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FINAL REPORT

CADILLAC MOUNTAIN TRANSPORTATION AND VISITOR USE MODEL

1.27.2017



PREPARED FOR:

FRIENDS OF ACADIA; ACADIA NATIONAL PARK

SUBMITTED BY:

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1.0 INTRODUCTION

The National Park Service (NPS) is initiating work to develop a Transportation Plan for Acadia National Park. The purpose of the Transportation Plan is to determine how best to provide safe and efficient transportation and a variety of high quality experiences to visitors within Acadia National Park while ensuring the protection of park resources and values. The plan will comprehensively examine several management options to improve safety on park roads and reduce crowding and congestion at key visitor destinations and travel corridors.

One of several areas of focus for the Transportation Plan is Cadillac Mountain, where, during peak summer periods, intensive visitation causes traffic congestion, parking shortages, visitor crowding, resource impacts, and public safety issues. These issues have increased in recent years to the point that park staff have had to close Cadillac Mountain Road on occasion in reaction to severe traffic congestion and crowding on the mountain summit. For example, during the summer of 2015, the Cadillac Mountain road was closed due to extreme traffic congestion on seven occasions (Jacobi, 2016).

The Transportation Plan will identify management strategies to address these and other transportation-related issues in Acadia National Park. To help inform the development of management strategies, the NPS is conducting an analysis of current use levels and desired conditions for resources and values for key areas in Acadia National Park, including Cadillac Mountain.

This project was contracted by the Friends of Acadia in 2015 to develop a simulation model of transportation and visitor use on the summit of Cadillac Mountain to help support the Transportation Plan. The specific purposes of the simulation model developed in this project are to provide:

- Precise, quantitative information about traffic, parking, visitor use, and crowding conditions on the summit of Cadillac Mountain during “typically busy” peak summer season days.
- Scientifically rigorous estimates of the maximum number of visitors that can be accommodated per day on the summit of Cadillac Mountain without exceeding physical parking-related and potential crowding-related capacities.

The remainder of this report is organized into sections that present: the study area and data collection methods; data analysis; model algorithm and programming; simulation analyses and results; and model validation methods and results.

2.0 METHODS

2.1 | STUDY AREA

The study area for the Cadillac Mountain model was designed to encompass all points of access for visitor use on Cadillac Mountain and is depicted in Figure 1. It includes the Cadillac Mountain Road; Blue Hill Overlook and Cadillac Mountain Summit parking lots; the hiking trails that lead to the summit of Cadillac Mountain including the North Ridge Trail, the South Ridge Trail, and the Gorge Path; and summit visitor use areas including the Summit Loop Trail and its interpretive/viewing platform. Each of these sub-areas is described in the following paragraphs.

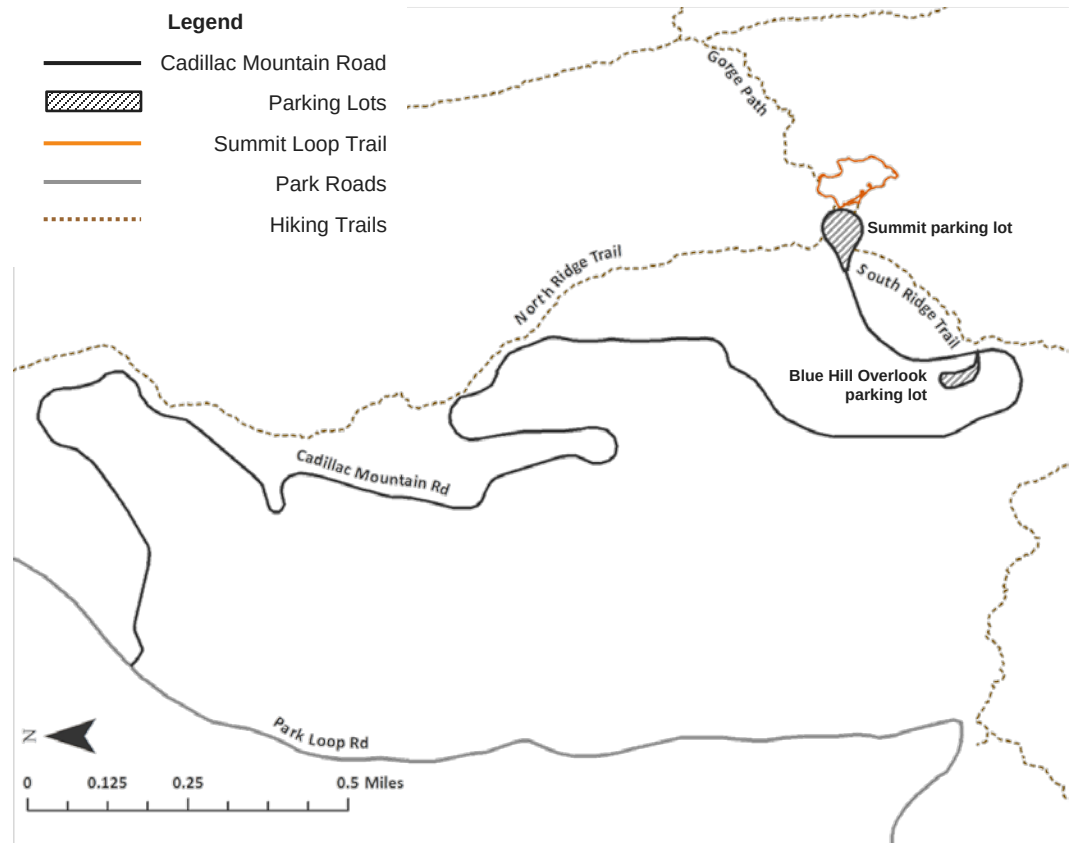


FIGURE 1: CADILLAC MOUNTAIN STUDY AREA

VISITOR ACCESS

The vast majority of visitors access the Cadillac Mountain summit area via the Cadillac Mountain Road. The road provides access to the mountain summit for those traveling by private vehicle, tour bus, taxi, or bicycle. A small minority of visitors arrive to the Cadillac Mountain summit area by foot on the North Ridge Trail, South Ridge Trail, and Gorge Path. The North Ridge and South Ridge Trails deliver visitors to the summit parking lot while the Gorge Path delivers visitors to the Summit Loop Trail. **Daily visitor use via these points of access provide the basis for programming the Cadillac Mountain Transportation and Visitor Use Model and conducting simulations with the model.**

PARKING AREAS

All tour busses and most private vehicles park in the Cadillac Mountain summit parking lot, which at the time of the study had 119 designated parking spaces for automobiles and designated spaces for approximately 6 tour buses. When the Cadillac Mountain Summit parking lot is full, some private vehicles use the Blue Hill Overlook parking lot as an overflow parking lot, although many do not and instead wait in or orbit the Cadillac Mountain summit parking lot until parking spaces become available. At the time of the study, the Blue Hill Overlook parking lot had 38 designated parking spaces for automobiles. It should be noted, this description of the Blue Hill Overlook parking lot reflects this study's focus on transportation and visitor use during daytime hours; the Blue Hill Overlook parking lot is visitors' first choice for parking to view the sunset. **The Cadillac Mountain Summit and Blue Hill Overlook parking lots are points of focus for estimating parking conditions and parking-related capacities for Cadillac Mountain with the computer simulation model in this project.**

VISITOR ATTRACTIONS

The Summit Loop Trail and surrounding summit area is the primary visitor attraction on Cadillac Mountain. The Summit Loop Trail is approximately one-half mile long, paved, and circumnavigates the summit area of Cadillac Mountain. Interpretive signs and scenic viewing points are located at various points along the Summit Loop Trail, providing visitors with expansive views of the park's glaciated coast and island landscape. A small portion of the Summit Loop Trail adjacent to the summit parking lot is accessible in compliance with the Americans with Disabilities Act. This section of the Summit Loop Trail accesses an interpretive/viewing platform near the height of land (Figure 2 and Figure 3); **this interpretive/viewing platform is a key feature of the summit area and a point of focus for estimating visitor use and crowding-related capacities for Cadillac Mountain with the computer simulation model in this project.**

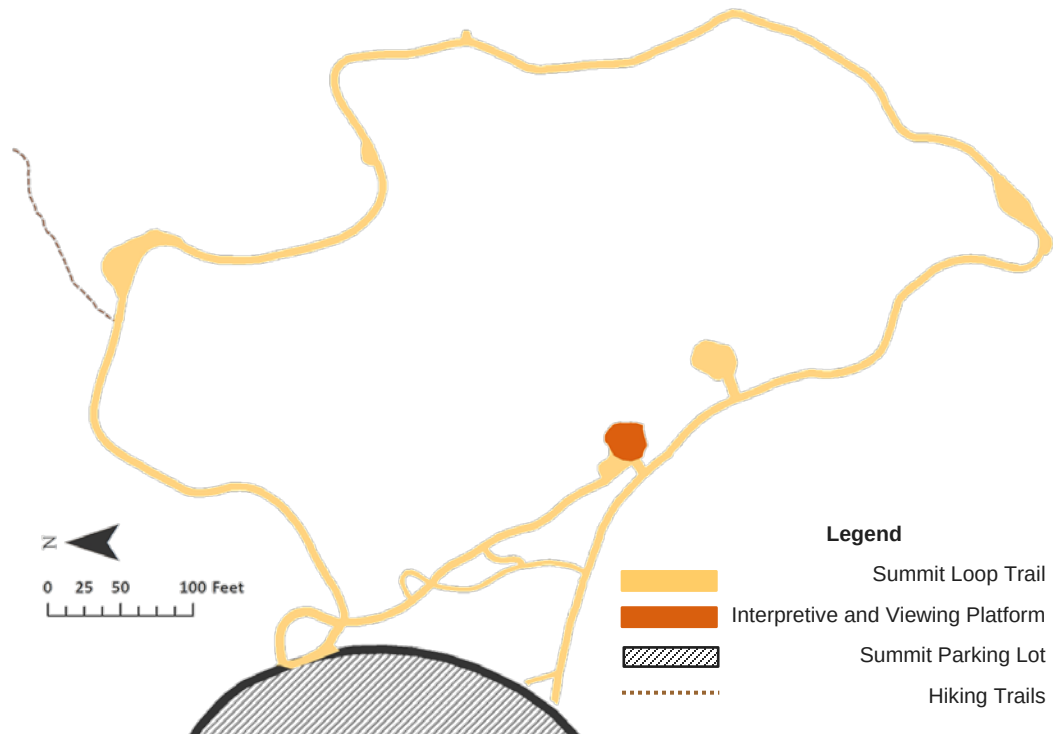


FIGURE 2: LOCATION OF THE INTERPRETIVE/VIEWING PLATFORM ON THE SUMMIT LOOP TRAIL



FIGURE 3: PHOTOGRAPH OF THE INTERPRETIVE/VIEWING PLATFORM ON THE SUMMIT LOOP TRAIL

2.2 | DATA COLLECTION

As part of this project, transportation and visitor use data were collected on Cadillac Mountain in Acadia National Park during the summer of 2015. These data served as the primary source of inputs for the Cadillac Mountain Transportation and Visitor Use Model developed in this project, and include:

- Vehicle traffic volume counts
- Trail use counts
- Visitor use patterns in the Cadillac Mountain summit area
- People at one time (PAOT) counts on the summit of Cadillac Mountain
- Tour and coach bus use counts (provided to RSG by Acadia National Park staff)

This section of the report summarizes the data collection methods for each of the types of data listed above.

VEHICLE TRAFFIC VOLUME COUNTS

- Vehicle traffic volume counts were collected with a JAMAR TRAX Apollyon automatic traffic recorder (ATR) near the base of the Cadillac Mountain Road (Figure 4).
- The ATR was configured to record vehicle traffic counts by direction of travel and vehicle class in hourly bins, 24 hours per day from August 1 through September 29, 2015.
- Due to the high degree of accuracy and precision of the ATR used, it was not necessary to calibrate the vehicle traffic count data with direct observation counts.

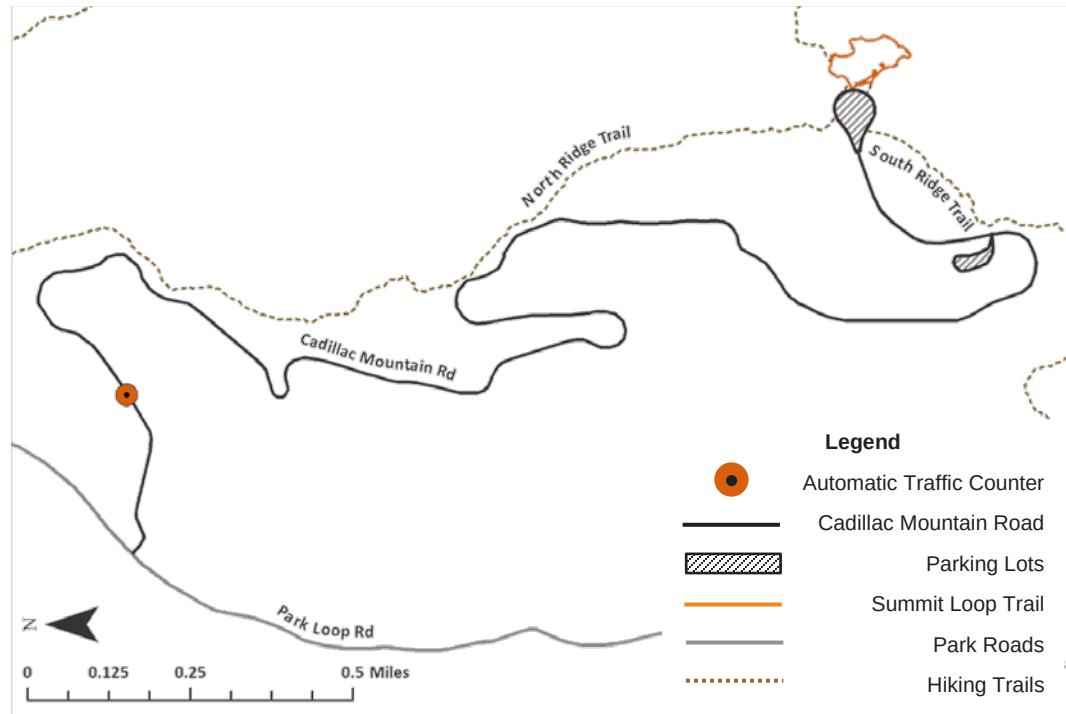


FIGURE 4: ATR LOCATION ON THE CADILLAC MOUNTAIN ROAD

TRAIL USE COUNTS

- Trail use counts were recorded with infrared trail counters located on the North Ridge Trail, South Ridge Trail, and Gorge Path (Figure 5).
- The infrared trail counters recorded visitor use counts in hourly bins, 24 hours a day from August 10 through September 26, 2016.
- The locations of the infrared trail counters used to record trail use counts were selected in consultation with Acadia National Park. The locations were selected to capture counts of the number of visitors arriving to Cadillac Mountain via the trails and minimize the number of counts generated by visitors that arrive to the mountain by the Cadillac Mountain Road and simply wander past the trail counters during their visits in the summit area.
- Field staff conducted trail use counts via direct observation at each of the infrared trail counter locations for a minimum of 16 hours. The direct observation counts, which included observations of visitors' direction of travel, were used to correct and adjust (i.e., calibrate) the raw infrared trail counter data and estimate hourly arrivals and departures from the calibrated total counts.

