



Saguaro National Park

Visitor Use Study—Descriptive Data

Final Report

Natural Resource Report NPS/SAGU/NRR—2023/XXXX



ON THE COVER

Sunset at Saguaro National Park

Photo by NPS

Saguaro National Park

Visitor Use Study—Descriptive Data

Final Report

Natural Resource Report NPS/SAGU/NRR—2023/XXXX

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The Otak Team



Prepared for:
Saguaro National Park



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Introduction

Saguaro National Park (SAGU) is located in Tucson, Arizona, and offers its visitors the experience to see enormous cacti in a desert landscape. Visitation to SAGU has increased significantly in recent years. Paired with visitation increases are anecdotal observations by park staff of visitors increasingly accessing the park from previously low-use areas. These visitor behaviors are causing crowding-related issues in the park, especially at trailhead access points, where existing parking capacities cannot accommodate the growing demand. As such, the SAGU management team needs updated information about where visitors access the park, how many visitors enter the park from these access locations, and what visitors are doing at these sites in order to accurately estimate park visitation and guide monitoring strategies and management planning processes.

As part of the SAGU Visitor Use Study, the research team was tasked with collecting and summarizing updated descriptive data measures of transportation and visitor-use conditions at key locations within the park. The data collected and summarized in this report will help inform important decisions about park infrastructural improvements (e.g., parking lot expansions) and visitor use management, as well as update the official visitor use statistics protocols for estimating visitation to SAGU.

Another key challenge for SAGU park staff is accurately defining procedures for differentiating between visitors engaging in recreational activities and those visiting the park for non-recreation purposes, such as commuting to work. Park staff's current counting procedure relies on a method that distinguishes between visitor types (i.e., recreation vs. non-recreation visitors) with limitations. For example, estimates of non-recreation visitors to SAGU are derived from counts at limited locations near the West Picture Rocks Road area, but this approach does not fully capture the proportion of non-recreation visitors throughout the entire park. Developing a method that effectively differentiates between these visitor categories and explicitly estimates the proportion of recreation visitors to SAGU will provide valuable insights to park staff about visitation. Moreover, the findings from this study will help inform future updates and improvements to the current visitor use counting procedures.

In sum, the primary purposes of this project are to:

- Gather and summarize updated descriptive data on transportation and visitor use conditions in the park, which include (1) trail and traffic counter counts, (2) trail and traffic counter calibration counts, and (3) parking accumulation counts.
- Analyze passive mobile data (PMD) to estimate the proportions of recreation and non-recreation visitors to SAGU, particularly focusing on the proportion of recreation traffic on park-maintained roads.

The remainder of this report is organized as follows:

- The Methods section describes the study area and study period, as well as the methods used to collect, clean, and analyze the on-site data. This section also describes the methods used to acquire, clean, and analyze PMD to estimate the proportion of recreation visitors.
- The Results section provides graphical and/or tabular summaries of (1) descriptive data collected on traffic, parking, and/or trail use conditions during the spring 2022 peak visitor use season, and (2) PMD analysis results. Given the exploratory nature of the PMD analysis used in this study to differentiate visitor types, this section also reports insights from comparing PMD with visitor survey data.

Methods

This section of the report describes the study area; study period; methods used to collect, clean, and analyze data collected on site; and methods used for acquiring and analyzing passive mobile data as part of the SAGU Visitor Use Study.

Study area

Located in southwestern Arizona, SAGU includes roughly 92,000 acres of land spread across two districts: the Rincon Mountain District and the Tucson Mountain District, separated by the City of Tucson, Arizona (Figure 1). The Rincon Mountain District (Figure 2) is also referred to as the East District, and the Tucson Mountain District (Figure 3) is also referred to as the West District. The park offers a variety of recreation experiences, including hiking, scenic driving, sight-seeing, camping, and bicycling. It's important to note that the three main access roads into the West District (i.e., West Picture Rocks Road, North Sandario Road, and North Kinney Road) are trafficked by both recreation visitors and commuters traveling through the park. The presence of pass-through traffic poses a challenge in distinguishing between recreation and non-recreation visits in this part of the park.

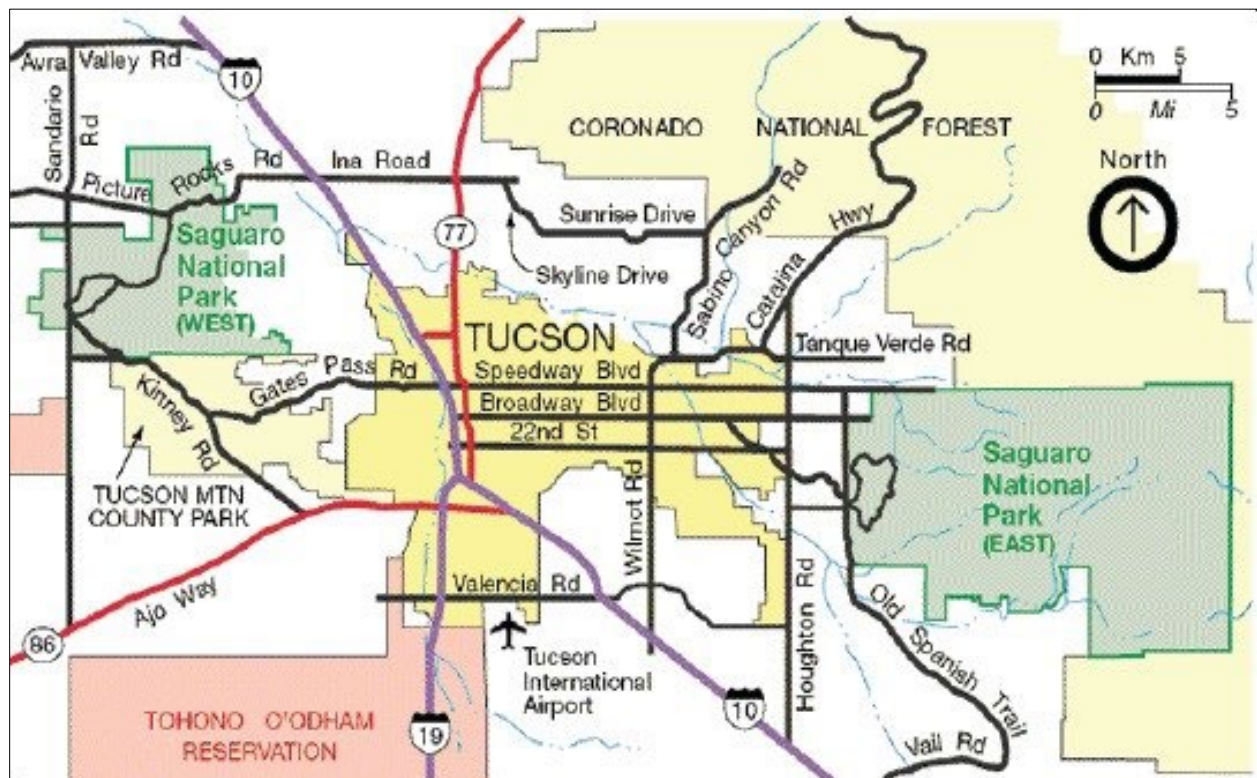


Figure 1. East and West Districts of SAGU in Tucson, Arizona.

