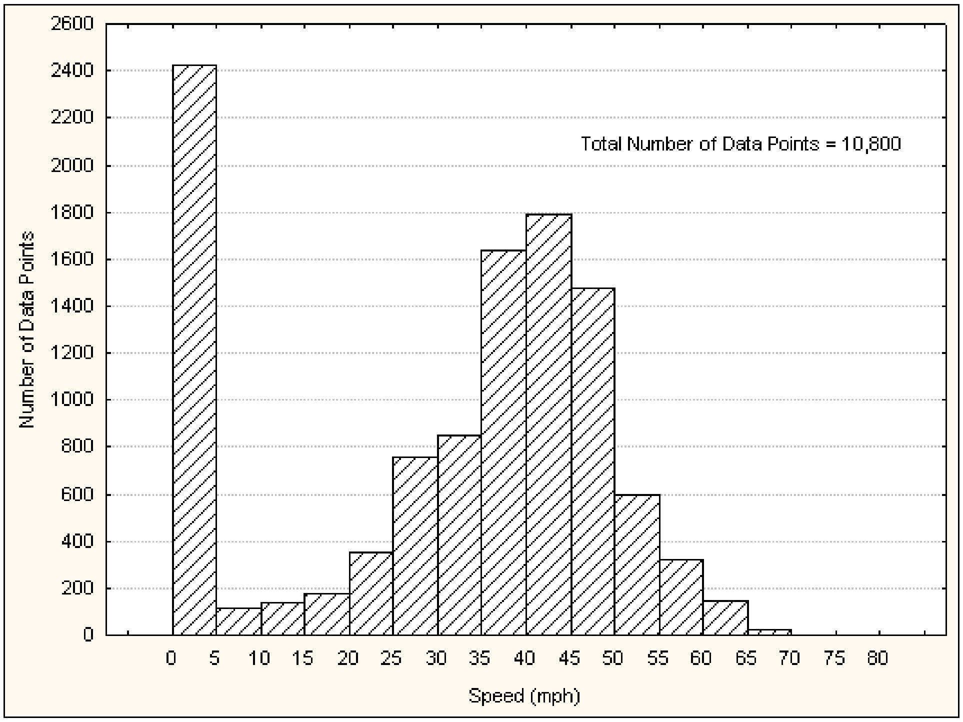


Figure 6. Distribution of speeds at Joshua Tree

Since Joshua Tree is not a very large park, drive times are shorter, and visitors spend more time stopped by the roadside at attractions. Also, GPS reception in the park was very good, and speed data were recorded automatically on a laptop, making it much easier to log idle time. This resulted in a distribution dominated by speeds between 0 and 5 mph. The next most common speed range was 40 to 45 mph.

3.3 Pt. Reyes National Seashore

The representative speed distribution for Pt. Reyes National Seashore is presented in Figure 7.

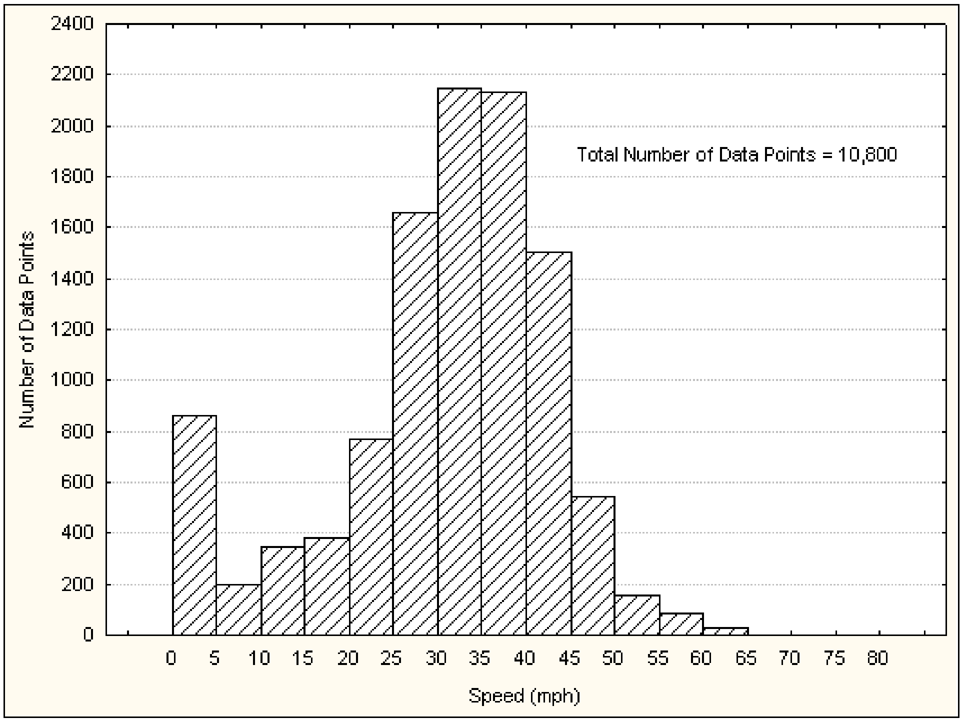


Figure 7. Distribution of speeds at Pt. Reyes

Pt. Reyes is not a very large park either, but distance between attractions is a little further, resulting in longer drive times and less, shorter stops than in Joshua Tree. GPS reception in Pt. Reyes was good but not so good as in Joshua Tree. The dominant speed range was 30 to 35 mph, followed very closely by the 40 to 45 mph range.

3.4 Kolmogorov-Smirnov Test of Speed Distributions

In comparing the speed distributions, the representative data from Yosemite was thrown out due to the intermittent GPS reception mentioned in Section 3.1. The Kolmogorov-Smirnov test was run on the Joshua Tree and Pt. Reyes speed datasets, and distribution characteristics of the data are presented in Table 4.

Table 4. A comparison of the Kolmogorov-Smirnov test characteristics for speeds

Dataset	N	Confidence -95%	Confidence +95%	p	Lilliefors-p	Mean	Standard Deviation	Variance	D
Joshua Tree Speed Distribution	10800	30.25866	30.96864	< 0.0100	< 0.00999999978	30.61365	18.82264	354.2918	0.15882
Pt. Reyes Speed Distribution	10800	30.34841	30.82686	< 0.0100	< 0.00999999978	30.58763	12.68436	160.8929	0.10609

The D statistics have an arithmetic mean of 0.132455 and a standard deviation of 0.026365, which is 19.9% of the mean. These statistics and the large differences among the standard deviations and variances for the two parks' data show that the speed datasets from Joshua Tree and Pt. Reyes differ considerably from one another.