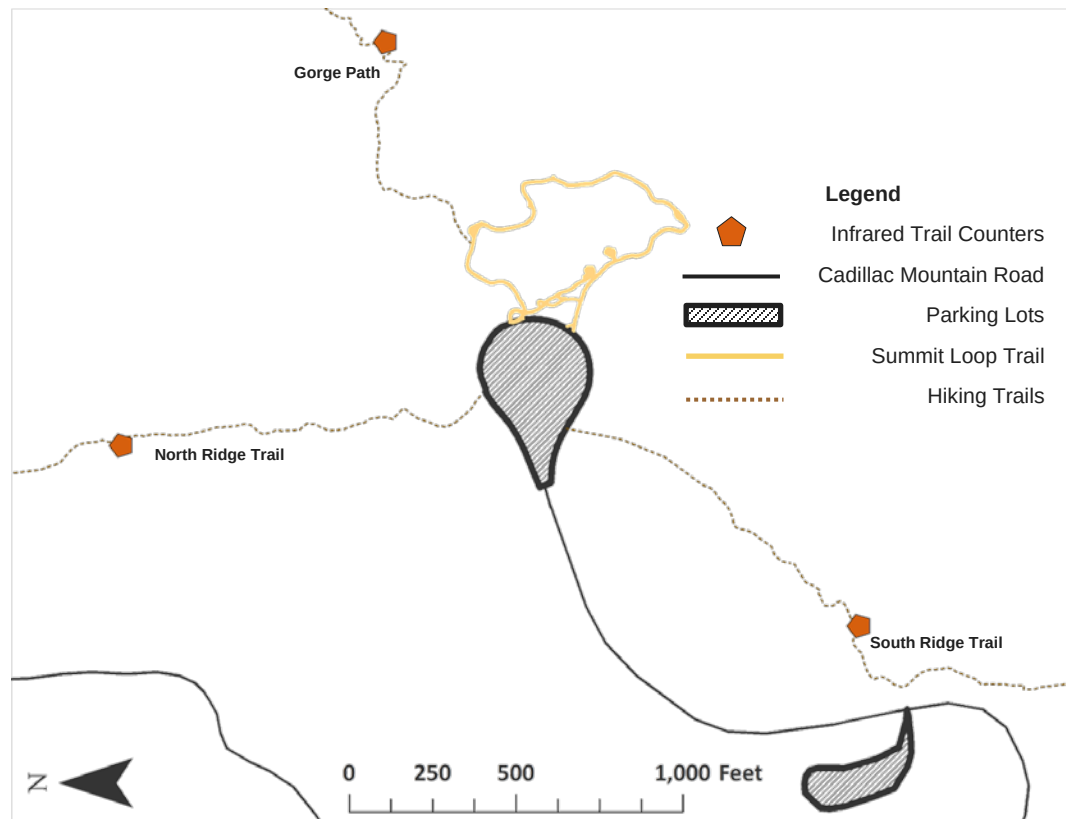


FIGURE 5: INFRARED TRAIL COUNTER LOCATIONS

VISITOR USE PATTERNS IN THE SUMMIT AREA

- Visitor use patterns in the Cadillac Mountain summit area were measured using route survey cards. Specific information collected with the route survey cards included visitor groups:
 - Routes of arrival, use, and departure from the Cadillac Mountain summit area
 - Dwell times in the Summit Loop Trail interpretive/viewing platform area and other key locations in the Cadillac Mountain summit area
 - Group sizes
 - Modes of transportation to the Cadillac Mountain summit area
- Route survey cards were distributed to a random sample of visitor groups arriving by private vehicle, bus, and bicycle to the summit parking lot and to all visitor groups arriving to Cadillac Mountain via the North Ridge Trail, South Ridge Trail, and Gorge Path (Figure 6). Visitors were asked to carry the route survey cards while they were in the Cadillac Mountain summit area, hand the card to each field staff they encountered during their visit, and return the card at the end of their visit to the summit area. Visitors departing Cadillac Mountain by private vehicle, bus, or bicycle were instructed to return their route survey cards to drop boxes distributed throughout the summit and Blue Hill Overlook parking lots. Visitors departing the mountain by trail returned their route survey cards to field staff stationed at the trails. In addition to field staff distributing and collecting route survey cards in the parking lot and at the trails, two field staff members were stationed at the entrances to the Summit Loop Trail. The field staff on the Summit Loop Trail collected the route survey cards from study participants each time they reached the location, recorded routing information on the route survey cards, and then returned the cards to the study participants and instructed them to continue carrying the cards until they completed their visits to the summit area.
- Route survey cards were administered for three days in August, 2015 between the hours of 8:00 AM and 5:00 PM. Distribution of route survey cards was stopped 90 minutes prior to the end of data collection to minimize the number of study participants who were still carrying the survey cards at the end of the sampling day after field staff had departed.
- Overall, 531 visitor groups were contacted and 501 visitor survey cards were administered to visitor groups, resulting in a 94% cooperation rate. Table 1 presents route survey card distribution and cooperation rates by date.

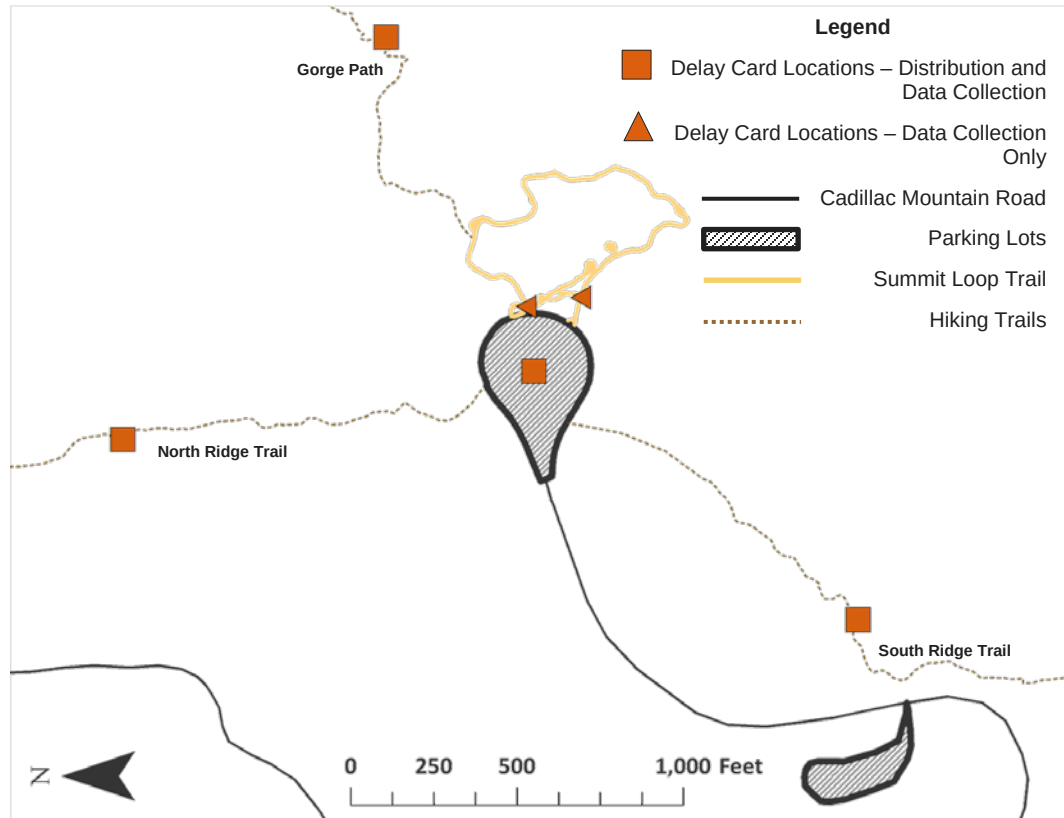


FIGURE 6: ROUTE SURVEY CARD FIELD STAFF LOCATIONS

TABLE 1: ROUTE SURVEY CARD SAMPLING RESULTS

DATE	ARRIVAL LOCATION	VISITOR CONTACTS	DELAY CARDS ADMINISTERED	COOPERATION RATE
8/15/2015	Cadillac Mountain Road	68	57	84%
8/15/2015	North Ridge Trail	40	40	100%
8/15/2015	South Ridge Trail	53	50	94%
8/15/2015	Gorge Path	25	23	92%
8/16/2015	Cadillac Mountain Road	108	101	94%
8/16/2015	North Ridge Trail	38	37	97%
8/16/2015	South Ridge Trail	32	28	88%
8/16/2015	Gorge Path	21	21	100%
8/21/2015	Cadillac Mountain Road	86	80	93%
8/21/2015	North Ridge Trail	35	35	100%
8/21/2015	South Ridge Trail	25	25	100%
8/21/2015	Gorge Path*	---	---	---
Total		531	497	94%

* Route survey cards were not distributed on the Gorge Path on 8/21/15.

PEOPLE AT ONE TIME (PAOT) COUNTS IN THE SUMMIT AREA

- Counts of the number of people at one time (PAOT) in select areas on the summit of Cadillac Mountain were measured via direct observation. The PAOT counts were designed to approximate, as close as possible, simultaneous and instantaneous counts of the number of people in each of the observation areas where counts were conducted.
- The observation areas for the PAOT counts included: 1) the full extent of the Cadillac Mountain summit area visible from the Summit Loop Trail; and 2) the Summit Loop Trail interpretive/viewing platform¹ (Figure 7).
- PAOT counts were simultaneously conducted in each of the two observation areas every 10 minutes between the hours of 8:00 AM and 4:00 PM on three days in August, 2015.
- To conduct PAOT counts for the full extent of the Cadillac Mountain summit area visible from the Summit Loop Trail, the visible area was divided into a northern section and a southern section. Independent and simultaneous PAOT counts for each of these sections were conducted and subsequently (during the analysis phase of the project) summed to estimate a PAOT count for the full extent.
- The PAOT count procedures resulted in paired PAOT counts for: 1) the full extent of the Cadillac Mountain summit area visible from the Summit Loop Trail; and 2) the Summit Loop Trail interpretive/viewing platform.

¹ Field staff inadvertently included in the PAOT counts for the Summit Loop Trail interpretive/viewing platform a lesser used, nearby viewing platform. Based on field staff observations of relative use patterns in the two platform areas, total counts for the two platforms was reduced by 25% to estimate PAOT in the Summit Loop Trail interpretive/viewing platform area.



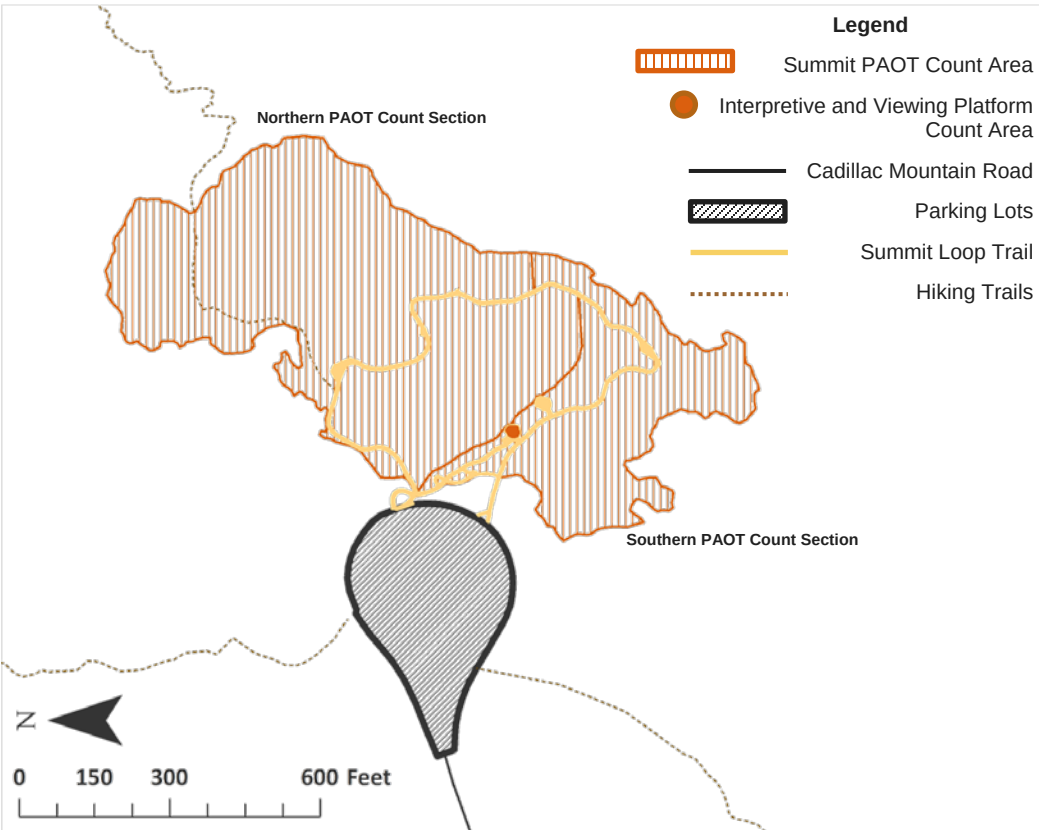


FIGURE 7: PAOT COUNT AREAS

TOUR AND COACH BUS USE

Tour and coach bus use schedules and counts for Cadillac Mountain were provided to RSG by Acadia National Park staff. Park staff provided schedules and count data for three types of tour and coach buses that provide visitor access to Cadillac Mountain, including:

- Buses that transport visitors from cruise ships docked in Bar Harbor, ME to the summit of Cadillac Mountain.
- Over-the-road coach buses that transport visitors to Cadillac Mountain as part of single or multi-day tours of Acadia National Park and the surrounding area.
- Concession tour buses that transport visitors to Cadillac Mountain as part of day tours of Acadia National Park (e.g., Oli's Trolley and Acadia National Park Tours).