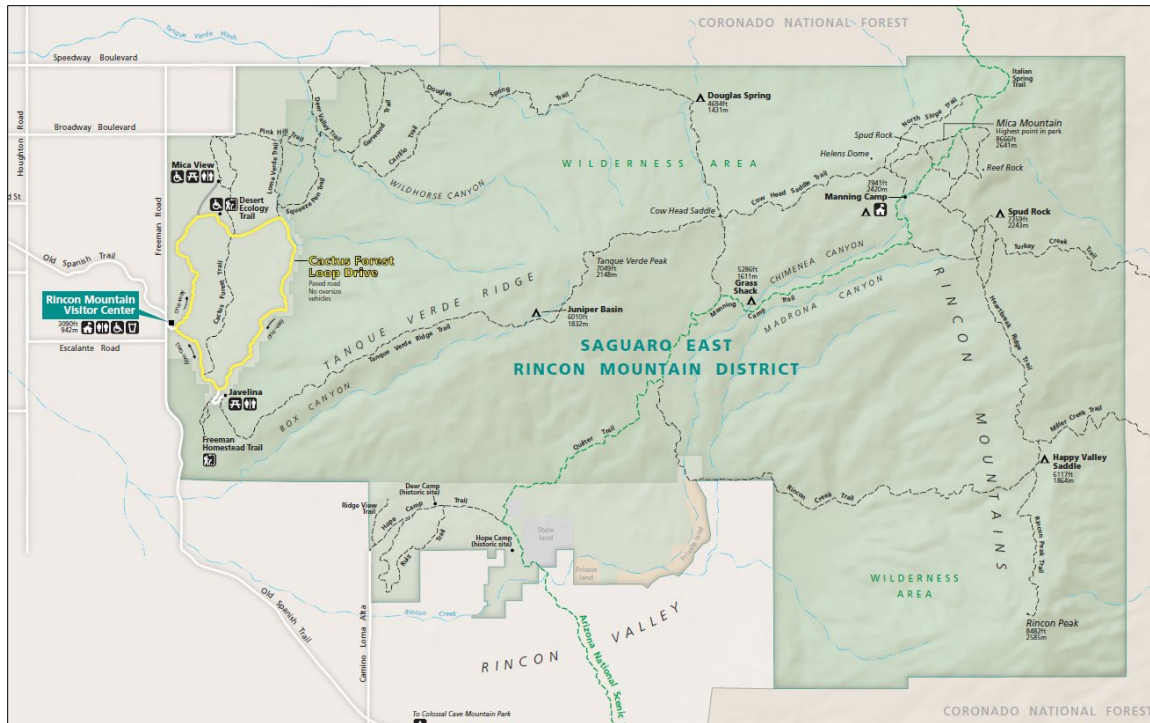


Figure 2. SAGU's Rincon Mountain (East) District.

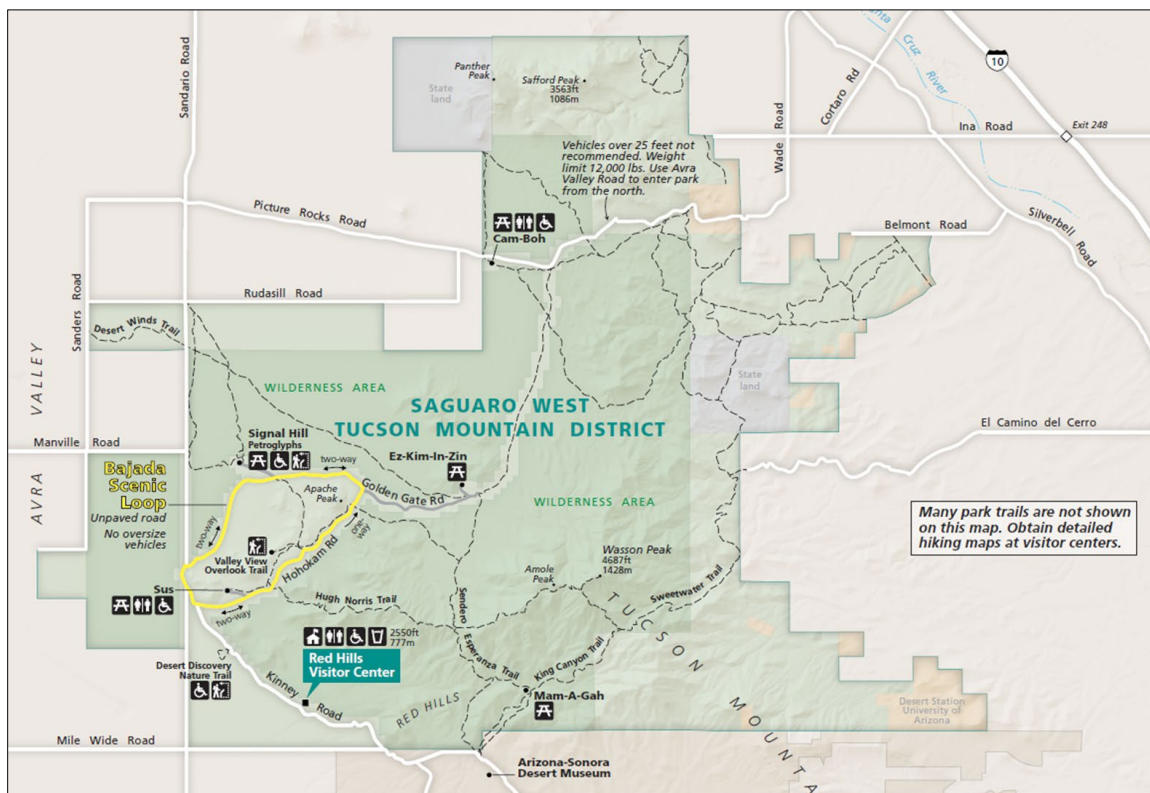


Figure 3. SAGU's Tucson Mountain (West) District.

Study period

This subsection defines and contextualizes the data collection periods for the various types of data sampled for the SAGU Visitor Use Study. Traffic and trail counter data are collected year-round at SAGU by park staff, and a subset of these data were analyzed for the period between February 1 and April 30, 2022, which is referred to hereafter as the “counting period.” The parking data were collected from March 18 through March 20, 2022 which is referred to hereafter as the “parking sampling period.” The trail camera calibration data were collected between March 17 through March 23, 2022, which is referred to hereafter as the “calibration sampling period.”

Figure 4 presents the total number of recreation visits to SAGU per year from 1985 through 2022, as reported by the NPS Visitor Use Statistics Program. From 1985 through 2015, the number of recreation visits to SAGU was relatively consistent from year to year, ranging from approximately 600,000 to 800,000 annual recreation visits per year. In the last six years, however, the annual recreation visit count to the park has risen substantially, with nearly 1.08 million recreation visits in 2021. In the year 2022, there were roughly 908,000 recreation visits, making it SAGU’s fifth busiest year-to-date. As such, the data collected as part of the 2022 SAGU Visitor Use Study and presented in this report summarize visitor use conditions during one of the park’s busiest years in the last three decades.