4 Comparison of Acceleration Datasets

Vehicle profiling at Yosemite National Park, Joshua Tree National Park, and Pt. Reyes National Seashore yielded representative vehicle speed distributions for each park. The differences in these speeds on a second-by-second basis yielded one-second acceleration data. For detailed information on how vehicle speed data was collected and acceleration data calculated, see the companion technical report produced for each of the three California parks. Similar to the speed distributions, the acceleration distributions were based on 3-hour driving cycles.

4.1 Yosemite National Park

The representative acceleration distribution for Yosemite National Park is presented in Figure 8.

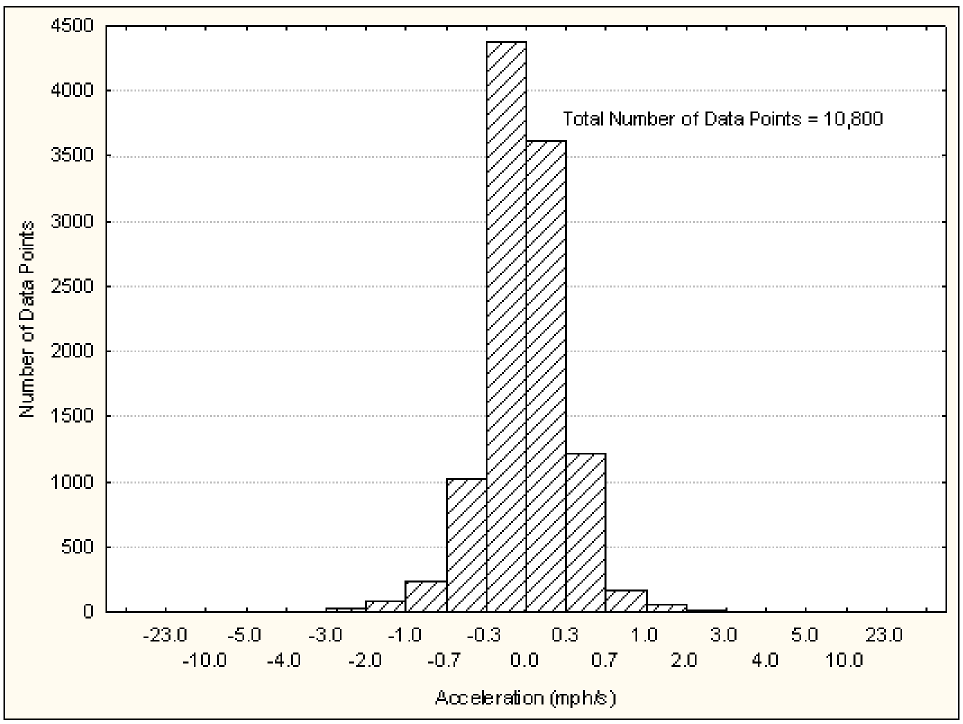


Figure 8. 2-dimensional distribution of accelerations at Yosemite

This distribution consists almost entirely of accelerations ranging from 0 mph/s to ±0.7 mph/s. There are very few accelerations greater than ±0.7 mph/s due to intermittent GPS reception in the Park: Acceleration data were generated from speed data recorded almost exclusively by the voice of the chase-car operator on a DAT recorder as he viewed the chase-car speedometer, and this limited the capture of consistent, accurate accelerations. Similar to the Yosemite speed data, the derived accelerations were deemed unreliable for these comparisons. Figure 9 shows the accelerations distributed in relation to the speeds in an overhead contour graphic.

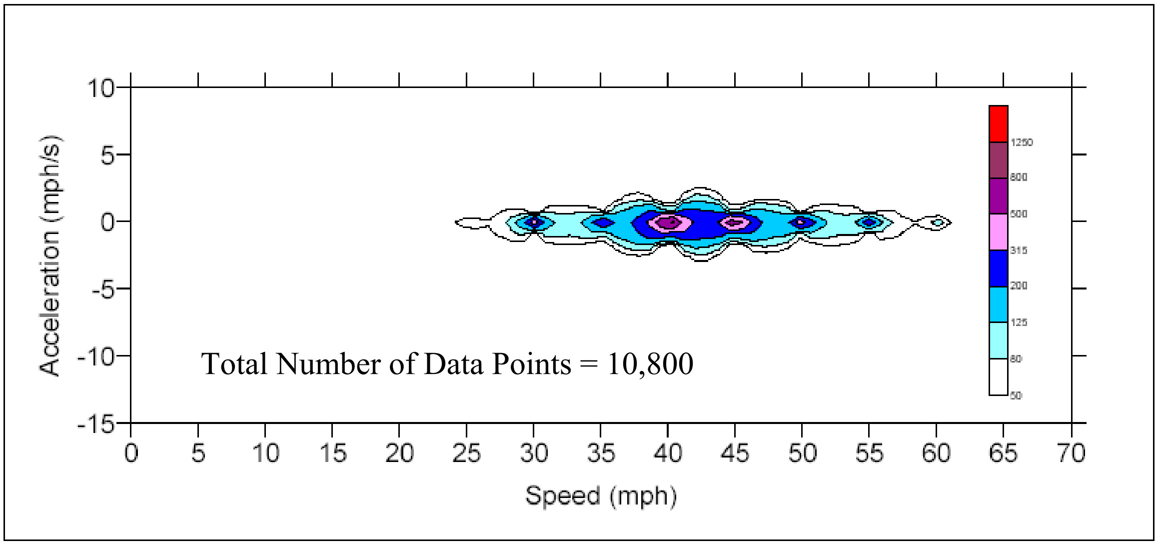


Figure 9. Yosemite speed and acceleration contours

4.2 Joshua Tree National Park

The representative acceleration distribution for Joshua Tree National Park is presented in Figure 10.