2.3 | MODEL INPUT ANALYSIS

The transportation and visitor use data collected during summer 2015 were analyzed to develop the model inputs needed to program the Cadillac Mountain Transportation and Visitor Use Model, and conduct model simulations. These data were also analyzed to establish a “design day” for analysis and modeling to represent transportation and visitor use conditions during the peak summer season. The methods and results of these analyses are summarized in this section of the report.

DESIGN DAY

The “design day” concept was applied in this project to focus analyses and modeling on “typically busy” traffic, parking, and visitor use conditions on Cadillac Mountain during the peak summer season. The design day provides a basis for designing transportation and visitor use management strategies for Cadillac Mountain that are effective on most days, while recognizing that it will be necessary to temporally adapt under extreme conditions (i.e., on the busiest of days). In the context of this project, the design day was used to identify the level of daily visitor use on Cadillac Mountain to model for estimating transportation and visitor use conditions on “typically busy” days during the peak summer season. As noted, the vast majority of visitors access Cadillac Mountain via Cadillac Mountain Road; correspondingly, the vehicle traffic data recorded with the ATR on Cadillac Mountain Road during summer 2015 provide a suitable basis for identifying a design day in this project.

Commonly, the 85th percentile day of vehicle traffic volumes in a study area is selected as the design day for community and urban transportation planning. In the context of national parks, however, where visitor use tends to be temporally concentrated (e.g., during peak days and peak hours), it is arguably more suitable to select a design day based on the percentage of visitors that experience conditions at or better than design day conditions, rather than the percentage of days that are at or better than design day conditions.

With that in mind, the vehicle traffic count data recorded on Cadillac Mountain Road during summer 2015 were analyzed to estimate a design day such that approximately 85% of peak summer season visitors to Cadillac Mountain would experience transportation and visitor use conditions at or better than design day conditions. Results of this analysis suggest 86% of visitors to Cadillac Mountain during the study period experienced the same or less daily inbound traffic than those on August 14, 2015; it is inferred from this that 86% of visitors during the study period also experienced transportation and visitor use conditions at or better than those on August 14, 2015. Correspondingly, August 14, 2015, which was the 90th percentile day of vehicle traffic during the study period, was selected as the design day for analysis and modeling in this project. Figure 8 plots daily inbound private vehicle traffic² on Cadillac Mountain Road during the summer 2015 period, and highlights the design day (August 14, 2015) to provide context for the design day used in this project.

² These counts exclude bus traffic, which is incorporated in the Cadillac Mountain Transportation and Visitor Use Model via bus schedules and counts provided by Acadia National Park staff.

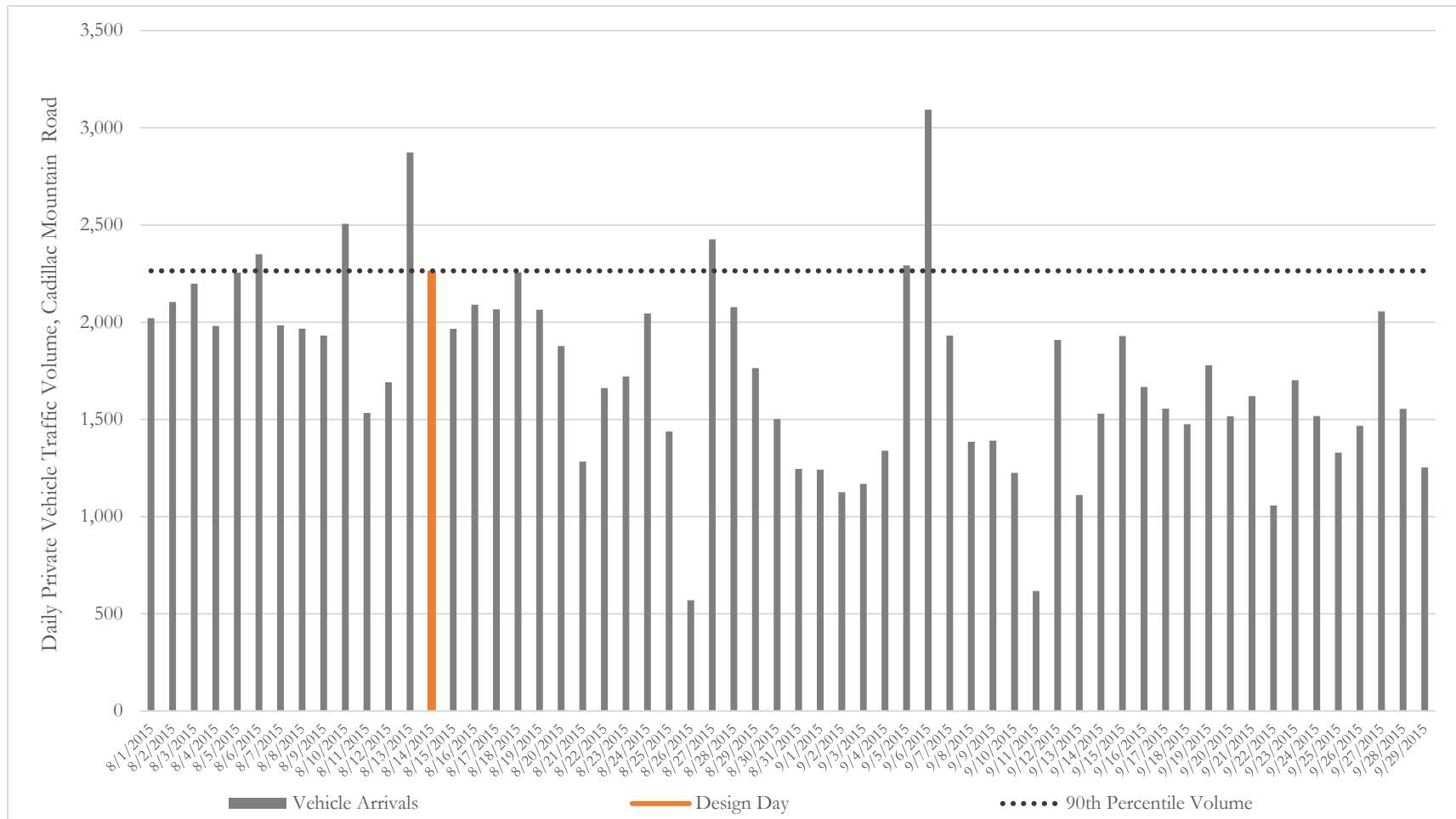


FIGURE 8: DAILY AND DESIGN DAY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN DURING THE SUMMER 2015 STUDY PERIOD

DAILY AND HOURLY VISITOR USE

Hourly visitor use, by mode and location of arrival for the design day are presented in Table 2 through Table 4. More specifically, hourly private vehicle use is reported in Table 2 as vehicles per hour; hourly trail use is reported in Table 3 as people per hour, by trail; and the design day schedule of coach and tour bus use is reported in Table 4 as passengers per bus by type of bus and time of arrival. These are the daily and hourly visitor use levels used to program the model for design day simulations to estimate transportation and visitor use conditions on Cadillac Mountain during the peak summer season. In other words, simulated visitor groups were generated in the model based on the daily and hourly schedules of use reported in Table 2, Table 3 and Table 4.

TABLE 2: DESIGN DAY HOURLY PRIVATE VEHICLE ARRIVALS, CADILLAC MOUNTAIN ROAD

Hour	Cadillac Mountain Road (Private Vehicles)
12:00 AM – 1:00 AM	6
1:00 AM – 2:00 AM	5
2:00 AM – 3:00 AM	7
3:00 AM – 4:00 AM	22
4:00 AM – 5:00 AM	172
5:00 AM – 6:00 AM	100
6:00 AM – 7:00 AM	6
7:00 AM – 8:00 AM	14
8:00 AM – 9:00 AM	42
9:00 AM – 10:00 AM	108
10:00 AM – 11:00 AM	188
11:00 AM – 12:00 PM	222
12:00 PM – 1:00 PM	179
1:00 PM – 2:00 PM	152
2:00 PM – 3:00 PM	183
3:00 PM – 4:00 PM	144
4:00 PM – 5:00 PM	129
5:00 PM – 6:00 PM	124
6:00 PM – 7:00 PM	189
7:00 PM – 8:00 PM	139
8:00 PM – 9:00 PM	34
9:00 PM – 10:00 PM	31
10:00 PM – 11:00 PM	17
11:00 PM – 12:00 AM	8
Total:	2221/1347
24-Hour/8 AM to 5 PM	

TABLE 3: DESIGN DAY HOURLY VISITOR ARRIVALS, CADILLAC MOUNTAIN TRAILS

HOUR	NORTH RIDGE TRAIL (PEOPLE)	SOUTH RIDGE TRAIL (PEOPLE)	GORGE PATH (PEOPLE)
12:00 AM – 1:00 AM	0	0	0
1:00 AM – 2:00 AM	0	0	0
2:00 AM – 3:00 AM	0	0	0
3:00 AM – 4:00 AM	0	0	0
4:00 AM – 5:00 AM	6	6	0
5:00 AM – 6:00 AM	7	7	0
6:00 AM – 7:00 AM	11	11	0
7:00 AM – 8:00 AM	3	3	0
8:00 AM – 9:00 AM	0	2	2
9:00 AM – 10:00 AM	15	1	3
10:00 AM – 11:00 AM	51	12	12
11:00 AM – 12:00 PM	54	58	11
12:00 PM – 1:00 PM	56	34	10
1:00 PM – 2:00 PM	52	99	15
2:00 PM – 3:00 PM	27	9	12
3:00 PM – 4:00 PM	19	12	15
4:00 PM – 5:00 PM	21	17	6
5:00 PM – 6:00 PM	9	7	3
6:00 PM – 7:00 PM	6	5	2
7:00 PM – 8:00 PM	3	3	1
8:00 PM – 9:00 PM	0	0	0
9:00 PM – 10:00 PM	0	0	0
10:00 PM – 11:00 PM	0	0	0
11:00 PM – 12:00 AM	0	0	0
Total: 24-Hour/8 AM to 5 PM	340/295	286/244	92/86

TABLE 4: DESIGN DAY SCHEDULE OF VISITOR ARRIVALS BY TIME OF DAY AND TYPE OF BUS, CADILLAC MOUNTAIN ROAD

TIME	BUS TYPE	PASSENGERS
9:05 AM	Cruise ship	49
10:05 AM	Over-the-road	44
10:35 AM	Concession	23
10:35 AM	Concession	30
10:35 AM	Concession	30
10:50 AM	Concession	34
11:20 AM	Over-the-road	44
11:35 AM	Cruise ship	31
11:35 AM	Concession	23
12:05 PM	Concession	34
12:15 PM	Over-the-road	44
1:35 PM	Concession	23
1:35 PM	Concession	23
1:45 PM	Over-the-road	44
2:00 PM	Over-the-road	44
2:05 PM	Over-the-road	44
2:35 PM	Concession	23
2:35 PM	Concession	30
2:50 PM	Concession	34
3:45 PM	Over-the-road	44
4:05 PM	Concession	34
4:40 PM	Over-the-road	44
Total		773

VISITOR GROUP SIZE

Frequency distributions of group sizes, by mode and location of arrival to the Cadillac Mountain summit area, were derived from analysis of the route survey data with extreme outliers removed (group size > 10; Table 5). These frequency distributions were programmed into the model to assign group sizes to simulated visitor groups for visitors arriving by private vehicle or on hiking trails³.

TABLE 5: DISTRIBUTION OF VISITOR GROUP SIZES BY ARRIVAL LOCATION AND MODE

GROUP SIZE	PRIVATE VEHICLE (N = 187)	BUS (N = 16)	NORTH RIDGE TRAIL (N = 106)	SOUTH RIDGE TRAIL (N = 92)	GORGE PATH (N = 43)
1	4.3%	5.6%	10.4%	13.0%	25.6%
2	42.3%	72.2%	44.3%	56.5%	44.2%
3	16.0%	5.6%	13.2%	8.7%	4.7%
4	22.5%	5.6%	17.0%	12.0%	16.3%
5	9.6%	0.0%	9.4%	7.6%	4.7%
6	2.7%	0.0%	1.9%	1.1%	4.7%
7	1.1%	5.6%	1.9%	1.1%	0.0%
8	0.5%	0.0%	0.9%	0.0%	0.0%
9	1.1%	0.0%	0.9%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%

³ Note, for tour bus groups, the model was programmed to assign a group size of two people to each tour bus group, rather than to assign group sizes to tour bus groups stochastically. This was done because of the very small sample size for tour bus groups in the route survey data and the corresponding lack of reliability for assigning group size stochastically.