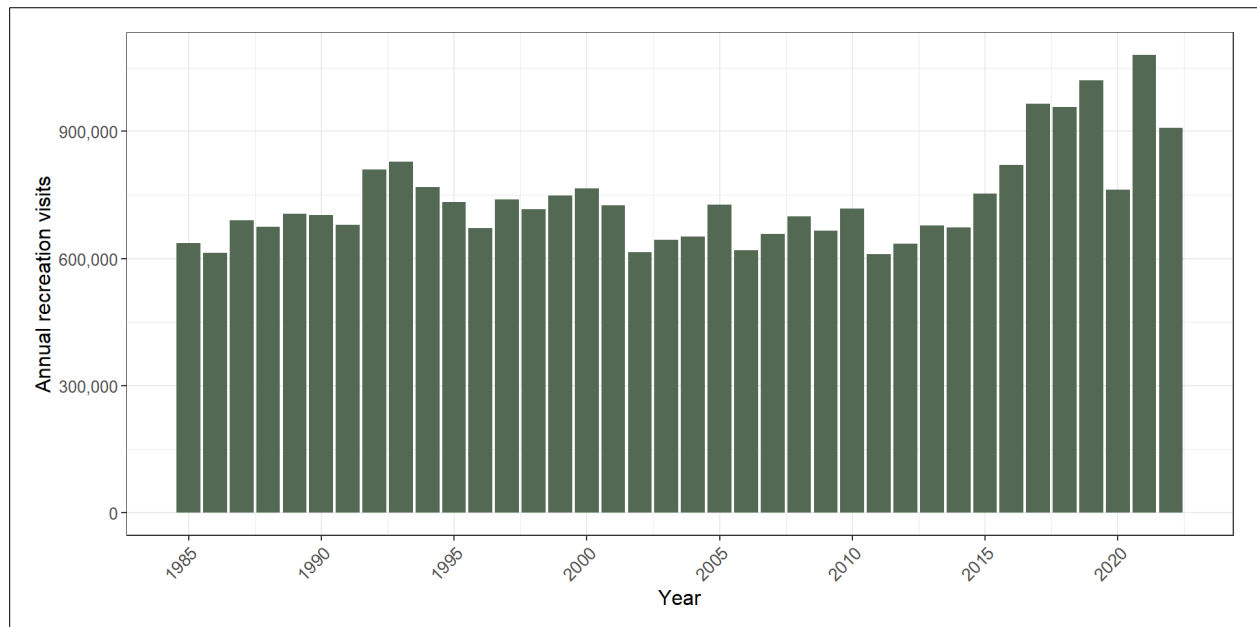


Figure 4. Annual recreation visits to SAGU (1985–2022).

Focusing specifically on 2022, Figure 5 presents the total number of recreation visits to SAGU by month for the 2022 calendar year. These results suggest that the February 1 through April 30 counting period occurred during the peak period of visitor use in 2022. Similarly, the parking sampling period and the calibration sampling period that occurred in late March overlapped with SAGU's peak month of visitor use in 2022. Correspondingly, the results presented in this study provide insight into transportation and visitor use conditions during the 2022 peak period of visitor use in SAGU.

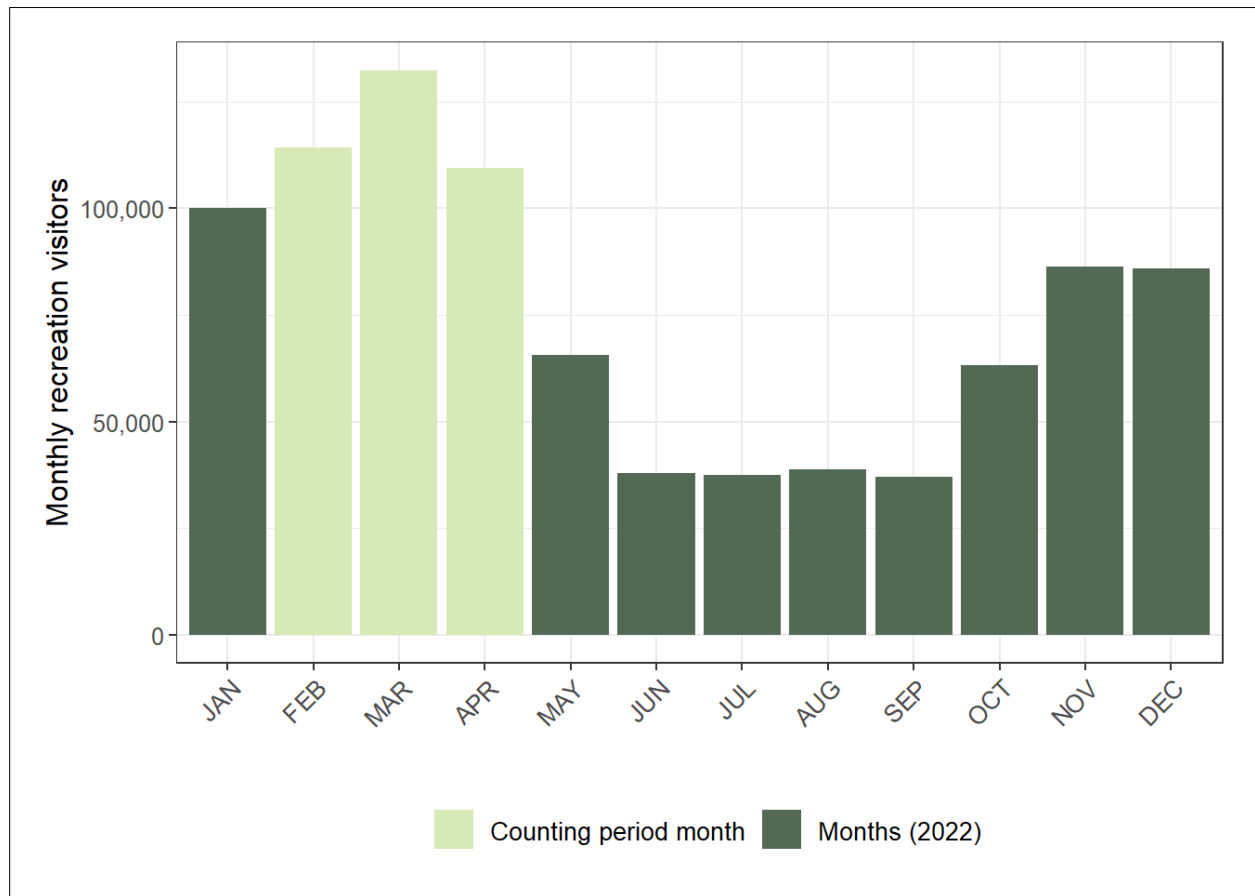


Figure 5. Monthly recreation visits to SAGU (January through December 2022).

Focusing further to the daily level, Figure 6 presents daily inbound traffic volumes recorded in the Rincon Mountain District¹ and Figure 7 presents total (bi-directional) daily traffic volumes recorded in the Tucson Mountain District² for February through April 2022 in order to describe the parking and calibration sampling periods in the context of the broader peak spring season. In the Rincon Mountain District, calibration and parking data were collected on weekend days with approximately average inbound vehicle traffic volumes, and on weekdays with slightly above average inbound vehicle traffic volumes during the peak spring season. Meanwhile, in the Tucson Mountain District, calibration and parking data were collected on weekend days and on weekdays with approximately average total vehicle traffic volumes for the peak spring season.