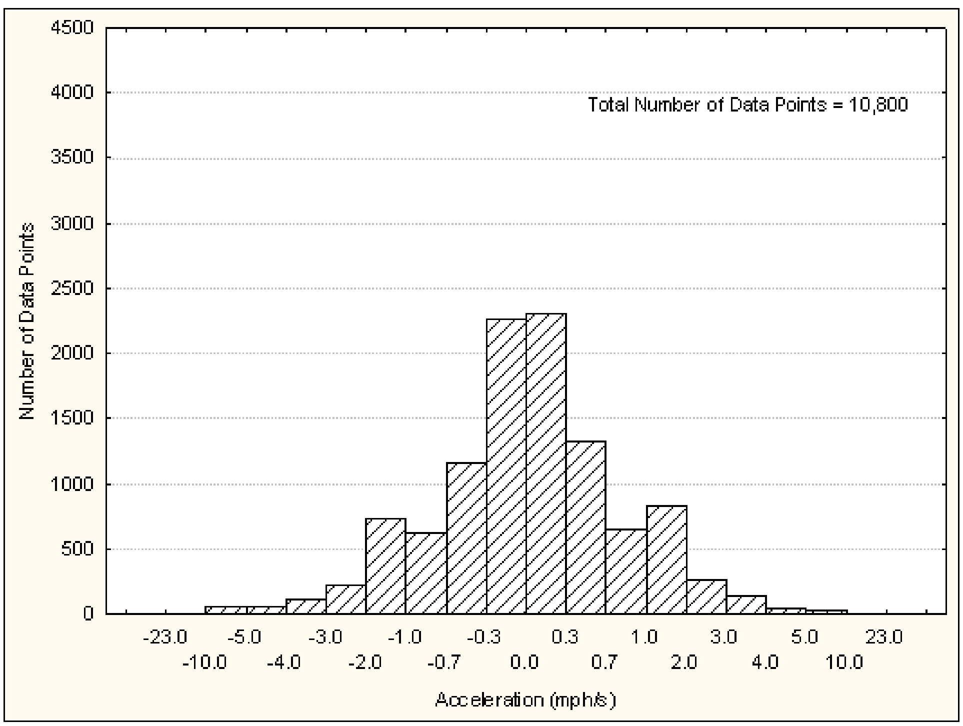


Figure 10. Distribution of accelerations at Joshua Tree

The Joshua Tree acceleration distribution is much flatter than the Yosemite distribution, with accelerations ranging out to ±10.0 mph/s. Since GPS reception in Joshua Tree was very good, speed data were recorded automatically on a laptop, making it much easier to calculate consistent, accurate accelerations. Figure 11 shows the accelerations distributed in relation to the speeds in an overhead contour graphic.

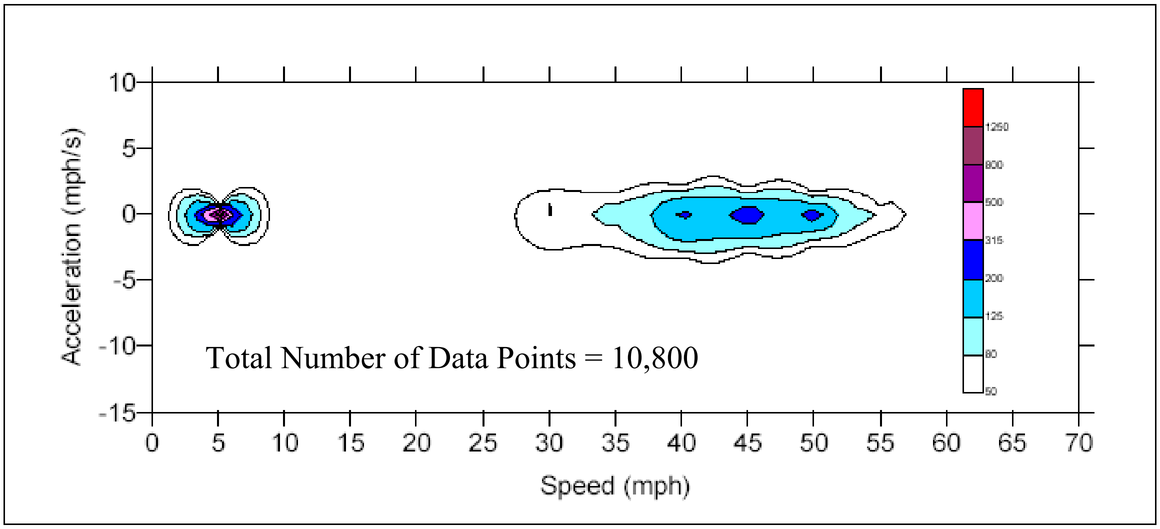


Figure 11. Joshua Tree speed and acceleration contours

4.3 Point Reyes National Seashore

The representative acceleration distribution for Pt. Reyes National Seashore is presented in Figure 12.

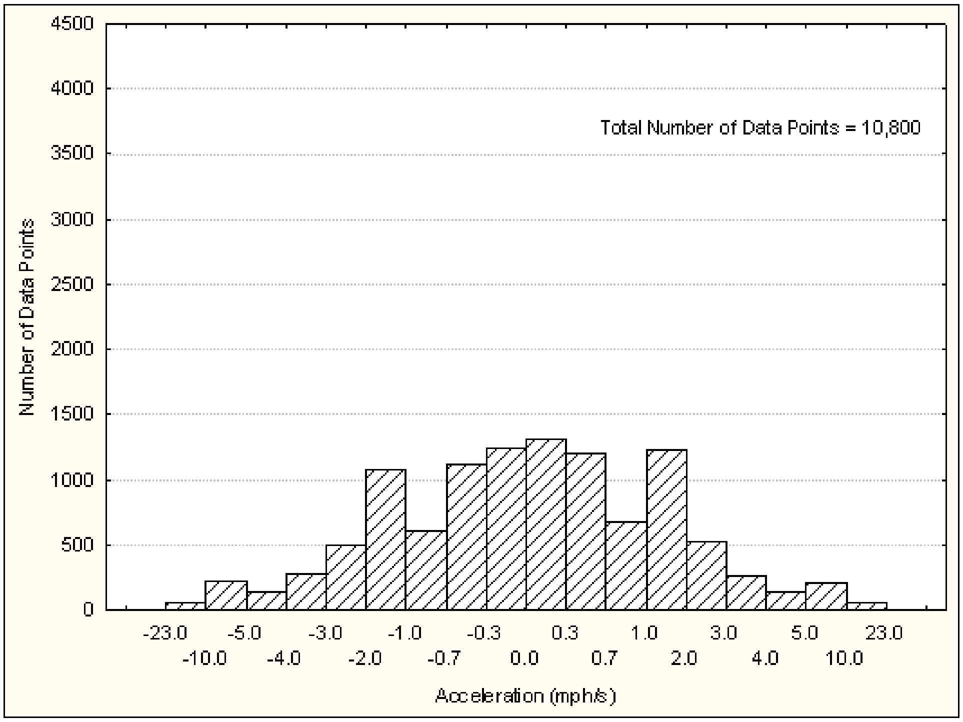


Figure 12. Distribution of accelerations at Pt. Reyes

The Pt. Reyes acceleration distribution is very flat, with accelerations ranging out to ±23.0 mph/s. Again, since GPS reception in Pt. Reyes was good, speed data were recorded automatically on a laptop, making it much easier to calculate consistent, accurate accelerations. Figure 13 shows the accelerations distributed in relation to the speeds in an overhead contour graphic.