VISITOR USE PATTERNS IN THE SUMMIT AREA

The route survey data were analyzed to estimate the percentage of visitor groups who enter the Summit Loop Trail area of the Cadillac Mountain summit (see the vertical-shaded area in Figure 7), by mode and location of arrival to the Cadillac Mountain summit area (Table 6). These distributions were programmed into the Cadillac Mountain Transportation and Visitor Use Model to assign, for each simulated visitor group, whether or not the group entered the Summit Loop Trail area of Cadillac Mountain during their simulated visit. This, in turn, provides a basis for simulating the number and percentage of visitors in the Summit Loop Trail area of Cadillac Mountain at one time.

TABLE 6: PERCENTAGE OF VISITOR GROUPS WHO ENTER THE SUMMIT LOOP TRAIL AREA BY ARRIVAL LOCATION AND MODE

ARRIVAL LOCATION	ARRIVAL MODE	% OF VISITOR GROUPS WHO ENTER SUMMIT LOOP TRAIL AREA
Cadillac Mountain Road	Private Vehicle	87.4%
Cadillac Mountain Road	Bus	83.3%
North Ridge Trail	Foot	79.2%
South Ridge Trail	Foot	62.5%
Gorge Path	Foot	100.0%

DWELL TIMES IN THE SUMMIT LOOP TRAIL AREA

The route survey data were analyzed to estimate means and standard deviations of dwell times in the Summit Loop Trail area of Cadillac Mountain (see the vertical-shaded area in Figure 7), by mode of arrival to the Cadillac Mountain summit area (Table 7). There were no statistical differences between private vehicle and trail use groups, with respect to average dwell times in the Summit Loop Trail area, so data for these group types were combined. These means and standard deviations were used to specify distributions in the Cadillac Mountain Transportation and Visitor Use Model to assign summit area dwell times for simulated visitor groups who entered the Summit Loop Trail area of Cadillac Mountain during their simulated visit.

TABLE 7: MEAN DWELL TIMES (MINUTES) IN SUMMIT LOOP TRAIL AREA BY ARRIVAL MODE (STANDARD DEVIATIONS IN PARENTHESES)

ARRIVAL MODE	MEAN	STANDARD DEVIATION
Private Vehicle/Trail	17.3	11.9
Bus	11.7	7.9

PRIVATE VEHICLE PARKING LOT DWELL TIMES

Private vehicle parking lot dwell times were originally programmed into the Cadillac Mountain Transportation and Visitor Use Model based on the route card survey data, the mean and standard deviation of which are reported in the first row of data in Table 8. As part of the process of calibrating the model, the parking lot dwell times were modified for consistency with visitors' mean length of stay on the summit of Cadillac Mountain from previous survey research. The calibrated mean and standard deviation of parking lot dwell times that were used in the calibrated model are reported in the second row of data in Table 8. A distribution with the calibrated mean and standard deviation was used to assign parking lot dwell times to simulated visitor groups traveling to the Cadillac Mountain summit area by private vehicle.

**TABLE 8: MEAN PRIVATE VEHICLE DWELL TIMES (MINUTES) IN PARKING LOTS
(STANDARD DEVIATION IN PARENTHESES)**

DATA SOURCE	MEAN	STANDARD DEVIATION
Route Survey Cards	26.2	13.7
Model Calibration	38.6	1.75

PAOT REGRESSION ANALYSIS

Regression analysis was conducted with the PAOT counts to estimate the statistical relationship between PAOT in the full extent of the Summit Loop Trail Area and PAOT in the Summit Loop Trail interpretive/viewing platform area (Figure 9). The coefficient of the regression equation is programmed into the Cadillac Mountain Transportation and Visitor Use Model to convert the simulation model's estimates of the total number of people in the Summit Loop Trail area to estimates of PAOT in the Summit Loop Trail interpretive/viewing platform area which provides a primary basis in the model to estimate visitor crowding and crowding-related capacities on Cadillac Mountain.

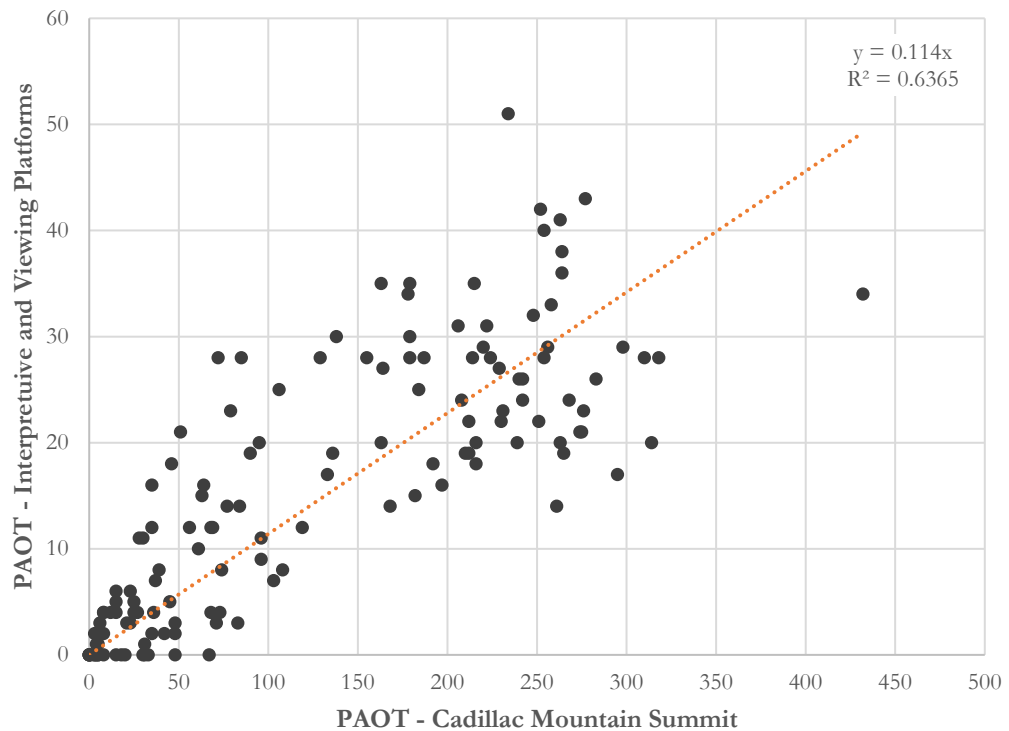


FIGURE 9: SCATTERPLOT AND REGRESSION EQUATION: PAOT IN THE FULL EXTENT OF THE SUMMIT LOOP TRAIL AREA AND PAOT IN THE INTERPRETIVE/VIEWING PLATFORM AREA

2.4 | MODEL ALGORITHM AND PROGRAMMING

The results of the data collection and model input analyses presented in the preceding sections of this report were used to develop the Cadillac Mountain Transportation and Visitor Use Model. The model was developed using ExtendSim, a discrete-event systems simulation software and is programmed to: 1) estimate transportation and visitor use conditions on Cadillac Mountain based on the design day level of visitor use selected in this project to represent “typically busy” days during the peak summer season; 2) estimate parking- and crowding-related capacities for daily visitor use on Cadillac Mountain.

The sequence of processes that occurs within the Cadillac Mountain Transportation and Visitor Use Model is as follows:

- Simulated visitor groups are generated at arrival locations according to arrival distributions by mode and location of arrival derived from automated traffic and trail use counts, and park-provided bus use data (Table 2, Table 3, and Table 4).
- Simulated visitor groups are attributed with groups sizes and summit area use patterns and dwell times based on frequency distributions derived from route card surveys (Table 5, Table 6, Table 7, and Table 8).
- Summit area facilities and attractions (i.e., parking lots and Summit Loop Trail area) are programmed in the model to “hold” simulated visitor groups for amounts of time based on the dwell times assigned to them in the model (Table 7).
- The model monitors and records simulated parking- and crowding-related conditions on Cadillac Mountain every five minutes of each simulated day.
- Simulated visitor groups are routed to exit the Cadillac Mountain study area when their simulated visits to the summit area are completed.

These modeling processes are stochastic, meaning the outcomes vary with each replication of the model. For example, the daily number of simulated visitor groups varies with each replication of the model run to simulate the design day, and the average of these daily arrivals is equal to the design day number of arrivals. This is similar to the way actual visitation to Cadillac Mountain varies from one day to another during “typically busy” peak summer season days (e.g., two days each with 2,000 daily visitors do not result in exactly the same parking, visitor use, and crowding conditions). Thus, mean values of outcome variables of interest are computed based on the results of multiple replications of the model. The method of independent replications was used to determine the number of replications needed to generate reliable model estimates (Kiser, Lawson, and Itami, 2008). Based on the results of the method of independent replications, outputs for the Cadillac Mountain Transportation and Visitor Use Model were computed by averaging the results of 120 replications of the model.

3.0 SIMULATION ANALYSIS OF TRANSPORTATION, VISITOR USE, AND CAPACITIES

The Cadillac Mountain Transportation and Visitor Use Model was used to simulate transportation and visitor use conditions during a “typically busy” peak summer season day, represented by the design day identified in the data analysis phase of this project of August 14, 2015. Results from these design day simulations were used to assess whether or not current levels of peak summer season visitation exceed preliminary draft thresholds for potential parking- and crowding-related indicators of quality.

In addition, a series of simulations was conducted with the Cadillac Mountain Transportation and Visitor Use Model to estimate the maximum daily number of private vehicles that can be accommodated on Cadillac Mountain, in combination with design day trail use and bus arrivals, without exceeding preliminary draft thresholds for potential parking- and crowding-related indicators of quality. These results represent potential transportation- and crowding-related capacities for Cadillac Mountain.

This section of the report first describes in detail the potential parking- and crowding-related indicators of quality and thresholds that were used in the simulation analyses in this study to estimate current transportation and visitor use conditions, and parking- and crowding-related capacities for Cadillac Mountain. Then results of the design day simulations of current transportation and visitor use conditions are presented, followed by results of simulation modeling to estimate parking- and crowding-related capacities for Cadillac Mountain.

3.1 | DRAFT INDICATORS AND THRESHOLDS

The NPS has developed preliminary draft indicators and thresholds as a component of the Acadia National Park transportation planning process. Preliminary draft indicators have been developed using the results of visitor use and survey research studies conducted in Acadia National Park, discussions and workshops with park staff, and expert judgement. For some indicators, preliminary draft thresholds have been developed based on the results of research conducted in Acadia National Park and/or by incorporating design/infrastructure characteristics when relevant (e.g., the design capacity of parking lots). This project incorporates two of the preliminary draft indicators and thresholds as a basis for the simulation analyses conducted with the Cadillac Mountain Transportation and Visitor Use Model; these include a transportation-related indicator and threshold and a visitor experience-related indicator and thresholds, each of which is described below.

PRELIMINARY DRAFT TRANSPORTATION-RELATED INDICATOR AND THRESHOLD

For the purposes of the simulation analyses conducted in this project, vehicles at one time (VAOT) in the Cadillac Mountain Summit and Blue Hill Overlook parking lots was used as an indicator of transportation and access quality on Cadillac Mountain. VAOT is a measure often used by park managers and researchers to quantify vehicle congestion in parking lots (Manning, Lawson, et al., 2014). VAOT provides an important measure of parking lot

conditions in relation to visitor access to popular destinations as well as potential park resource impacts as a result of parked vehicles in unauthorized areas. The Summit parking lot provides access to Cadillac Mountain's summit, including the Summit Loop Trail and interpretive and viewing platforms, as well as the Cadillac Mountain gift shop and bathrooms. The Blue Hill Overlook parking lot provides scenic views looking west and voluntary overflow parking for the Summit parking lot. Monitoring of VAOT at these locations provides a reasonable basis upon which overall transportation and access conditions on Cadillac Mountain can be inferred.

For the purposes of the simulation analyses conducted in this project, the threshold for this indicator was expressed as follows:

VAOT exceeds the design capacity of parking lots less than 1% of the time per day, from 8 AM to 5 PM.

The threshold was expressed with virtually no tolerance for overflow parking in undesignated locations because instances in which parking lot capacities are exceeded are indicative of vehicle congestion, potential safety concerns, and possible park resource impacts stemming from vehicles parking in unauthorized areas (Lawson, Newman, & Monz, 2016).

The parking-related threshold was operationalized in the model for two different scenarios; one of these scenarios is referred to as the "Unmanaged Parking" scenario and the other is referred to as the "Managed Parking" scenario. Each of these scenarios is described in the following bulleted paragraphs.

- **"Unmanaged Parking" scenario:** In the "unmanaged parking" scenario, it is assumed that visitors continue to use the Blue Hill Overlook parking lot for overflow parking on a voluntary basis when the Cadillac Mountain Summit parking lot is full. This scenario further assumes that because of the voluntary nature of overflow parking in the Blue Hill Overlook parking lot, many visitors will continue to opt to wait and/or orbit in the Cadillac Mountain Summit parking lot looking for a parking space to open up when it is full, rather than park in the Blue Hill Overlook parking lot. Correspondingly, the "effective" design capacity of the Cadillac Mountain Summit and Blue Hill Overlook parking lots is assumed to include a total of 138 parking spaces; this discounts the actual design capacity of the Blue Hill Overlook parking lot by 50% based on current patterns of parking, which suggest the lot never fills to more than 50% of its design capacity during daytime hours, even when the Cadillac Mountain Summit parking lot is full and visitors are waiting for parking spaces to open up there.
- **"Managed Parking" scenario:** The "managed parking" scenario assumes visitors are directed by on-the-ground parking management staff or other automated technology to park in the Blue Hill Overlook parking lot when the Cadillac Mountain Summit parking lot is full. In this scenario, the "effective" design capacity of the Cadillac Mountain Summit and Blue Hill Overlook parking lots is assumed to include 100% of the designated parking spaces in both parking lots (i.e., a total of

157 parking spaces). Among other things, the results of these two scenarios provide a basis to estimate the potential effect of on-the-ground parking management on parking-related capacities for Cadillac Mountain.