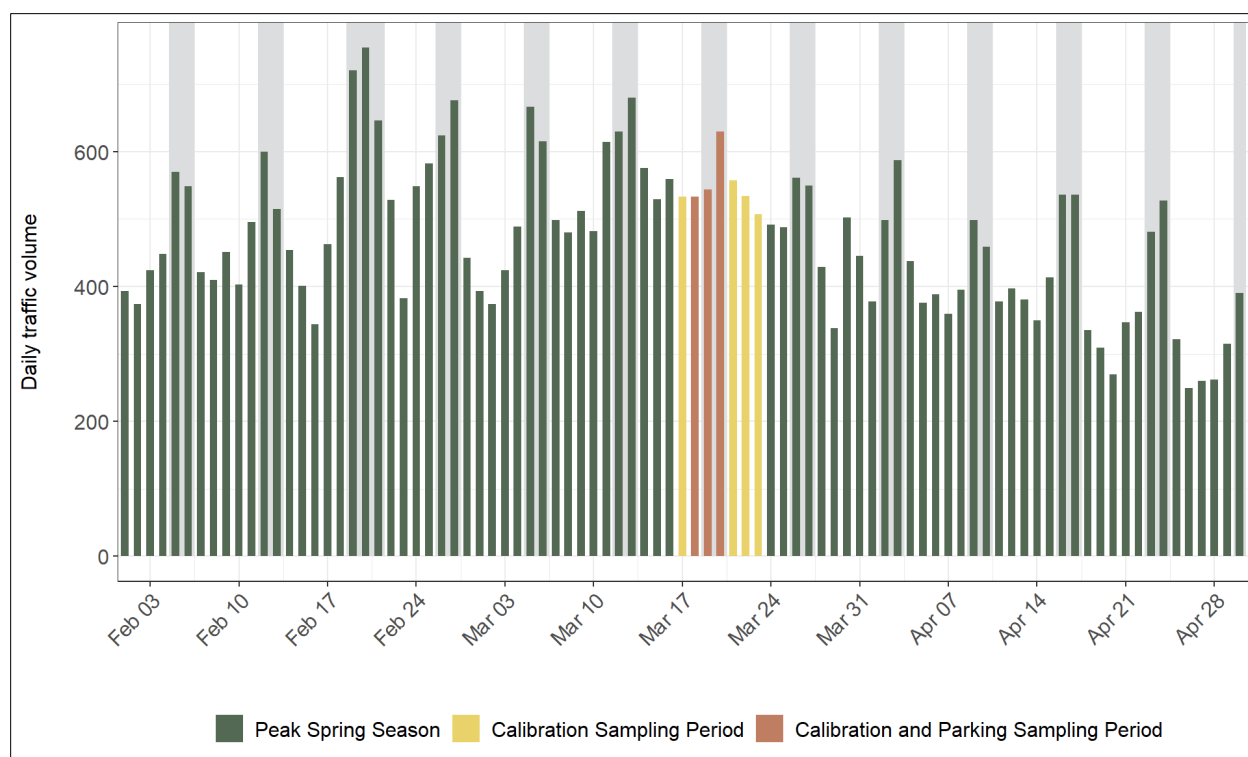


Figure 6. Daily inbound traffic volumes for the Rincon Mountain District, with the parking and calibration sampling periods highlighted (gray shading indicates weekends/holidays).

¹ Traffic volumes are the sum of lane 1 (south) and lane 3 (north) at the Rincon Mountain District FOTSC Station 903 traffic counter. These data were used to represent relative visitor use level trends in the Rincon Mountain District during the peak spring season as an approximation from best available data of trends at the locations in this district.

² Traffic volumes are the sum of eastbound and westbound vehicle counts along West Picture Rocks Road, just west of the turnoff for the Cam-Boh Picnic Area, as recorded by the FOTSC Station 904 traffic counter. These data were used to represent relative visitor use level trends in the Tucson Mountain District during the peak spring season as an approximation from best available data of trends at the locations in this district.

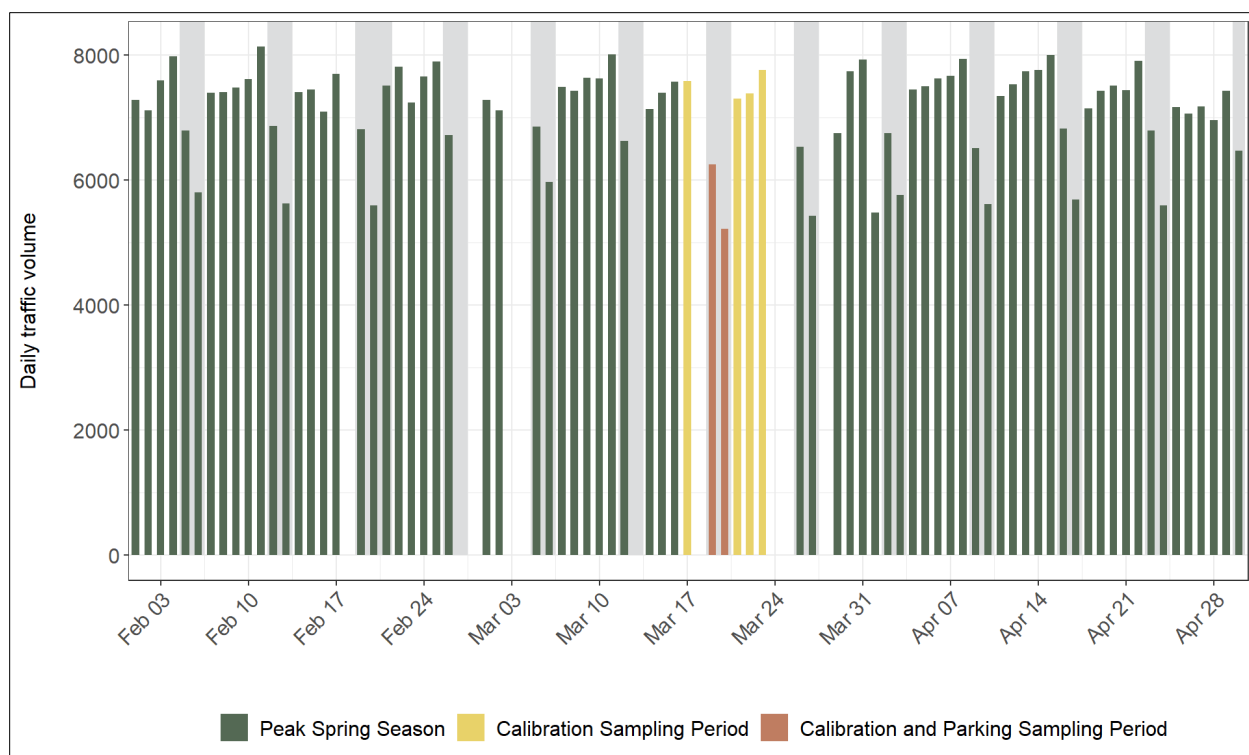


Figure 7. Total daily traffic volumes for the Tucson Mountain District, with the parking and calibration sampling periods highlighted (gray shading indicates weekends/holidays).³

On-site data collection

Three types of data were collected on site as part of the SAGU Visitor Use Study: (1) trail and traffic counter counts, (2) trail and traffic counter calibration counts, and (3) parking accumulation counts. Table 1 presents a detailed summary of each data collection type, by location and by district, with corresponding data collection dates, sources (i.e., “Research team” or “NPS”), and methods. The locations where data for each of the study components were collected is illustrated in Figure 8 and Figure 9.

³ Some data points are missing due to data gaps where traffic counts are unavailable during those periods.

Table 1. 2022 SAGU Visitor Use Study data collection locations.