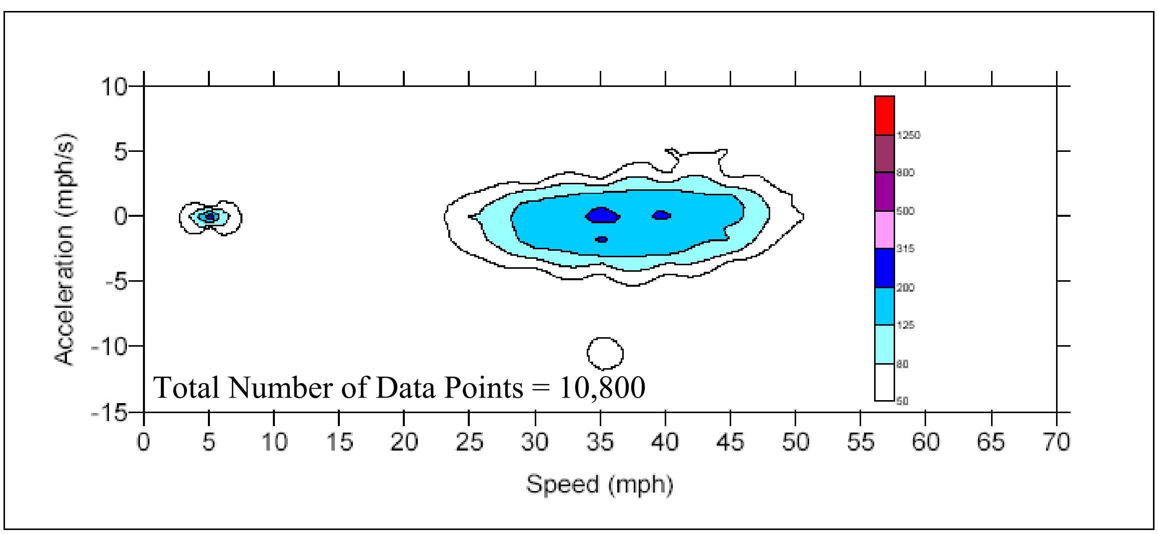


Figure 13. Pt. Reyes speed and acceleration contours

4.4 Kolmogorov-Smirnov Test of Acceleration Distributions

In comparing the acceleration distributions, the representative data from Yosemite was thrown out due to the intermittent GPS reception mentioned in Section 3.1. The Kolmogorov-Smirnov test was run on the Joshua Tree and Pt. Reyes acceleration datasets, and distribution characteristics of the data are presented in Table 5.

Table 5. A comparison of the Kolmogorov-Smirnov test characteristics for accelerations

Dataset	N	Confidence -95%	Confidence +95%	p	Lilliefors-p	Mean	Standard Deviation	Variance	D
Joshua Tree Acceleration Distribution	10800	-0.004570	0.041429	< 0.0100	< 0.00999999978	0.018429	1.219496	1.487171	0.127217682
Pt. Reyes Acceleration Distribution	10800	-0.025273	0.067111	< 0.0100	< 0.00999999978	0.020919	2.449240	5.998778	0.130134244

The D statistics, between 0.127217682 and 0.130134244, have an arithmetic mean of 0.128676 and a standard deviation of 0.001458281, which is 1.1% of the mean. The more striking statistics are the large differences among the standard deviations and variances for the two parks' data; these statistics and the very different shape of the two distributions show that the acceleration datasets from Joshua Tree and Pt. Reyes differ considerably from one another.

5 Comparison of California Park and Federal Test Procedure Datasets

MOBILE6 was developed through emissions measurements using a Federal Test Procedure (FTP) driving cycle with a length of 7.5 miles and an average speed of 19.6 mph. In this section, additional comparisons are made between the FTP speed and acceleration datasets and the Joshua Tree and Pt. Reyes speed and acceleration datasets. Since the FTP driving cycle contains 1,367 data points while the Joshua Tree and Pt. Reyes driving cycles each contain 10,800 data points, a scaling factor of 7.9 was applied to the FTP driving cycle dataset.

The FTP speed distribution is presented in Figure 14.

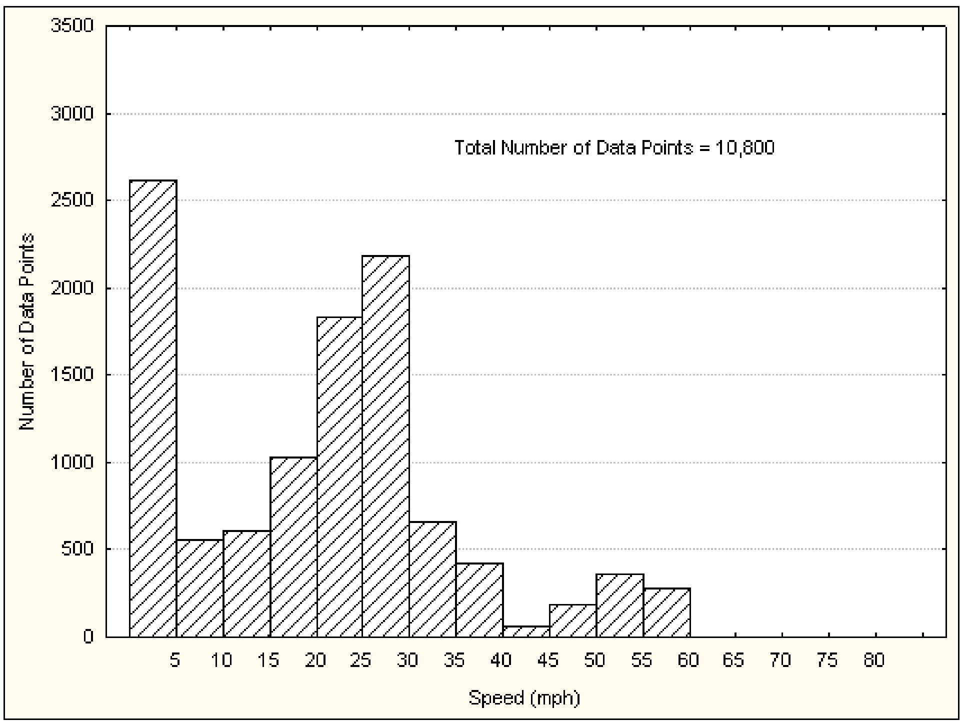


Figure 14. Distribution of FTP speeds

The dominant FTP speed range is 0 to 5 mph, followed very closely by the 25 to 30 mph range. These speeds are far slower than the dominant 40 to 45 mph speeds found in Joshua Tree and Pt. Reyes.