PRELIMINARY DRAFT VISITOR EXPERIENCE-RELATED INDICATOR AND THRESHOLDS

For the purposes of the simulation analyses conducted in this project, people at one time (PAOT) in the Summit Loop Trail interpretive/viewing platform was used as an indicator of the quality of visitors' experiences on Cadillac Mountain's summit. PAOT is a measure often used by park managers and researchers to quantify visitor crowding (Lawson, Chamberlin, et al., 2011; Lawson, Newman, et al., 2009; Lawson, Newman, & Monz, 2016; Manning, Valliere et al., 2011). Crowded conditions have been documented to adversely affect the visitor experience in national parks (Whittaker & Shelby, 2010). The Summit Loop Trail interpretive/viewing platform is among the most concentrated areas of visitor use on Cadillac Mountain during the daytime. Results of PAOT regression analyses reported above suggest PAOT in the interpretive/viewing platform is strongly correlated with overall visitor use on Cadillac Mountain. Monitoring of PAOT in the upper interpretive/viewing platform provides a reasonable basis upon which the quality of visitors' experiences on Cadillac Mountain's summit can be inferred. The well-delineated and contained space at the platform ensures that monitoring efforts will be reliable and accurate.

For the purposes of the simulation analyses conducted in this project, two alternative thresholds were specified for this indicator, one with a focus on visual crowding and the other with a focus on physical crowding:

Visual Crowding-related Threshold: There are no more than 8 PAOT on the Summit Loop Trail interpretive/viewing platform more than 25% of the time per day, from 8 AM to 5 PM.

Physical Crowding-related Threshold: There are no more than 15 PAOT on the Summit Loop Trail interpretive/viewing platform more than 25% of the time per day, from 8 AM to 5 PM.

Of the two thresholds, the visual crowding-related threshold is the more stringent, and focuses on the aesthetics of visitor use, density, and crowding derived from visitors' evaluations of photo simulations of varying levels of visitor use on the Cadillac Mountain summit (Manning, 2009). The numeric threshold represents the level and density of visitor use in the Summit Loop Trail interpretive/viewing platform beyond which visitors think the area looks unacceptably crowded. The physical crowding-related threshold represents a more relaxed tolerance for visitor crowding, representing the level of visitor use and density in the Summit Loop Trail interpretive/viewing platform area, beyond which visitors have difficulty moving freely (Pettengill, Manning, et al., 2009; Transportation Research Board, 2010).

3.2 | SIMULATION RESULTS: CURRENT TRANSPORTATION AND VISITOR USE CONDITIONS

Results of the design day simulations of current transportation and visitor use conditions on Cadillac Mountain are presented in this section. These results include estimates of VAOT in the Cadillac Mountain Summit and Blue Hill Overlook parking lots and PAOT in the Summit Loop Trail interpretive/viewing platform, by time of day, for “typically busy” peak summer season days. The results also include information about the percentage of time the preliminary draft thresholds for VAOT and PAOT are exceeded under current transportation and visitor use conditions on Cadillac Mountain. As noted, the simulation analysis results are average values from 120 replications of the model for each scenario.

VAOT

Mean VAOT by time of day for the design day simulations with the Cadillac Mountain Transportation and Visitor Use Model are plotted in Figure 10⁴. The horizontal lines in Figure 10 represent the “effective” design capacity of the Cadillac Mountain Summit and Blue Hill Overlook parking lots for the “unmanaged parking” and “managed parking” scenarios.

⁴ It should be noted, VAOT is plotted for the 24-hour period to illustrate parking patterns throughout the entire 24-hour period. However, some of the model inputs are based on data collected during the hours of 8 AM to 5 PM; correspondingly, caution should be used in interpreting simulation results for hours of the day other than 8 AM to 5 PM.

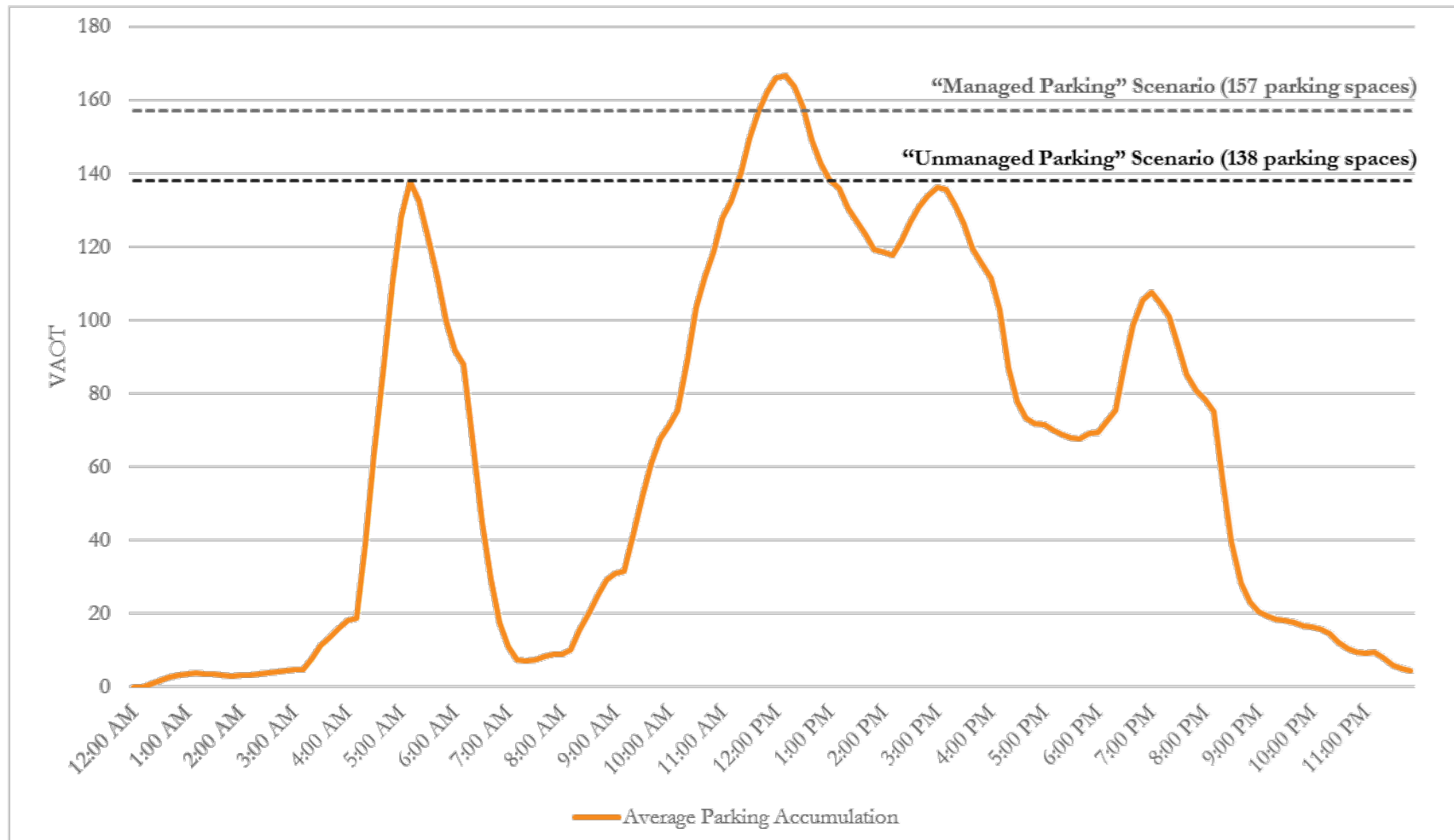


FIGURE 10: DESIGN DAY SIMULATION ESTIMATES OF PEAK SUMMER SEASON CONDITIONS – VAOT IN CADILLAC MOUNTAIN PARKING LOTS

The results of the design day simulations suggest VAOT exceeds the “effective” design capacity of the Cadillac Mountain Summit and Blue Hill Overlook parking lots approximately 28% of the time in the “unmanaged parking” scenario and approximately 8% of the time in the “managed parking” scenario during the 8 AM to 5 PM period on “typically busy” peak summer season days. These results suggest current levels of visitor use on Cadillac Mountain create potentially unacceptable parking shortages and traffic congestion in the summit area parking lots.

PAOT

Mean PAOT in the Summit Loop Trail interpretive/viewing platform area by time of day for the design day simulations with the Cadillac Mountain Transportation and Visitor Use Model are plotted in Figure 11⁵. The horizontal lines in Figure 11 represent the preliminary draft visual crowding-related and physical crowding-related thresholds for PAOT in the Summit Loop Trail interpretive/viewing platform.

⁵ It should be noted, PAOT is plotted for the 24-hour period to illustrate visitor use and crowding patterns throughout the entire 24-hour period. However, some of the model inputs are based on data collected during the hours of 8 AM to 5 PM; correspondingly, caution should be used in interpreting simulation results for hours of the day other than 8 AM to 5 PM.

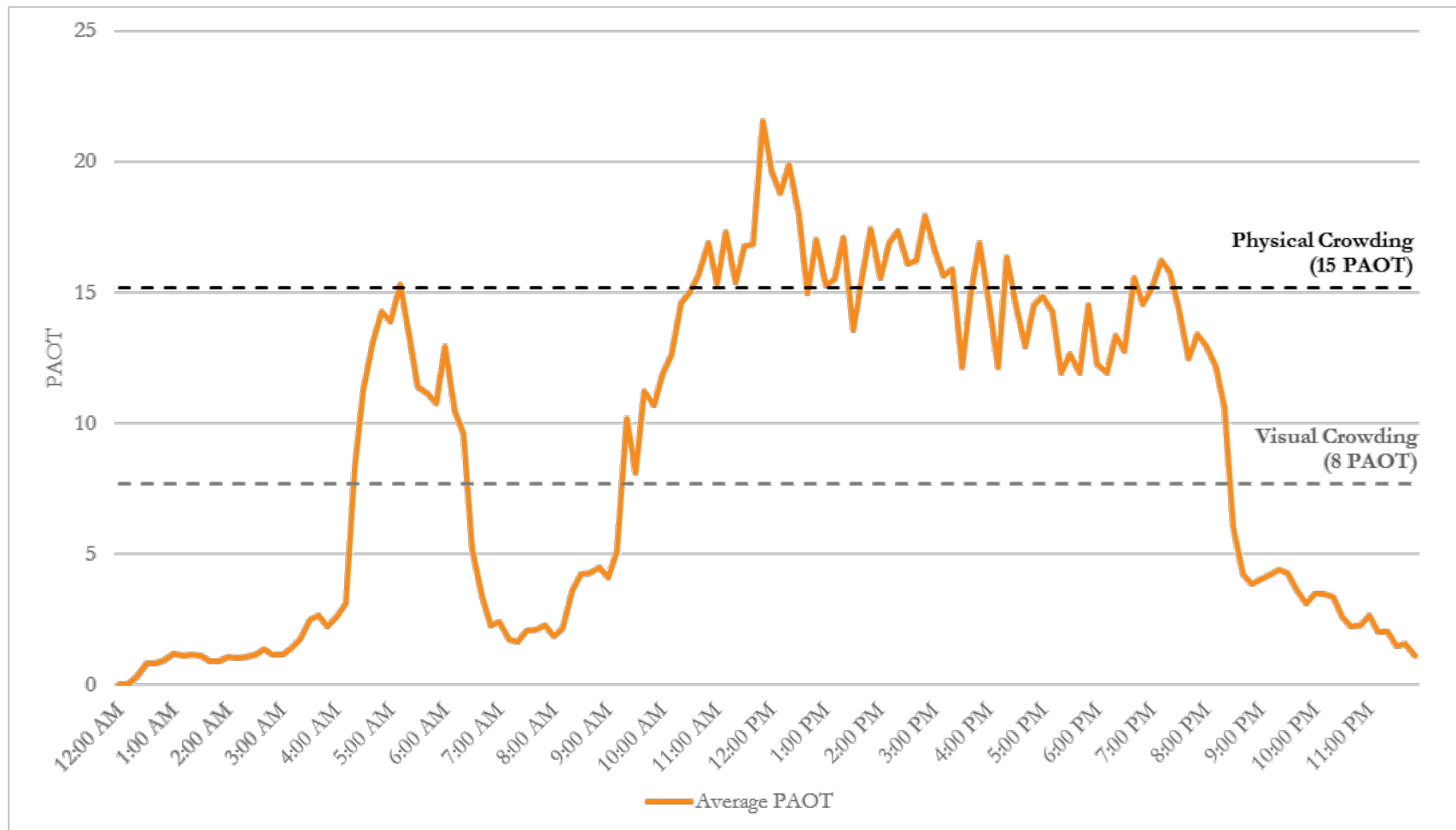


FIGURE 11: DESIGN DAY SIMULATION ESTIMATES OF PEAK SUMMER SEASON CONDITIONS – PAOT IN THE SUMMIT LOOP TRAIL INTERPRETIVE/VIEWING PLATFORM AREA

The results of the design day simulations suggest PAOT exceeds the preliminary draft visual crowding-related threshold approximately 80% of the time per day from 8 AM to 5 PM on “typically busy” peak summer season days. The design day simulation results also suggest PAOT in the Summit Loop Trail interpretive/viewing platform area exceeds the preliminary draft physical crowding-related threshold approximately 38% of the time per day from 8 AM to 5 PM on “typically busy” peak summer season days. These results suggest current levels of visitor use on Cadillac Mountain create potentially unacceptable levels of visitor crowding on the mountain summit.