Data Type	Location	District	Date (2022)	Source	Method
Roadway traffic calibration	Golden Gate Road	West	Mar 17 – Mar 23	Research team	Infrared camera
Roadway traffic calibration	Hohokam Road	West	Mar 17 – Mar 23	Research team	Infrared camera
Roadway traffic calibration	Tucson Mountain District Visitor Center	West	Mar 17 – Mar 23	Research team	Infrared camera
Roadway traffic volumes	Golden Gate Road	West	Feb 1 – Apr 30	NPS	Magnetometer traffic counter
Roadway traffic volumes	Hohokam Road	West	Feb 1 – Apr 30	NPS	Magnetometer traffic counter
Roadway traffic volumes	Tucson Mountain District Visitor Center	West	Feb 1 – Apr 30	NPS	Magnetometer traffic counter
Trail use volumes	Broadway Trailhead	East	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail use volumes	Camino Loma Alta Trailhead	East	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail use volumes	Douglas Spring Trailhead	East	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail use volumes	El Camino del Cerro Trailhead	West	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail use volumes	King Canyon Trailhead	West	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail use volumes	Scenic Loop Trailhead	West	Feb 1 – Apr 30	NPS	Infrared trail counter
Trail calibration	Broadway Trailhead	East	Mar 17 – Mar 23	Research team	Infrared camera
Trail calibration	Camino Loma Alta Trailhead	East	Mar 17 – Mar 23	Research team	Infrared camera
Trail calibration	Douglas Spring Trailhead	East	Mar 17 – Mar 23	Research team	Infrared camera
Trail calibration	El Camino del Cerro Trailhead	West	Mar 17 – Mar 23	Research team	Infrared camera
Trail calibration	King Canyon Trailhead	West	Mar 17 – Mar 23	Research team	Infrared camera
Trail calibration	Scenic Loop Trailhead	West	Mar 17 – Mar 23	Research team	Infrared camera
Parking conditions	Broadway Trailhead	East	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Cam-Boh Picnic Area	West	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Camino Loma Alta Trailhead	East	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Douglas Spring Trailhead	East	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Hugh Norris Trailhead	West	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Rincon Mountain District Visitor Center	East	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Scenic Loop Trailhead	West	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Signal Hill Picnic Area	West	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Tanque Verde Ridge Trailhead	East	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Tucson Mountain District Visitor Center	West	Mar 18 – Mar 20	Research team	Video camera footage
Parking conditions	Valley View	West	Mar 18 – Mar 20	Research team	Video camera footage

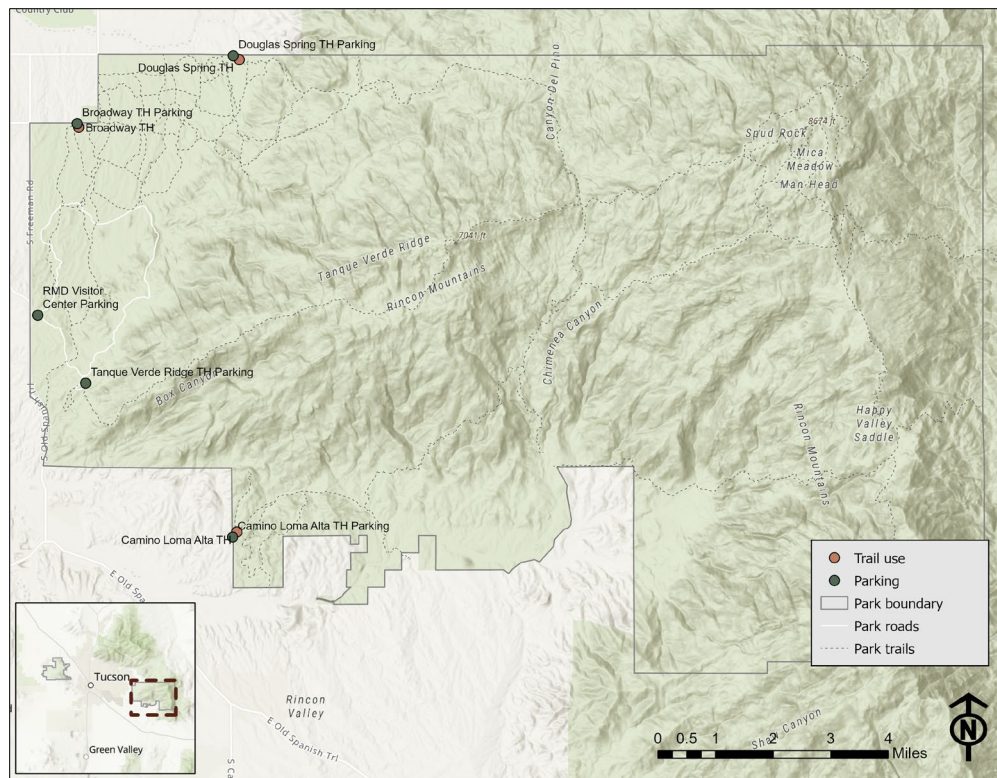


Figure 8. SAGU Visitor Study sampling locations: Rincon Mountain (East) District.

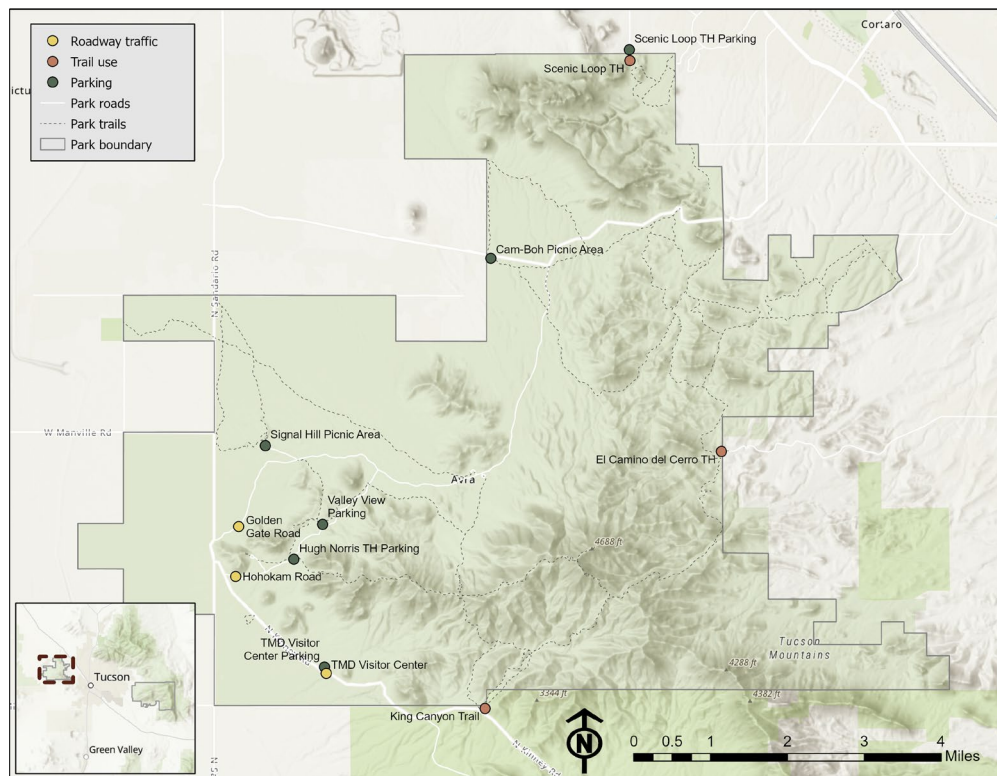


Figure 9. SAGU Visitor Study sampling locations: Tucson Mountain (West) District.

The following subsections describe on-site data collection methods and analysis protocols for each of the data types in more detail.