The FTP acceleration distribution is presented in Figure 15.

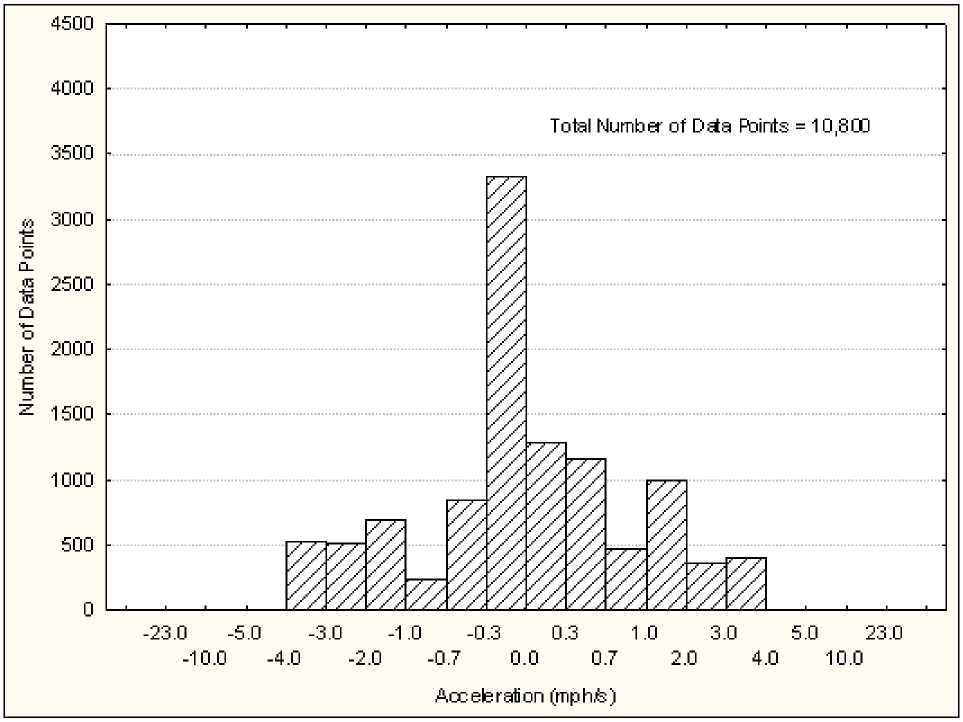


Figure 15. Distribution of FTP accelerations

The FTP acceleration distribution peaks dramatically in the –0.3 to 0.0 mph/s range, unlike the more flat distribution of Joshua Tree and Pt. Reyes accelerations. Figure 16 shows the accelerations distributed in relation to the speeds in an overhead contour graphic.

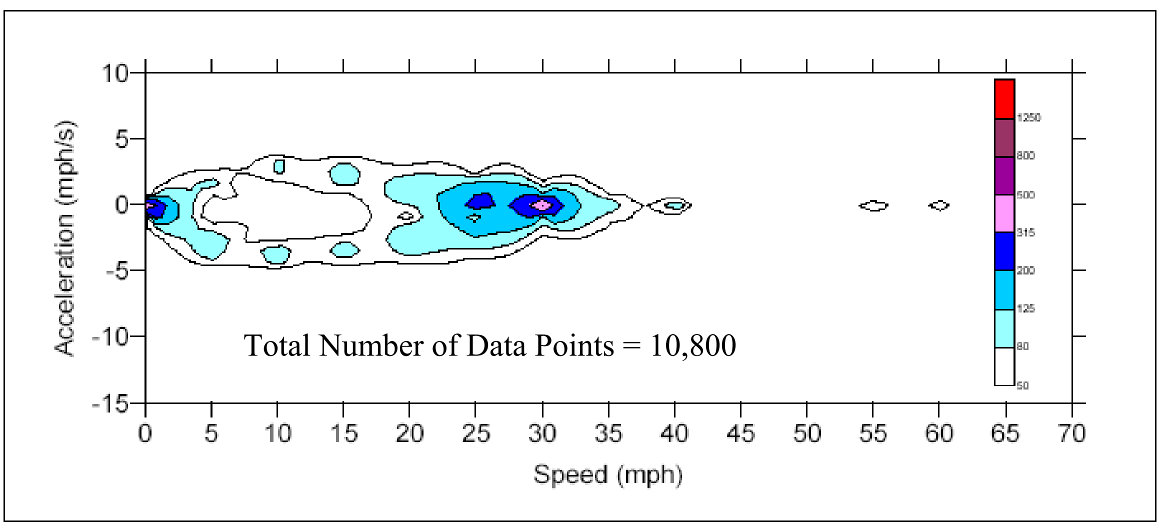


Figure 16. FTP speed and acceleration contours

The Kolmogorov-Smirnov test was run on the FTP speed and acceleration datasets, and distribution characteristics of the FTP data are compared to Joshua Tree and Pt. Reyes in Tables 6 and 7.

Table 6. A comparison of the Kolmogorov-Smirnov test characteristics for FTP speeds

Dataset	N	Confidence -95%	Confidence +95%	p	Lilliefors-p	Mean	Standard Deviation	Variance	D
FTP Speed Distribution	10800	19.63058	20.19141	< 0.0100	< 0.00999999978	19.91100	14.86861	221.0755	0.09799
Joshua Tree Speed Distribution	10800	30.25866	30.96864	< 0.0100	< 0.00999999978	30.61365	18.82264	354.2918	0.15882
Pt. Reyes Speed Distribution	10800	30.34841	30.82686	< 0.0100	< 0.00999999978	30.58763	12.68436	160.8929	0.10609

The D statistics, all between 0.09799 and 0.15882, have an arithmetic mean of 0.12097 and a standard deviation of 0.02697, which is 22.3% of the mean. This statistic, the widely varying standard deviations and variances, and the dissimilar shape of the three distributions show that the speed datasets from FTP, Joshua Tree, and Pt. Reyes are not similar.