3.3 | SIMULATION RESULTS: ESTIMATED PARKING- AND CROWDING-RELATED CAPACITIES

Results of simulations to estimate the parking- and crowding-related capacities of Cadillac Mountain are presented in this section. The capacity estimates are expressed as the maximum daily number of private vehicles that can be accommodated on Cadillac Mountain, in combination with design day trail use and bus arrivals, without exceeding preliminary draft thresholds for VAOT and PAOT. The capacity estimates were derived through an iterative process of simulations with the Cadillac Mountain Transportation and Visitor Use Model, ramping up and down the simulated daily number of private vehicles in each subsequent simulation, based on the results of the preceding simulation⁶. For example, if the simulated daily number of private vehicles in an iteration of the process produced results that exceeded the preliminary draft thresholds for VAOT and/or PAOT, the subsequent simulations were programmed to simulate a lower daily number of private vehicles. If the simulated daily number of private vehicles produced results that suggested more use could be accommodated without exceeding the preliminary draft thresholds for VAOT and/or PAOT, the subsequent simulations were programmed to simulate a higher number of daily private vehicles. This iterative process of simulations was continued to “solve for” the maximum daily number of private vehicles that can be accommodated in combination with design day trail use and bus arrivals on Cadillac Mountain, without exceeding the preliminary draft thresholds for VAOT and PAOT. As noted, the simulation analysis results at each step in the iterative process were average values from 120 replications of the model.

ESTIMATED DAILY PARKING-RELATED CAPACITIES

Results of the simulations to estimate daily parking-related capacities for Cadillac Mountain are presented in Figure 12 and Figure 13. The horizontal lines in Figure 12 and Figure 13 plot the estimated daily parking-related capacities for private vehicles on Cadillac Mountain based on the “unmanaged parking” and “managed parking” scenarios. The vertical bars in Figure 12 and Figure 13 plot the daily number of private vehicles on Cadillac Mountain measured during the 2015 summer data collection period, organized by date and by

⁶ Simulations to estimate capacities for Cadillac Mountain hold the number of trail uses and bus arrivals constant since bus arrivals maximize but don’t exceed designated bus parking capacities and trail use represents a nominal proportion of total visitor use on Cadillac Mountain.

descending order of daily number of private vehicles, respectively. The results of the simulations suggest, under the “unmanaged parking” scenario, a maximum of approximately 1,030 private vehicles (or 24% fewer than the design day number of private vehicles) can be accommodated per day on Cadillac Mountain without exceeding the preliminary draft threshold for VAOT. Under the “managed parking” scenario, the simulation results suggest approximately 1,172 private vehicles (or 10% fewer than the design day number of private vehicles) can be accommodated per day on Cadillac Mountain without exceeding the preliminary draft threshold for VAOT.

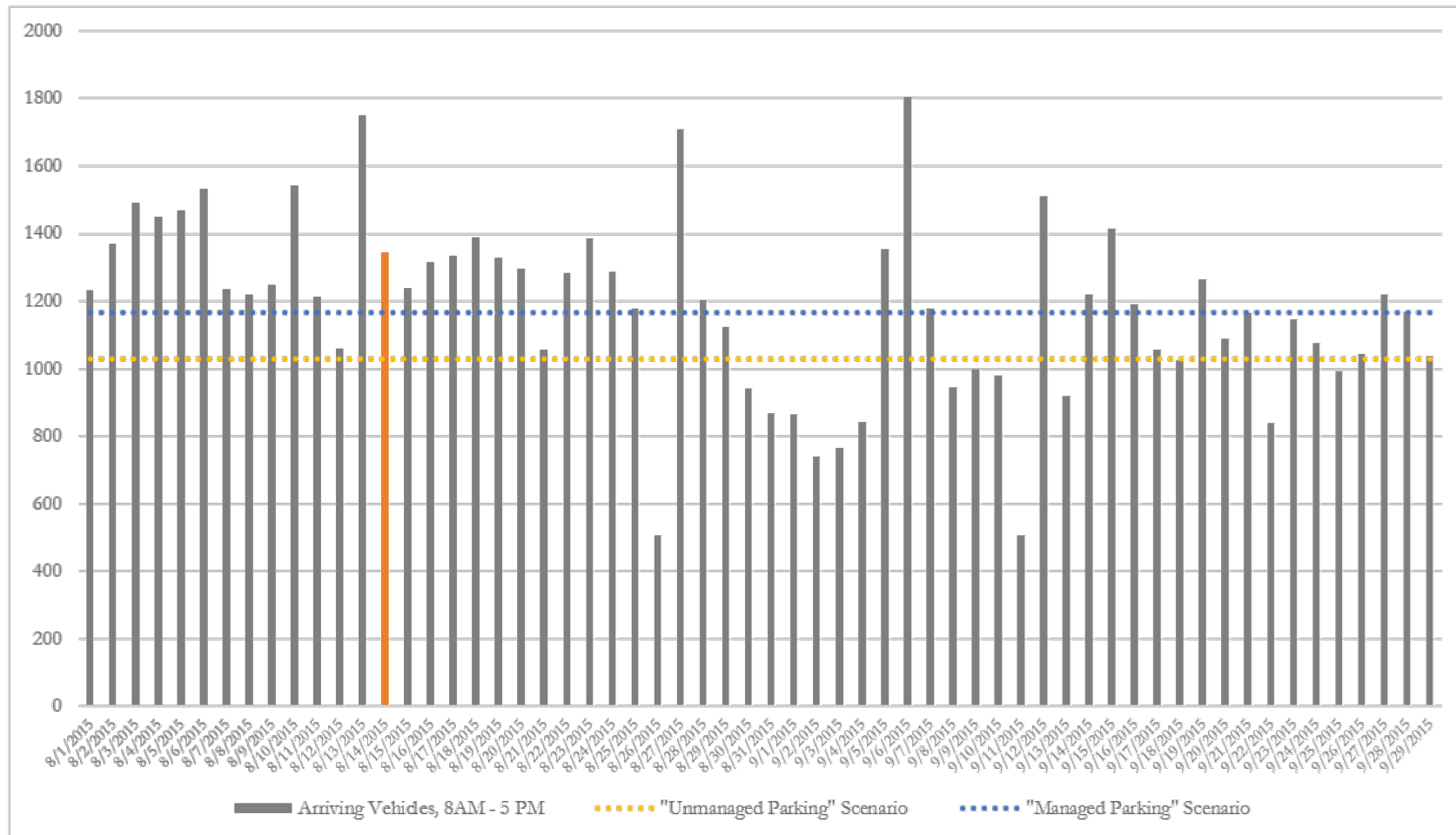


FIGURE 12: ESTIMATED PARKING-RELATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

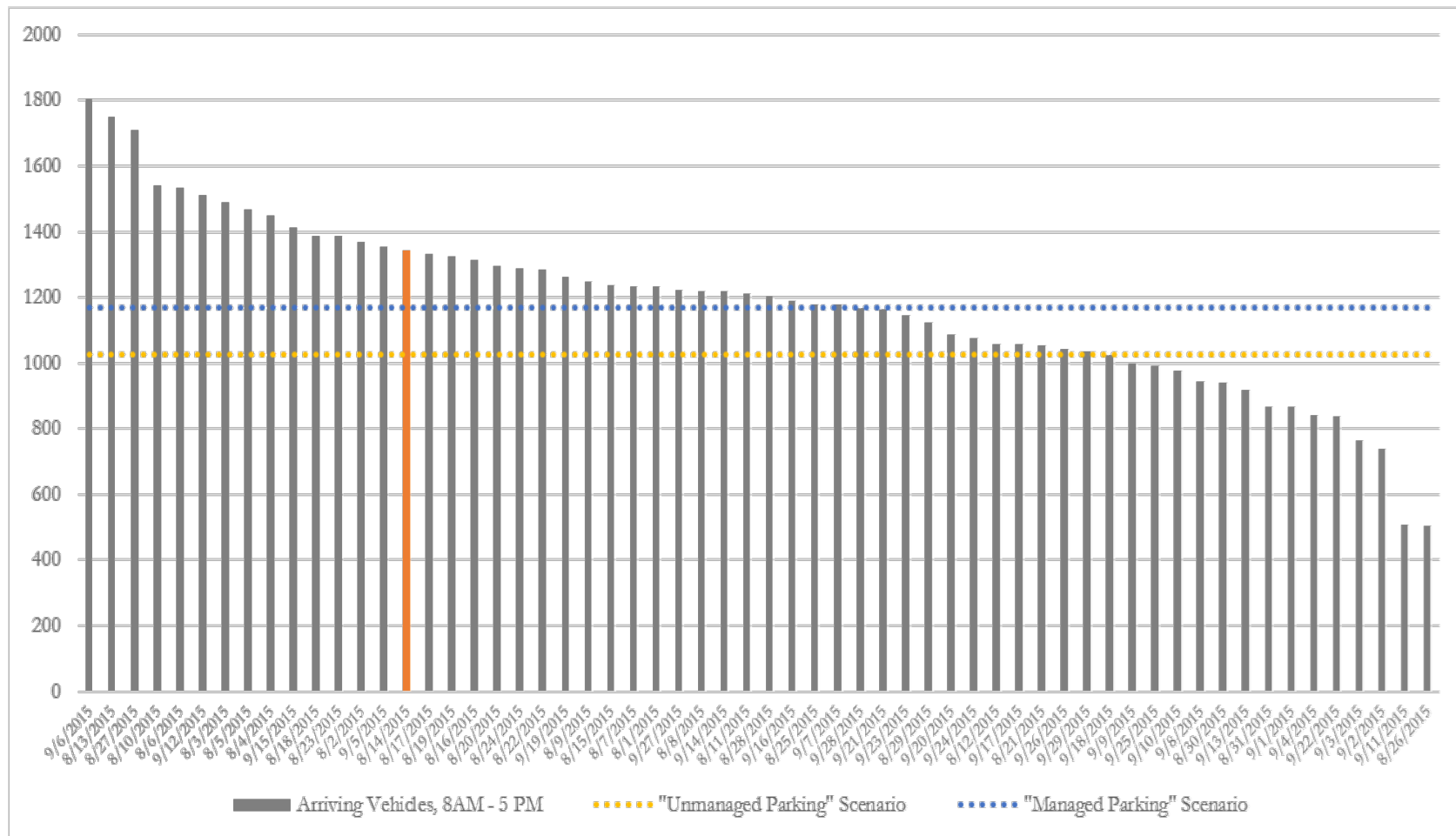


FIGURE 13: ESTIMATED PARKING-RELATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

ESTIMATED DAILY CROWDING-RELATED CAPACITIES

Results of the simulations to estimate daily crowding-related capacities for Cadillac Mountain are presented in Figure 14 and Figure 15. The horizontal lines in Figure 14 and Figure 15 plot the estimated daily crowding-related capacities for private vehicles on Cadillac Mountain based on the visual crowding- and physical crowding-related thresholds. The vertical bars in Figure 14 and Figure 15 plot the daily number of private vehicles on Cadillac Mountain measured during the 2015 summer data collection period, organized by date and by descending order of daily number of private vehicles, respectively. The results of the simulations suggest a maximum of approximately 350 private vehicles (or 74% fewer than the design day number of private vehicles) can be accommodated per day on Cadillac Mountain without exceeding the visual crowding-related threshold and approximately 962 private vehicles (or 29% fewer than the design day number of private vehicles) can be accommodated per day without exceeding the physical crowding-related threshold for PAOT in the Summit Loop Trail interpretive/viewing platform.

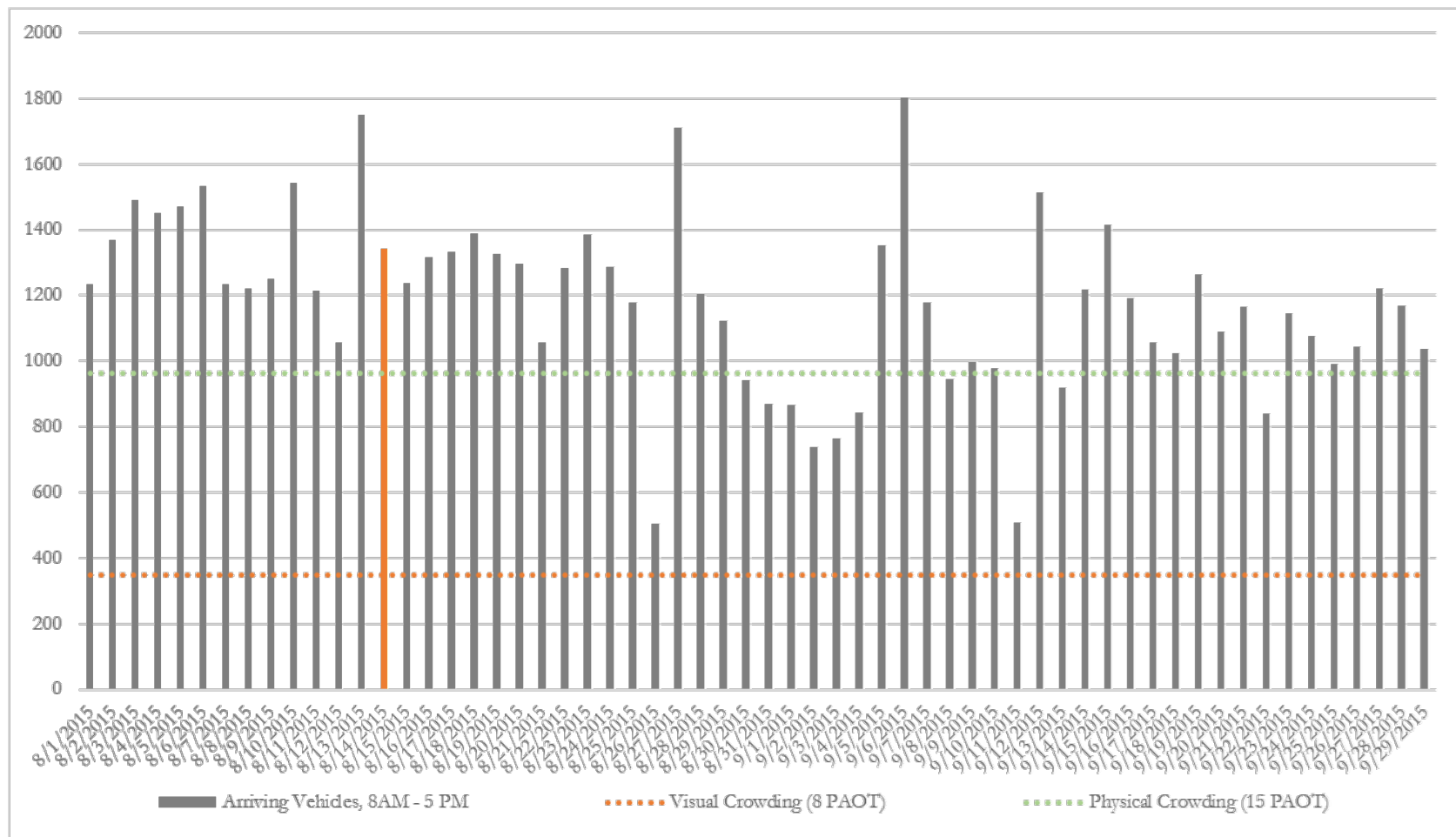


FIGURE 14: ESTIMATED CROWDING-RELATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