Traffic and trail use volumes and calibration

Sampling procedures

Field staff deployed ten cameras during the calibration sampling period of March 17 through March 23, 2023, along four roadways and six trails co-located with NPS traffic and trail counting equipment to collect calibration counts via photo data. These locations were selected in consultation with NPS. Because traffic counts at the counter located on Cactus Forest Drive west of the Rincon Mountain District Visitor Center are recorded as monthly totals instead of hourly counts, a calibration analysis was not possible for this location. As such, the nine counting locations for which calibration analyses were conducted are listed in Table 1 and depicted in Figure 8 and Figure 9. The resulting calibration photo data were post-processed into hourly inbound and outbound visitor use counts.

Analysis methods

Using traffic and trail counter data provided by NPS, regression analyses were conducted to model the relationship between raw hourly traffic and trail counter data, and the corresponding hourly calibration counts collected via cameras for each of the nine camera calibration counting locations. These regression analyses were conducted to derive correction factors (i.e., calibration multipliers) to convert raw counter data to estimates of actual visitor use. First, separate regression models⁴ were estimated for each counting location, with photo-based counts of total (inbound and outbound) use as the dependent variable and corresponding counter data of total use as the independent variable. The results section presents the final regression models by counter location.

After applying the calibration multipliers to the raw counter data, the research team applied a streamlined data cleaning process to treat outlier values and missing data for all traffic and trail counter datasets. For each counter location, total (inbound and outbound) calibrated hourly traffic and trail use counts were screened for statistically and substantive outlier values using a time series analysis that considered hourly, daily, and monthly trends. Dates with 50% or more missing, or outlier hourly counts combined for the hours between 5:00 a.m. through 6:59 p.m. (referred to hereafter as the “visitor use day”), were removed from daily-level results. Dates with fewer than 50% of missing or outlier hourly counts combined during hours of the visitor use day were retained in the daily-level results, and the missing or outlier hourly values were replaced with imputed values from all non-missing hourly counts based on the average count by location, month, day type (i.e., weekend day/holiday and weekday), and time of day. [Appendix 1](#) presents the table of (1) missing hourly traffic and trail counter counts and (2) calibrated hourly traffic and trail counts that were identified as outliers and removed during the data cleaning process. [Appendix 1](#) also presents the corresponding imputed values used to generate daily-level trail use volume summaries.

⁴ The regression scatterplots were inspected for outlier values using the Cook’s Distance analysis and Bonferroni Outlier Tests, and all outlier values were removed from the final regression models.

Missing data or outlier values were excluded from hourly summaries (i.e., no imputed values were included).

Cleaned and calibrated daily- and hourly-level traffic and trail use volume data were used to summarize (1) total daily traffic and trail use volumes during the counting period, and (2) mean hourly total traffic and trail use volumes, by day of week type, during the counting period. Camera calibration counts of the number of vehicles from the Cactus Forest Drive west of the Rincon Mountain District Visitor Center counting location are summarized as hourly calibration counts, by sampling date, in [Appendix 2](#).

Parking conditions

Sampling procedures

Video cameras were installed by All Traffic Data Services, LLC (ATD) to capture footage of vehicles inbound to and outbound from 11 parking areas during the parking sampling period of March 18 through March 20, 2022. The 11 parking areas are listed in Table 1 and are depicted in Figure 8 and Figure 9. Camera footage was captured twenty-four hours per day during the parking sampling period and post-processed for eight hours per sampling day. The eight-hour post-processing periods varied by parking area to capture peak parking use hours of the day, by location, and are reported in Table 2.

Table 2. Parking video camera data post-processing hours.

Location	District	Sampling hours
Broadway Trailhead	East	9:00 a.m. – 16:59 p.m.
Camino Loma Alta Trailhead	East	8:00 a.m. – 15:59 p.m.
Douglas Spring Trailhead	East	7:00 a.m. – 14:59 p.m.
Rincon Mountain District Visitor Center	East	7:00 a.m. – 14:59 p.m.
Tanque Verde Ridge Trailhead	East	8:00 a.m. – 15:59 p.m.
Cam-Boh Picnic Area	West	8:00 a.m. – 15:59 p.m.
Scenic Loop Trailhead	West	9:00 a.m. – 16:59 p.m.
Hugh Norris Trailhead	West	8:00 a.m. – 15:59 p.m.
Signal Hill Picnic Area	West	8:00 a.m. – 15:59 p.m.
Valley View	West	8:00 a.m. – 15:59 p.m.
Tucson Mountain District Visitor Center	West	9:00 a.m. – 16:59 p.m.

Cameras were positioned in each parking area to clearly capture all arriving and departing vehicles. In some cases, multiple cameras were installed to capture all inbound and outbound traffic flowing from the parking area.⁵ [Appendix 3](#) contains screen captures showing each of the installed parking camera viewscape areas.

⁵ Despite the use of multiple cameras, it may not always be possible to capture the full extent of overflow parking.

ATD post-processed the video data into a summary of five-minute binned counts of inbound vehicles and outbound vehicles. In addition to the binned inbound and outbound vehicle counts, ATD recorded a count of the number of vehicles in each of the parking areas at the start of each sampling day, referred to hereafter as the starting state count. The starting state counts and inbound and outbound counts were used to calculate net parking accumulation in the monitoring areas. ATD also post-processed the video camera footage to estimate instantaneous queue length counts of vehicles waiting to enter the park at the Rincon Mountain District entrance gate every five minutes. Figure 59 in [Appendix 3](#) contains a screen capture of the Rincon Mountain District Visitor Center camera viewscape area. It is important to note the limit of the extent of roadway included in this camera's viewscape area and for which the vehicle queue length was counted. Vehicles outside of the viewscape area of the camera are not accounted for in the instantaneous count of queue length there.

Analysis methods

Hourly parking accumulation was estimated as the cumulative sum of the starting-state count and the difference between total hourly inbound and outbound vehicle counts estimated based on post-processed video data during the eight hours of each sampling day.

Average parking duration,⁶ or the extent of time each vehicle parked, was estimated for each sampling day based on post-processed video data as the sum of hourly parking accumulation counts across the day divided by the sum of hourly inbound vehicles during the same day. To convert hourly parking duration estimates to minutes, the hourly parking duration estimates were multiplied by 60.

Hourly parking turnover rates,⁷ or the number of vehicles per parking space per hour, were estimated based on post-processed video data as the sum of total daily inbound vehicles⁸ divided by the total number of parking spaces at each location, and by the number of daily sampling hours (i.e., eight).

⁶ The video camera-based method provides an indirect approach to estimate parking duration using an equation developed in transportation engineering. The calculation of parking duration systematically underestimates true parking duration rates by assuming in the denominator of the equation that all vehicles that enter the parking area during the day park in the lot. In reality, at least some vehicles that enter the lot likely leave the lot without parking because they can't find a place to park, they are dropping off passengers, or for other reasons. The most reliable method for estimating parking duration is via direct observation.

⁷ The video camera-based method provides an indirect approach to estimate parking turnover using an equation developed in transportation engineering. The calculation of parking turnover systematically overestimates true parking turnover rates by assuming in the numerator of the equation that all vehicles that enter the parking area during the day park in the lot. In reality, at least some vehicles that enter the lot likely leave the lot without parking because they can't find a place to park, they are dropping off passengers, or for other reasons. The most reliable method for estimating turnover is via direct observation.

⁸ Daily parking turnover rates were estimated for the period for which parking data were collected at each location, as reported in Table 2.

Parking accumulation estimates were reported for each parking area as hourly parking accumulation by sampling date. Parking duration times (in minutes) and hourly parking turnover rates are also summarized in tabular format. The instantaneous vehicle queue length count at the Rincon Mountain District entrance gate is reported as interval counts recorded every five minutes for each of the three sampling dates.