Table 7. A comparison of the Kolmogorov-Smirnov test characteristics for FTP accelerations

Dataset	N	Confidence -95%	Confidence +95%	p	Lilliefors-p	Mean	Standard Deviation	Variance	D
FTP Acceleration Distribution	10800	-0.02310	0.02893	< 0.0100	< 0.00999999978	0.00292	1.37920	1.9022	0.15858
Joshua Tree Acceleration Distribution	10800	-0.00457	0.04143	< 0.0100	< 0.00999999978	0.01843	1.21950	1.4872	0.12722
Pt. Reyes Acceleration Distribution	10800	-0.02527	0.06711	< 0.0100	< 0.00999999978	0.02092	2.44924	5.9988	0.13013

The D statistics, all between 0.12722 and 0.15858, have an arithmetic mean of 0.13864 and a standard deviation of 0.01415, which is 10.2% of the mean. This statistic, the widely varying standard deviations and variances, and the dissimilar shape of the three distributions show that the acceleration datasets from FTP, Joshua Tree, and Pt. Reyes are not similar.

6 Conclusion

The close similarity in vehicle type distribution among the three California parks is to be expected, since any typical National Park road system would normally be visited in the vast majority by passenger automobiles. The dissimilarities in speed distribution, and, to a lesser extent, in acceleration, are also to be expected, since road layout, grade, length, width, and condition vary from park to park and require visitors to drive differently.

The similarity of the vehicle type datasets measured in three very different parks may indicate a relatively consistent vehicle type distribution across most units of the National Park System and perhaps justify the use of a single, representative, average vehicle type distribution for all California parks, as shown in Table 3, and perhaps all National Parks in emissions inventory modeling. This assumption would spare parks personnel the necessity of measuring and inputing park-specific vehicle type data and would allow the use of the CMEM Meta-Model, which utilizes internally an average vehicle type distribution drawn from the data measured in the three California parks and only requires the measurement and input of park-specific traffic count and speed data. When applying the CMEM Meta-Model to other national parks (either within or outside of California), a judgment must be made considering the similarity of the park's vehicle types to the average vehicle type distribution derived in this report. This comparison will determine whether the Meta-Model can be used.

The collection of traffic count and speed data are described in the CMEM Meta-Model User's Manual included in Appendix A. Actual examples of this data collection process are described in the companion technical reports from each of the three California parks.

7 References

Statsoft Inc. (2003). STATISTICA (data analysis software system), version 6. www.statsoft.com.

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.

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.

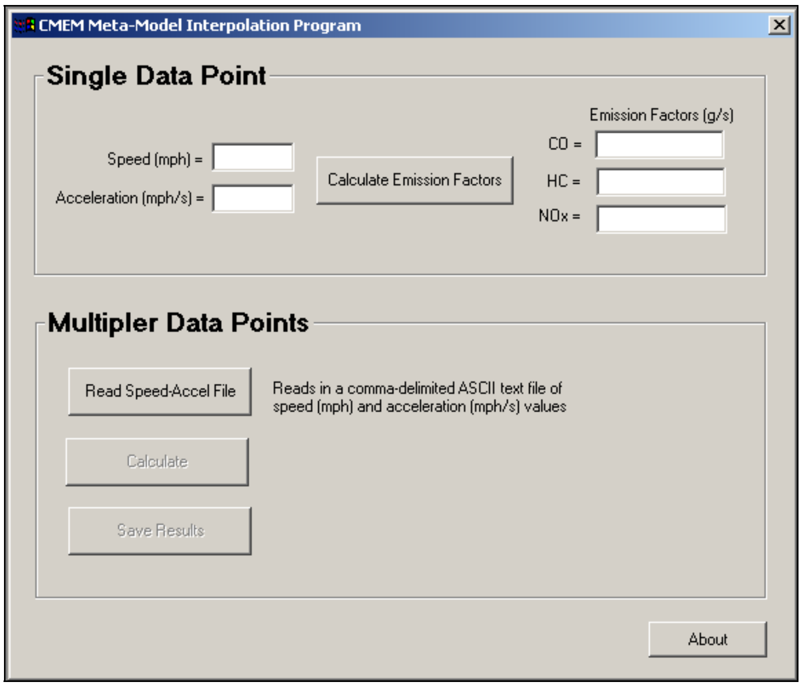


Figure A-2. Portal screen of CMEM Meta-Model

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*

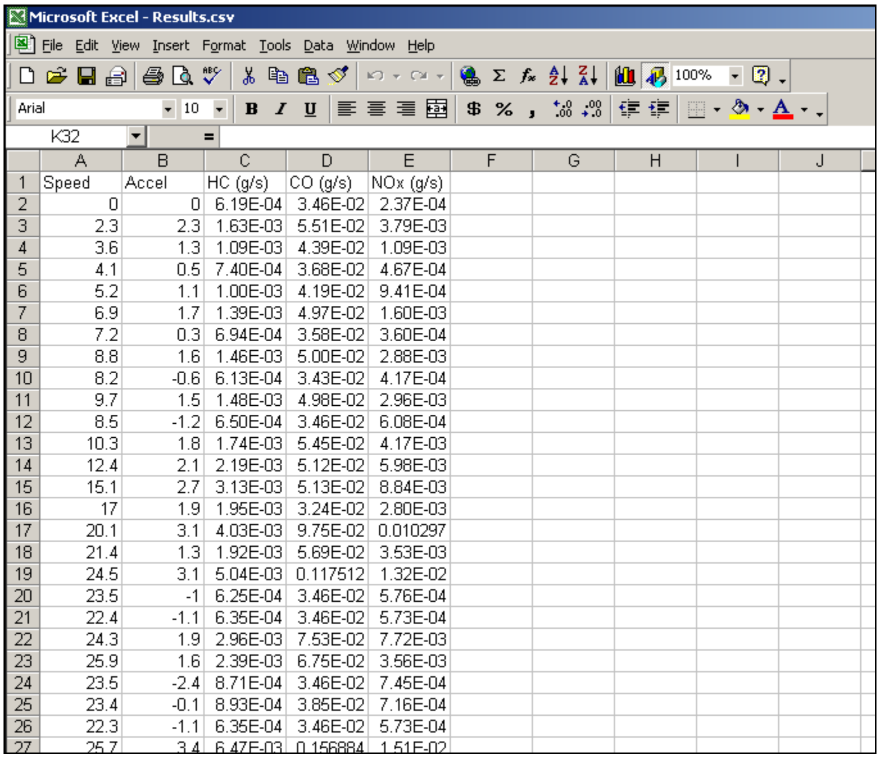
  This means that record 51* was the last record for which the interpolations were conducted. This should always equal the total number of records that were read in. The ***Calculate*** button should now be disabled and the ***Save Results*** button should be active.