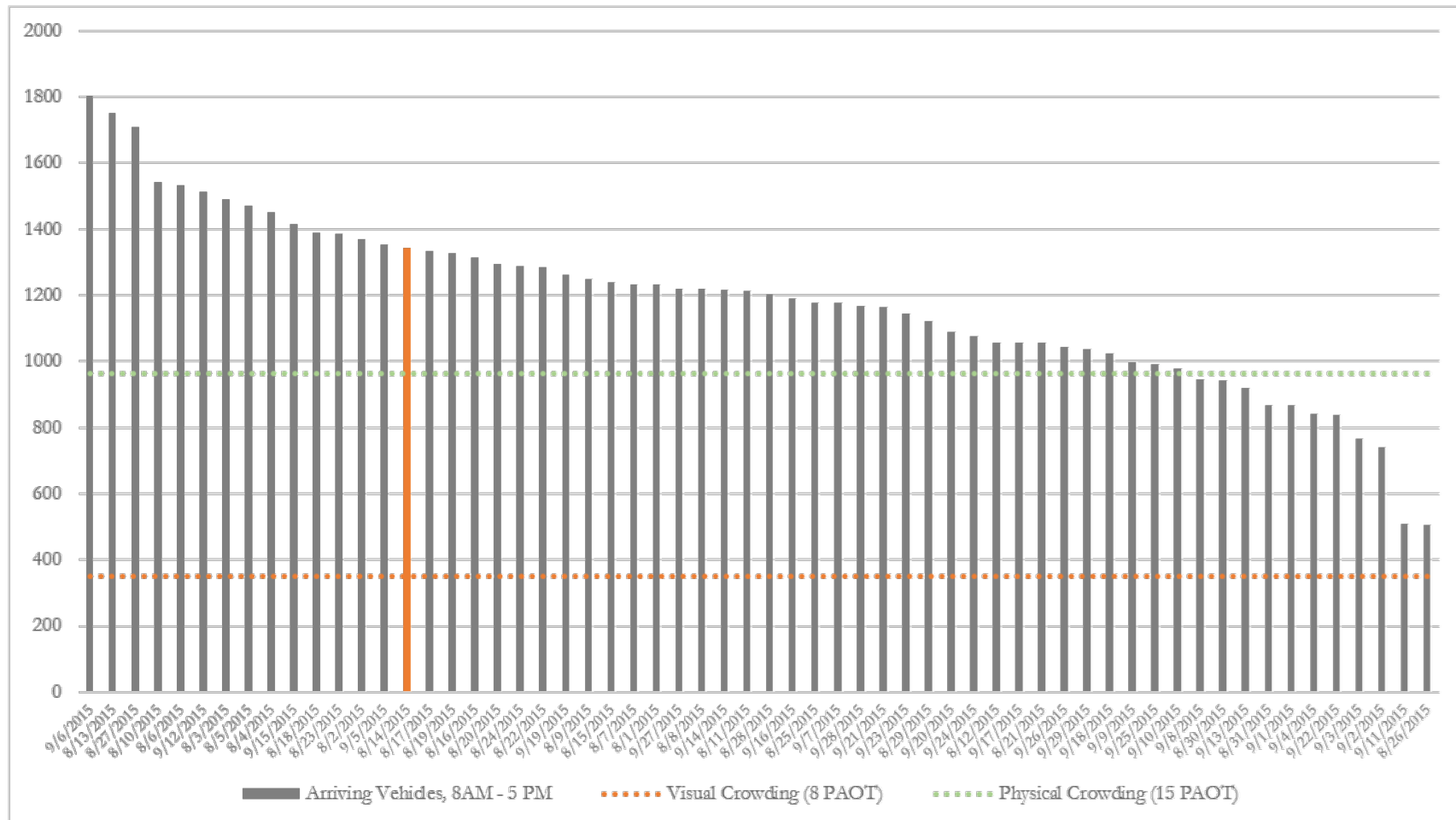


FIGURE 15: ESTIMATED CROWDING-RELATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

SUMMARY OF ESTIMATED DAILY CAPACITIES

The daily parking- and crowding-related capacities for Cadillac Mountain reported in the preceding paragraphs are presented together in Figure 16 and Figure 17. As in preceding figures with capacity estimates, the vertical bars in Figure 16 and Figure 17 plot the daily number of private vehicles on Cadillac Mountain measured during the 2015 summer data collection period, organized by date and by descending order of daily number of private vehicles, respectively. Viewing the capacity estimates together in Figure 16 and Figure 17 suggests the crowding-related capacities of Cadillac Mountain are slightly to substantially more limiting than the parking-related capacities, depending on which parking- and crowding-related capacities are compared. This suggests that even if visitor use on Cadillac Mountain can be managed according to the parking-related capacities estimated in this study by introducing transit service to offset overflow parking, it would potentially result in levels of visitor use that exceed the crowding-related capacities of Cadillac Mountain. Interestingly, the results suggest the parking-related capacity for Cadillac Mountain under the “managed parking” scenario and the crowding-related capacity based on the “physical crowding-related” threshold are very similar. The results further suggest it might not be practically feasible to manage daily visitor use according to the “visual crowding-related” threshold.

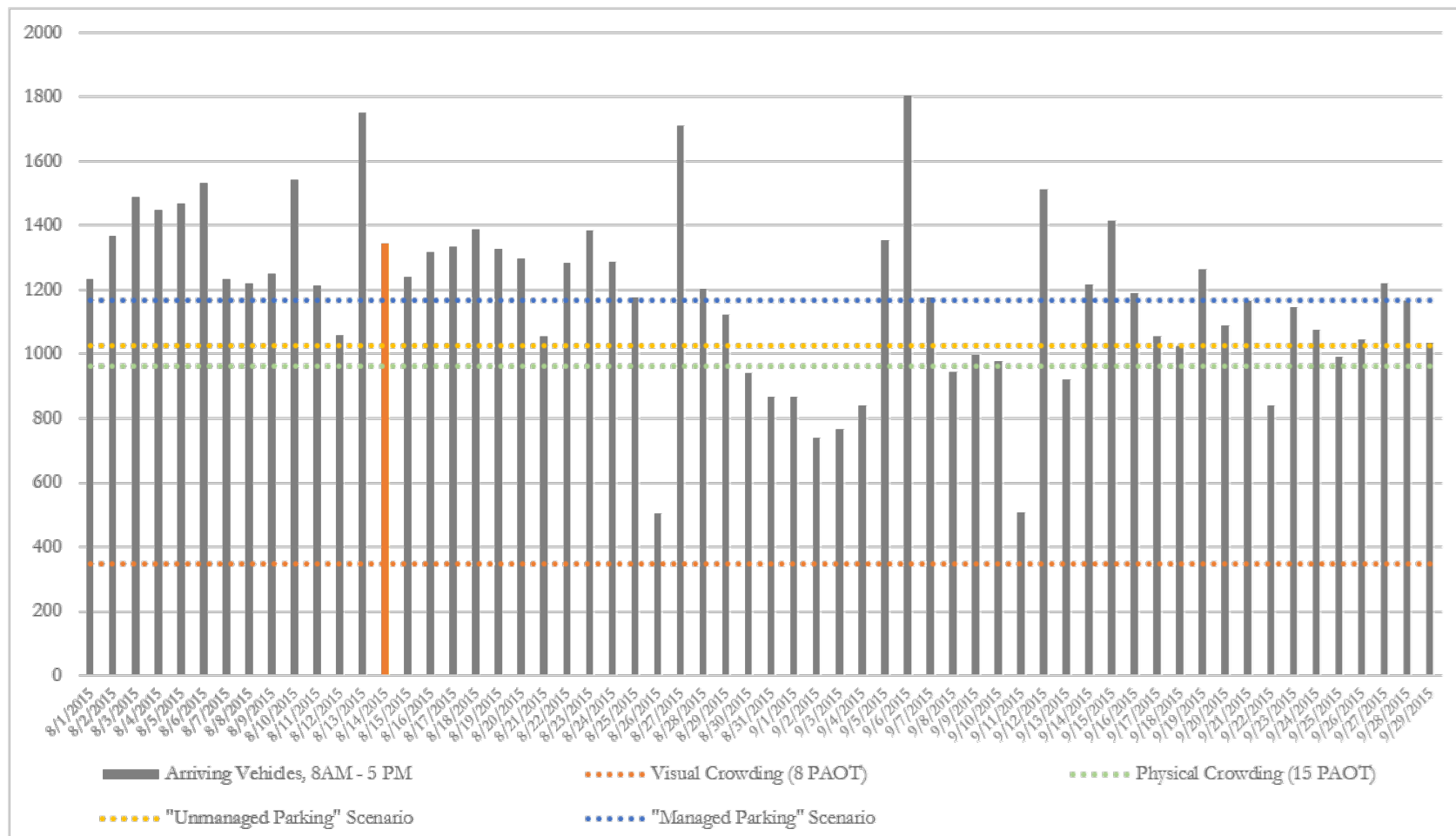


FIGURE 16: ESTIMATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

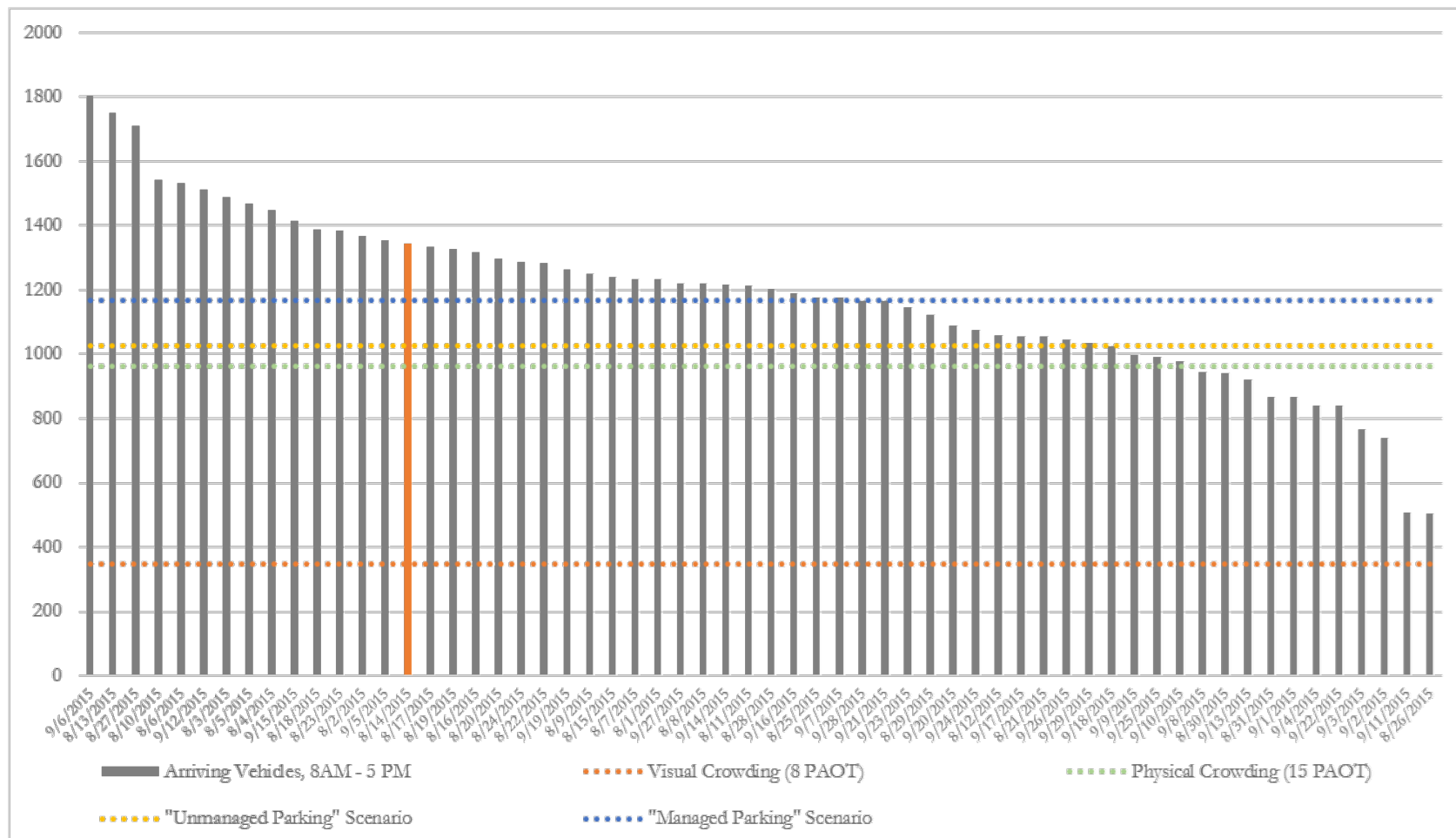


FIGURE 17: ESTIMATED CAPACITIES FOR DAILY NUMBER OF PRIVATE VEHICLES ON CADILLAC MOUNTAIN

4.0 MODEL VALIDATION

Model validation is defined as “the process of determining whether a simulation model is an accurate representation of a system, for particular objectives of the study” (Law and Kelton, 2000). In this project, a series of simulations was conducted with the Cadillac Mountain Transportation and Visitor Use Model to assess the validity of the simulation model estimates and results. Specifically, estimates from the Cadillac Mountain Transportation and Visitor Use Model for the two indicators of interest in this project (VAOT and PAOT) were validated against observation data collected on Cadillac Mountain during summer 2015 as part of this study and as part of a parking study conducted on Cadillac Mountain during summer 2014. Results of the model validation are presented in this section.