Passive mobile data acquisition

To supplement field data collection, passive mobile data (PMD), or mobility data, were utilized to estimate the proportions of “recreation” vs. “non-recreation” visits to SAGU. PMD has been widely used in transportation research to analyze travel patterns and trends. In recent years, PMD has gained attention as a data source for understanding visitor use and mobility patterns in parks and protected areas. Specifically, this study leverages connected vehicle (CV) data, which is a type of emerging data collected from vehicles equipped with built-in wireless communication technologies. Connected vehicles refer to those vehicles with onboard computer systems that regularly record geolocation and operating conditions information. The CV data provide detailed information on the vehicle’s location, speed, and vehicle heading along with other metrics at a high frequency, typically every few seconds or minutes. Each location record in the CV data contains a hashed but persistent ID associated with the corresponding vehicle.⁹

The CV data used in this study were acquired from Otonomo, a provider of CV data that assigns a unique and persistent ID to each vehicle’s record on a daily basis. Otonomo reportedly collects over four billion CV data points daily from more than 40 million licensed vehicles (Otonomo, n.d.). Unlike other CV data providers, Otonomo typically does not reset a vehicle’s hashed ID each time it is turned off and on during a single day, which ensures that all records for a particular vehicle have a consistent and unique ID throughout the entire day, referred to as “24-hour device ID continuity.” This characteristic makes the Otonomo CV data particularly promising for estimating visitors’ daily movement patterns along park-maintained roads.¹⁰

For this study, PMD (i.e., CV data) were obtained and analyzed for a full 12-month time period from March 1, 2022, through February 28, 2023 (referred to hereafter as the “analysis period”) in order to encompass both the on-site data collection period (February to April 2022) and the visitor survey sampling period (January to February 2023).¹¹ The PMD were obtained for an extended spatial boundary of SAGU in order to cover a wider area and capture activities on the road network,

⁹ The vehicle IDs in the CV data have been anonymized to protect data privacy.

¹⁰ Otonomo data are no longer commercially available.

¹¹ Please note that the PMD used in this study is a representative sample of visitor movement and patterns within the park. While it provides valuable insights into visitor use patterns, it may not capture the complete population of park visitors.

particularly the peripheral roads right at the edge of the SAGU boundary (Figure 10).¹² The PMD acquired from Otonomo contained vehicle waypoints for each connected vehicle sighted at least once in the SAGU extended polygon during the analysis period. The recorded information included a hashed unique ID for each vehicle, its latitude and longitude, and a timestamp for when the location was recorded. The majority (96.4%) of the obtained data exhibit 24-hour device ID continuity. The data format and a sample of the PMD are shown in Table 3. Each row presents a “sighting” of an individual vehicle, which is defined as a single location record (i.e., latitude and longitude) for a unique vehicle with a unique timestamp. After obtaining the raw PMD from Otonomo, the project team processed the data to create a clean file for analysis.

Table 3. Sample of the Otonomo connected vehicle data.

vehicle_id	date_time	latitude	longitude
87f2d...	2022-03-01 04:27:00	32.1723	-110.7380
87f2d...	2022-03-01 04:27:30	32.1793	-110.7380
d3cfe...	2022-03-01 07:58:19	32.2356	-110.7210
d3cfe...	2022-03-01 07:58:27	32.2354	-110.7211

Passive mobile data analysis

Data cleaning and processing

Before the analysis was conducted, a series of data cleaning steps was applied to the raw PMD to identify and remove duplicate sightings, anomalies, and spurious records. The CSV files containing the raw data were imported into R 4.2.2 and formatted to allow the project team to perform spatial operations and analysis on the data. Duplicate records, indicated by identical timestamp values, were removed from the analysis to address potential technical errors in the data generation process and ensure data consistency. Additionally, anomalies characterized by an erratic vehicle trajectory that deviated significantly from the curvature of the road network were identified and removed.¹³ Finally, any vehicles with an unrealistic median speed (i.e., a median speed over 250 miles per hour) were regarded as poor quality and removed from the analysis. As the last data cleaning step, vehicles that did not have 24-hour device ID continuity were discarded. Overall, 97% of the sightings and 91% of the vehicles were removed from the dataset, resulting in a cleaned analysis dataset containing 1,065,383 sightings across 15,206 vehicles.

¹² It should be noted that the extended polygon closely aligns with the park boundary, with only a small variation to encompass additional areas.

¹³ To identify these anomalies, a 220-foot buffer of the OpenStreetMap road network was used as a reference. Only vehicles with sightings that remained within the 220-foot road buffer for the majority of the recorded time were retained for further analysis.

Process for estimating proportions of recreation versus non-recreation visitors

Given that one of the primary objectives of this study is to estimate the proportions of recreation versus non-recreation visitors to SAGU, the analysis focuses exclusively on vehicles traveling on three select park-maintained roads in the West District that pass through the park and also serve areas outside the park. These roads, which include West Picture Rocks Road, North Sandario Road, and North Kinney Road, were selected in consultation with the NPS and are depicted in Figure 10. To capture vehicle travel along these roads, three road corridor polygons were created by applying a 220-foot buffer on either side of the road's centerline. The buffer size of 220 feet was determined through a sensitivity analysis to ensure that the captured data points pertain to the actual visitor travel along the road segments of interest while filtering out unrelated waypoints that may be located farther away. To ensure accurate vehicle counts recorded specifically along the road segments, manual verification of road corridor polygons was conducted. The SAGU trails layer was used as a reference to ensure the road corridor polygons do not overlap with intersecting spur roads and adjacent park attractions (i.e., pullouts and trailhead parking areas) (Figure 10).

The cleaned PMD were then georeferenced to three road corridor polygons to identify vehicles that were observed within the corresponding polygon. To determine the amount of recreation traffic on each of the three park roads, the analysis focused on examining vehicles that had intermediate stops exceeding a specified duration within the park on the same day, referred to hereafter as "recreation stops." Vehicles that made recreation stops were assumed to have a higher likelihood of engaging in recreational activities and exploring the park. On the other hand, vehicles that did not stop or had very short stops within the park, were assumed to be non-recreation visitors using the roads through SAGU for non-recreation purposes, such as commuting to work. The proportion of recreation versus non-recreation traffic on each road was calculated by dividing the number of daily vehicles that were both observed within the corresponding road corridor polygon and made recreation stops within the park by the total number of daily vehicles recorded within that polygon.