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."

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

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 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)

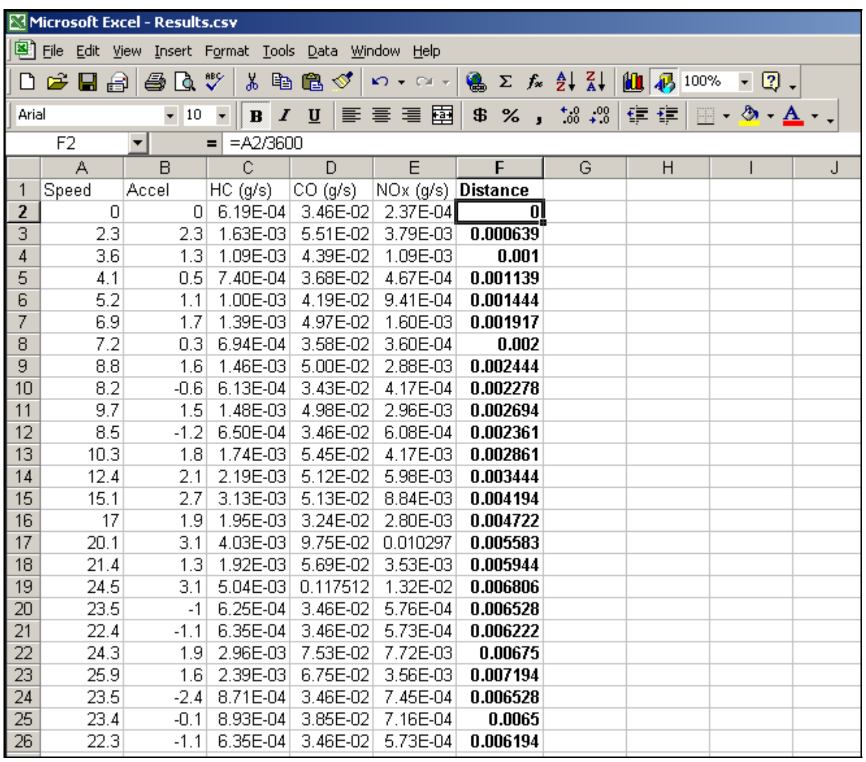
If emissions per mile are necessary (e.g., g/vehicle-mile), then the total distance must be determined. Add an additional "Distance" column to the spreadsheet, and use the following formula to calculate distance for each 1-second time interval in cells ***F2, F3, F4, etc.***:

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.



	A	B	C	D	E	F
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)

A.4 Conclusion

Because of the science behind CMEM and the Meta-Model, by definition it is expected that the CMEM Meta-Model will provide more representative emissions inventories within a National Park environment, as compared with Federally accepted tools such as MOBILE6. However, the CMEM Meta-Model is not accepted for Federal, state, or local policy or environmental decisionmaking.

If utilized and compared regularly by park personnel, CMEM Meta-Model results can serve to identify for park personnel the effects major changes in driving behavior and vehicle count are having on park emissions of CO, HC, and NOx.

Appendix B: Vehicle Count Logsheet

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

Appendix C: Use of the Volpe Center's GPS System for Vehicle Speed Sampling

Introduction

The Rover for the VCAF dGPS system was deployed standalone (i.e., without a base station and associated differential corrections) to exhibit that the system is viable for use in obtaining vehicle speed profiles in Yosemite National Park. Potential concerns prior to the test included: (1) erroneous data collected due to the presence of GPS satellite shielding from local terrain features; and (2) accuracy of standalone GPS data.

Test Procedure

The rover system was installed in the Volpe Center minivan. The survey antenna was mounted in the standard choke ring (to minimize multipath at the receiver), placed on top of single piece of foam, and secured to the van using bungee cords through the rear windows, which were open. The laptop and GPS receiver were secured on the front, passenger-side seat. The laptop and GPS receiver were powered using the van's cigarette lighter. Total system set-up time took about 15 minutes. It is recommended that a more secure means of fastening the antenna to the vehicle is explored prior to field use at higher speeds and in more rugged terrain.

On Thursday afternoon, 7/1/2002, the van was driven from the Volpe Center down Broadway towards Harvard Square in Cambridge, Massachusetts. A one-block detour was taken on a street chosen for a particularly large amount of satellite shielding due to the close proximity of several multi-story buildings. After passing through the underpass in Harvard Square, travel continued down Garden Street to Concord Ave., terminating between Fresh Pond and Danehy Park.

This route was retraced in reverse the following morning.

Observations

Between 0 and 7 satellites were noted at any given time. Satellite lock (indicated both by the LED on the front of the GPS receiver as well as real-time data updates on the laptop) was intermittent, due to both the close proximity of buildings, as well as dense tree cover. Altitude data appeared to be significantly more inconsistent than horizontal (X-Y) data.

Data

When the GPS receiver did not have satellite lock, no data were collected. This eliminates the need for culling these data. There were, however, several instances in which multiple data records were collected and assigned the same reference time stamp. Several of these data points were noted as erroneous; consequently, all data points with identical time stamps were eliminated from the speed profile data.

Figure 1 represents the culled speed profile data (in knots) for the Volpe to Fresh Pond run. After data culling, an average trip speed of 7.1 knots is identified, with maximum and minimum speeds of 35.3 and 0.0 knots, respectively. Note that many of the speeds with identical time stamps were 0.0 knots, so inclusion of these data would have necessarily biased the data in the downward direction. No comparisons were made between GPS-reported speeds and those indicated by the speedometer.