4.1 | VAOT

During summer 2014, a parking study was conducted on Cadillac Mountain. Results of the parking study included vehicle traffic volume counts on Cadillac Mountain Road and VAOT counts in the Cadillac Mountain Summit and Blue Hill Overlook parking lots on August 17, 2014 (VHB, 2014). To assess the validity of the simulation model’s VAOT estimates, the model was programmed with the vehicle traffic volume data collected on August 17, 2014 to estimate VAOT in the Cadillac Mountain Summit and Blue Hill Overlook parking lots. The average VAOT estimates from 50 replications of the model were compared to the VAOT data collected through direct observation on August 17, 2014 (Figure 18). The VAOT estimates from the Cadillac Mountain Transportation and Visitor Use Model closely overlap in Figure 18 with the VAOT counts measured through direct observation on August 17, 2014. Additionally, nearly all of the direct observation-based VAOT counts lie within the range of VAOT estimates from the 50 replications of the Cadillac Mountain Transportation and Visitor Use Model. These results provide a high degree of confidence in the validity of the VAOT estimates from the Cadillac Mountain Transportation and Visitor Use Model presented in this report.

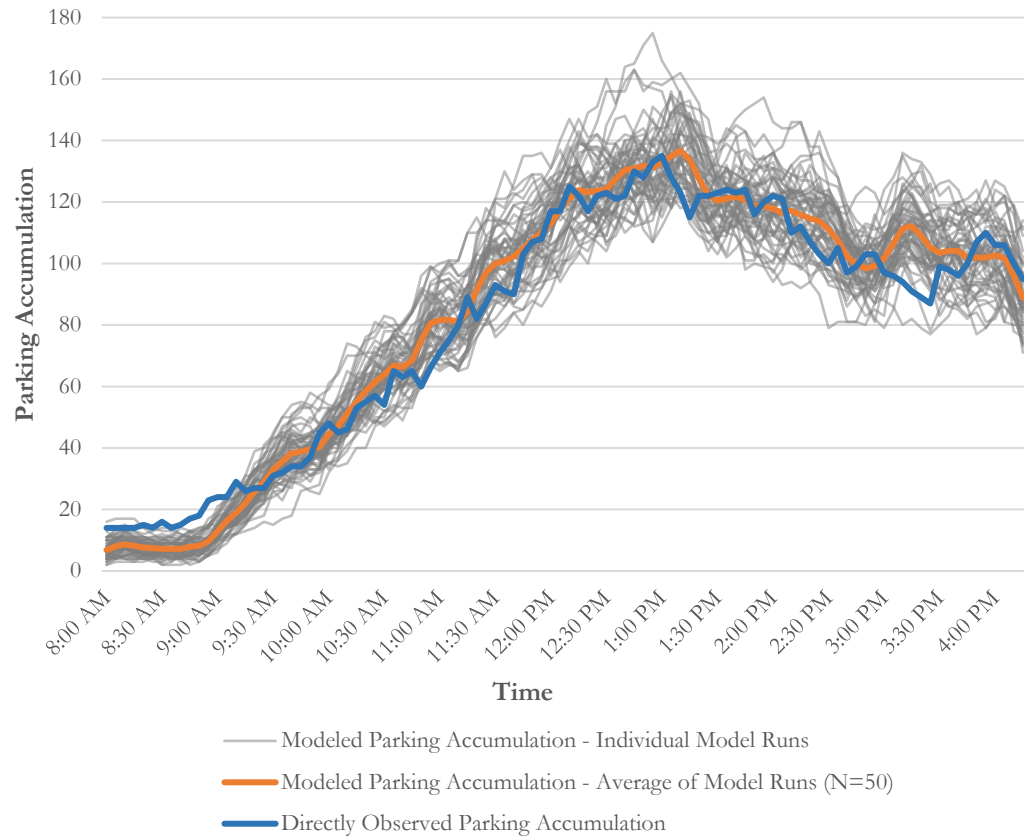


FIGURE 18: VALIDATION RESULTS FOR VAOT ESTIMATES

4.2 | PAOT

As noted, PAOT counts were conducted on the summit of Cadillac Mountain during summer 2015. These data, coupled with vehicle traffic counts for the days on which PAOT counts were conducted, provide a basis to assess the validity of the Cadillac Mountain Transportation and Visitor Use Model's estimates of PAOT on the Cadillac Mountain summit. Specifically, a series of simulations was conducted with the model programmed to simulate the vehicle traffic volume data collected on each of the three days in summer 2015 when PAOT counts were conducted. The average PAOT estimates from 50 replications of the model at each of the three daily traffic volumes were compared to the corresponding PAOT data collected through direct observation on Cadillac Mountain (Figure 19 through Figure 21). The scatterplots of direct observation counts and corresponding model estimates of PAOT on the Summit Loop Trail platforms directly overlap with each other, suggesting the model estimates of PAOT are in the same range as on-the-ground observations of PAOT. These results provide a high degree of confidence in the validity of the PAOT estimates from the Cadillac Mountain Transportation and Visitor Use Model presented in this report.

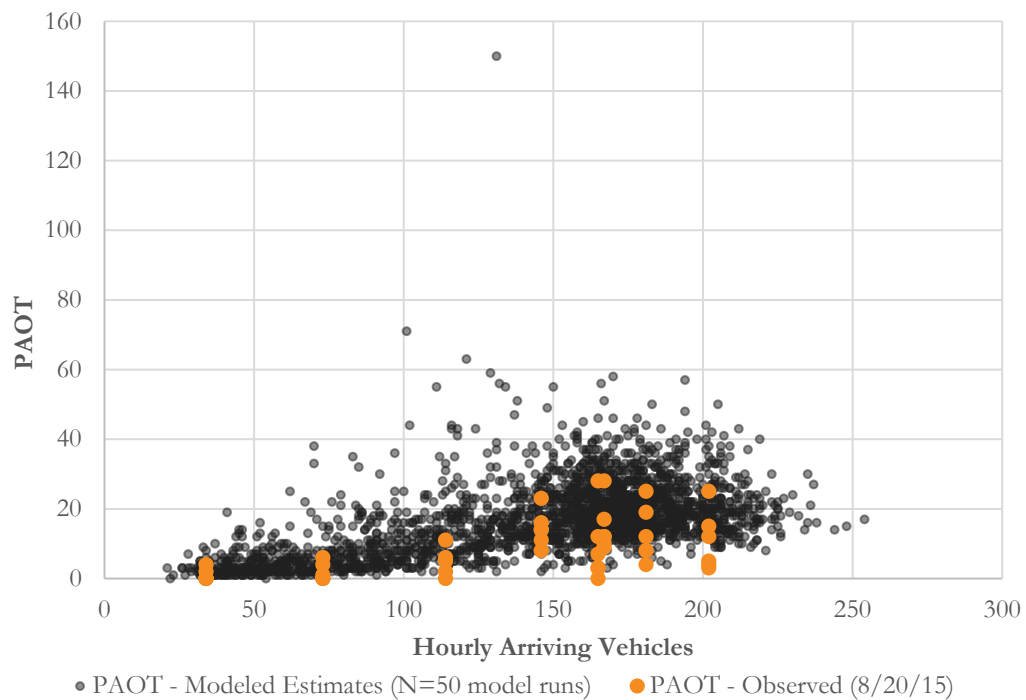


FIGURE 19: VALIDATION RESULTS FOR PAOT ON THE SUMMIT LOOP TRAIL PLATFORMS (AUGUST 20, 2015)

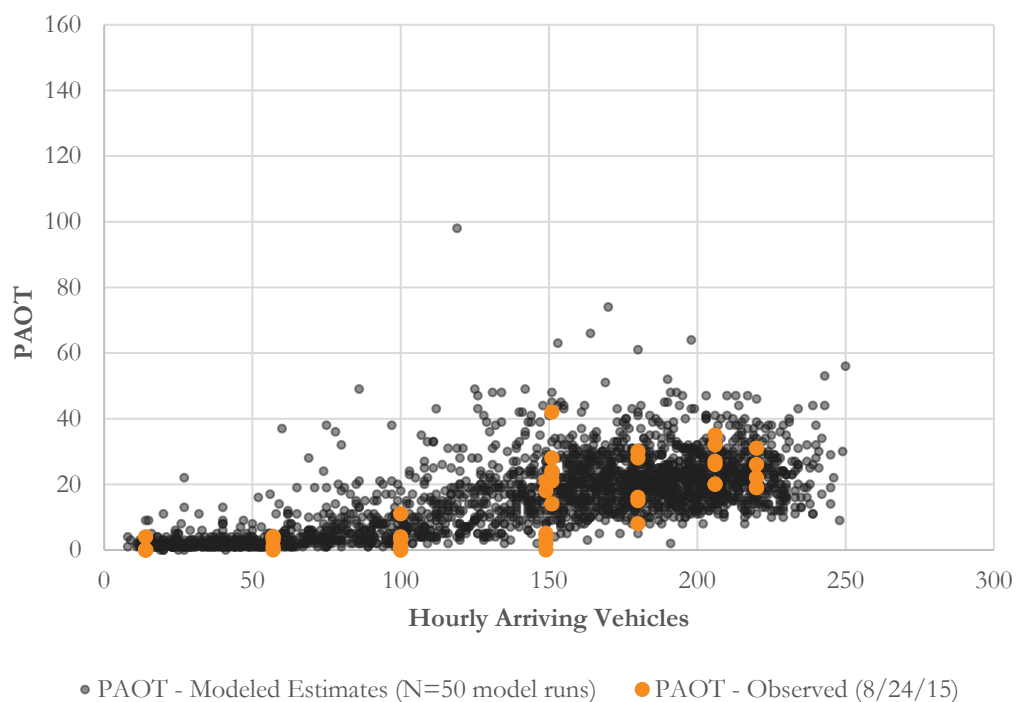


FIGURE 20: VALIDATION RESULTS FOR PAOT ON THE SUMMIT LOOP TRAIL PLATFORMS (AUGUST 24, 2015)

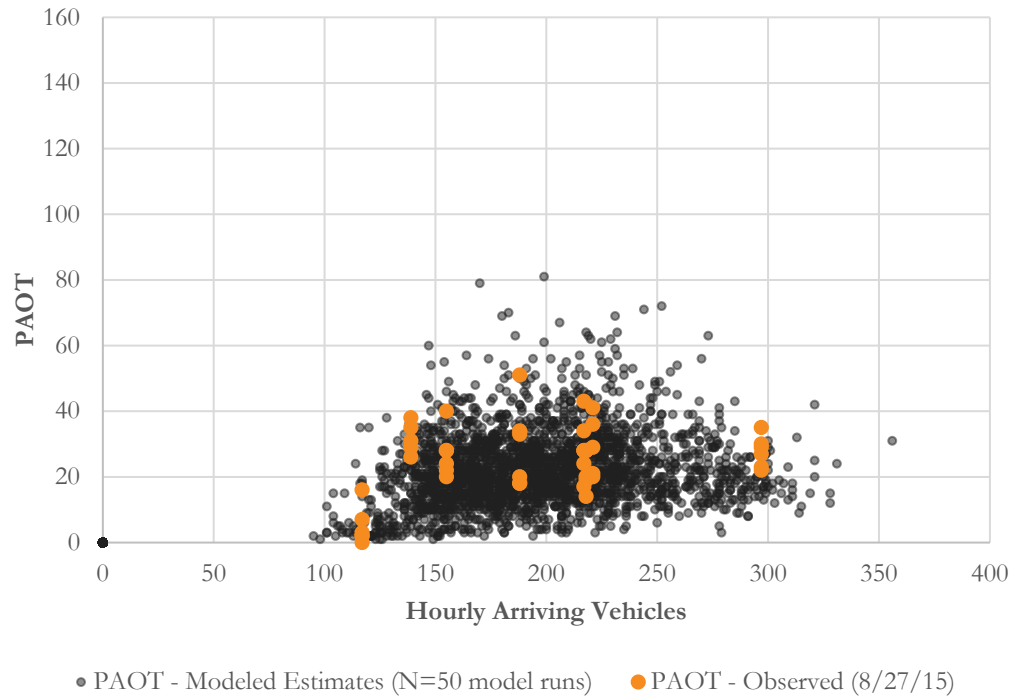


FIGURE 21: VALIDATION RESULTS FOR PAOT ON THE SUMMIT LOOP TRAIL PLATFORMS (AUGUST 27, 2015)

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