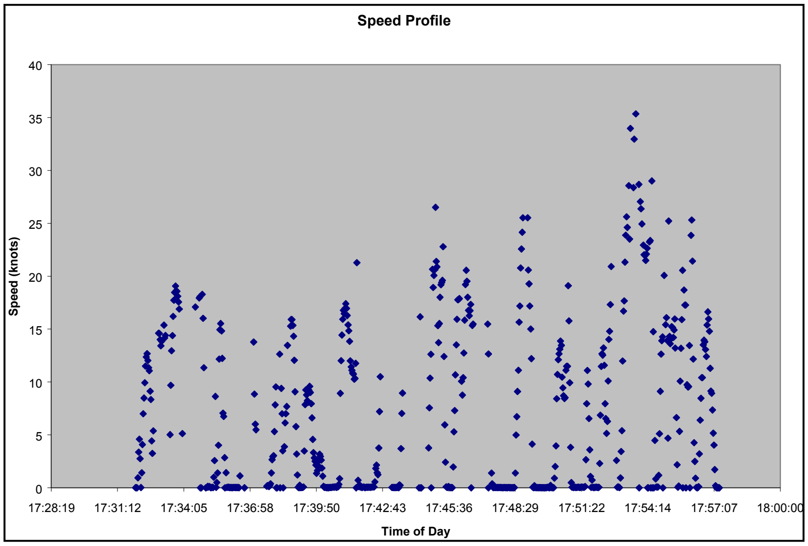


Figure C-1. Speed Profile Data

Figure C-2 represents all X-Y position data for both the Volpe to Fresh Pond and return legs of the test.

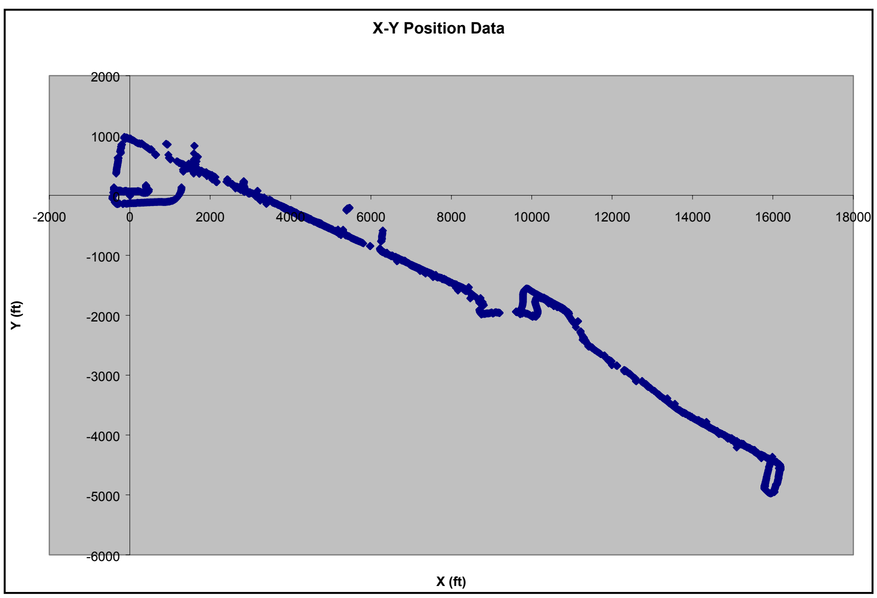


Figure C-2. X-Y position data

Conclusion

The standalone rover from the Volpe Center GPS system appears to be both robust and efficient for the collection of vehicle speed profile data. While terrain features do obstruct satellite reception at times, the collection of average speed/profile data is viable using the system.

Final GPS System Protocol

1.0 Equipment

1.1 Audio Recording

- Sony TCD-D100 DAT recorder
- Sony AC Power Adaptor
- Sony dynamic microphone
- DAT tapes
- Tripp Lite 140-Watt power inverter with cigarette lighter male end
- 2 cigarette lighter male ends with Y-cable, 2 female ends

1.2 GPS

- NovAtel GPS receiver with cigarette lighter male end power cord
- NovAtel GPS antenna
- Choke ring with foam pad, zip ties, and bungies
- TNC cable
- Null modem
- IBM laptop computer with cigarette lighter male end power cord

2.0 Procedure

2.1 Beginning of profiling shift

2.1.1 Setup and secure equipment. Drive to assigned gate.
2.1.2 Power up laptop, check time and data directory.
2.1.3 Turn on dGPS rover, check for data reception.
2.1.4 Put new DAT tape into DAT recorder. Set time.
2.1.5 Turn on DAT recorder; record name, date, position.
2.1.6 Rewind and test DAT recording of name, date, position.

2.2 Begin vehicle profiling

2.2.1 After setup is complete, pick third vehicle to arrive at assigned gate.
2.2.2 Start TSPI file in laptop, turn on DAT recorder.
2.2.3 Note location, begin time, TSPI ID, RT20 status, number of satellites, and DAT ID on Yosemite Vehicle Profiling Log Sheet (see end of document).
2.2.4 As vehicle passes, follow at a distance of 75 ft – 100 ft. DO NOT DISTURB, simply DRIVE NORMALLY.
2.2.5 Speaking clearly, announce start time and describe vehicle, including make, model, color, license plate #, state, and number of passengers.
2.2.6 As you follow vehicle through Yosemite, describe speed, location, and any slowdowns or stops. If passengers get out of vehicle, park and wait until they resume tour, then follow again. If passengers are stopped for more than 10 minutes, skip to 2.3. Continue to follow vehicle and record observations until vehicle leaves the park.
2.2.7 End TSPI file, turn off DAT recorder, note End Time on log sheet.
2.2.8 Return to assigned gate.

2.3 New vehicle profile, at assigned gate or inside Yosemite

2.3.1 Systems check:

- Check all vehicle power.
- Check DAT tape. Refresh if necessary.
- After systems check, pick third vehicle to pass and begin again as at 2.2.2.

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Public distribution/availability.

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 Traffic Impact Study (the 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. Mainly due to their ability to take into account park-specific driving cycles, modal emissions models are likely to provide results that are more appropriate for the National Parks. For further emissions modeling, a simplified approach using a modal emissions model is recommended. This comparison report contains a technical comparison of the three California national parks emissions inventory input data and instructions on how to produce emissions inventories for other parks through a simplified approach.

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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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

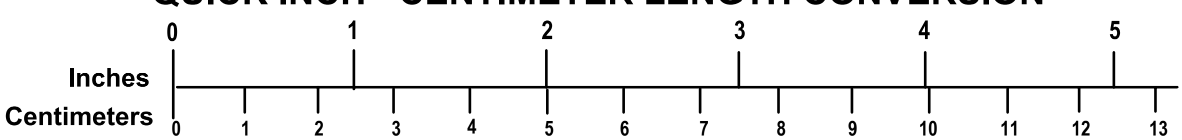
VOLUME (APPROXIMATE)

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

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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-2112 / January 2005