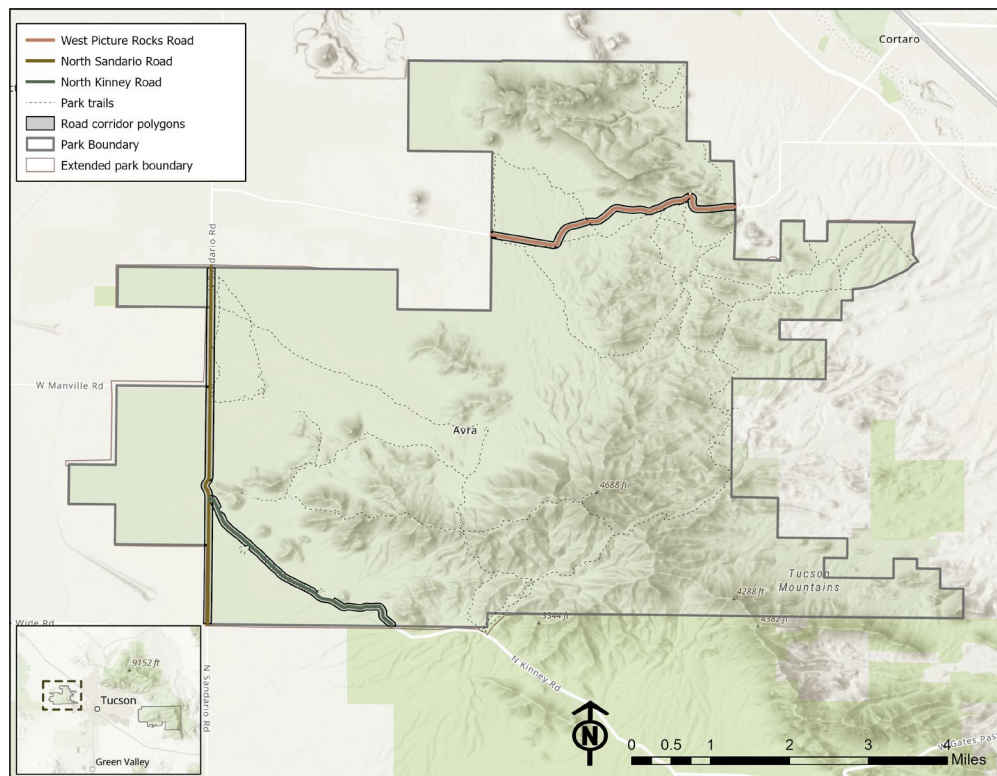


Figure 10. Polygon used to acquire passive mobile data and select park roads for analysis.

Recreation stops identification

Stop duration-based methods are commonly used in research to analyze mobility data and identify stops during a trip under normal circumstances, where all locations are recorded without any satellite signal loss (Du & Aultman-Hall, 2007; Gong et al., 2014). In this method, “stop duration” refers to the amount of time a vehicle remains stationary at a particular location. In these ideal situations, where there is no signal loss and GPS devices in vehicles record data at regular time intervals, the time spacing between consecutive sightings is usually fixed. By comparing the duration of a stop when a vehicle is stationary or moving at a very low speed with a predefined threshold value, a recreation stop can be identified. The stop duration-based methods are particularly effective in differentiating longer stops, which are more likely to be associated with recreational activities, from shorter stops, such as brief pauses at traffic signals or stop signs.

However, the applicability of the stop duration method relies on having complete and regular GPS data streams. Unfortunately, there are unavoidable situations where satellite signals are lost, such as when a vehicle is not running (e.g., while parked at a trailhead) and the GPS device is turned off. As a result, irregular gaps in the data can occur, ranging from a few seconds to several minutes, during which no information is recorded. It appears from the cleaned PMD that 65% of the vehicles had 2-minute time gaps, and 56% had 15-minute time gaps. Given the significant portion of vehicles with time gaps longer than the data frequency (which is primarily recorded every 9 seconds), these gaps were considered in the analysis. As a result, the analysis considered two distinct situations: vehicles without time gaps and vehicles with time gaps. The method for addressing time gaps and the specific filters applied in each situation to identify recreation stops are detailed in [Appendix 4](#). The recreation

stops identified in both situations were combined to estimate the share of recreation traffic on each road based on the share of daily vehicles that were both detected within the corresponding road corridor polygon and made recreation stops among the daily vehicles recorded within that polygon. These results were estimated for a range of stop duration threshold values.

Results

In this section of the report, tabular, graphical, and descriptive results from the SAGU Visitor Use Study are presented. The results are organized into three subsections: (1) traffic and trail use conditions, (2) parking conditions, (3) the estimated proportions of recreation and non-recreation visits, and (4) the comparison of select passive mobile data results to select visitor survey results.

Traffic and trail use conditions

This subsection of the report contains descriptive summaries of traffic and trail use conditions.

Traffic conditions

This subsection of the report presents descriptive results of roadway traffic volumes. The roadway traffic counting locations are depicted in Figure 8 and Figure 9 and include:

- Golden Gate Road
- Hohokam Road
- Tucson Mountain District Visitor Center (TMD VC)

Traffic counter calibration

Table 4 reports the calibration regression model specifications for traffic counter data from the three traffic counting locations. Coefficients from regression models with intercepts were used to calibrate the traffic counter data for each location. Figure 11 through Figure 13 contain traffic counter calibration scatterplots with intercept and non-intercept linear regression models plotted.

Table 4. Traffic counter calibration regression model results.

Location	Intercept	Coefficient	Intercept p-value	Coefficient p-value	R ²	N
Golden Gate Road	-0.4824067	1.0209253	0.73	< 0.001	0.75	42
Hohokam Road	-0.0152575	0.8285195	0.97	< 0.001	0.98	46
Tucson Mountain District Visitor Center	0.2647377	1.3335312	0.76	< 0.001	0.99	70

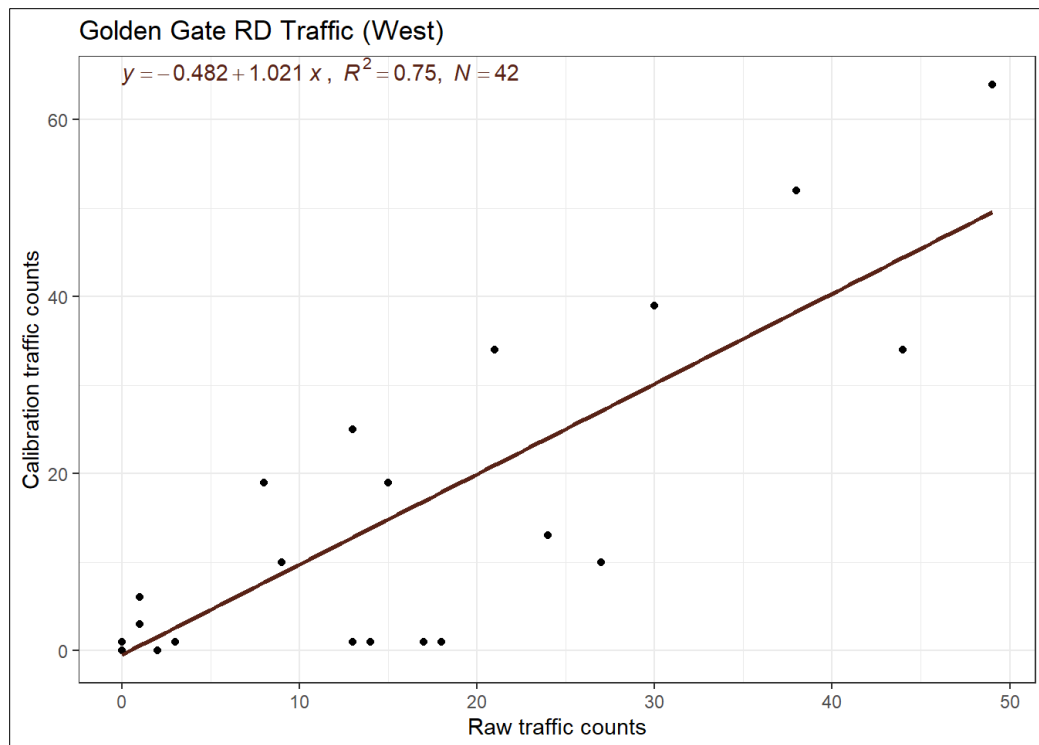


Figure 11. Roadway traffic counter calibration scatterplot with intercept and non-intercept regression models: Golden Gate Road.

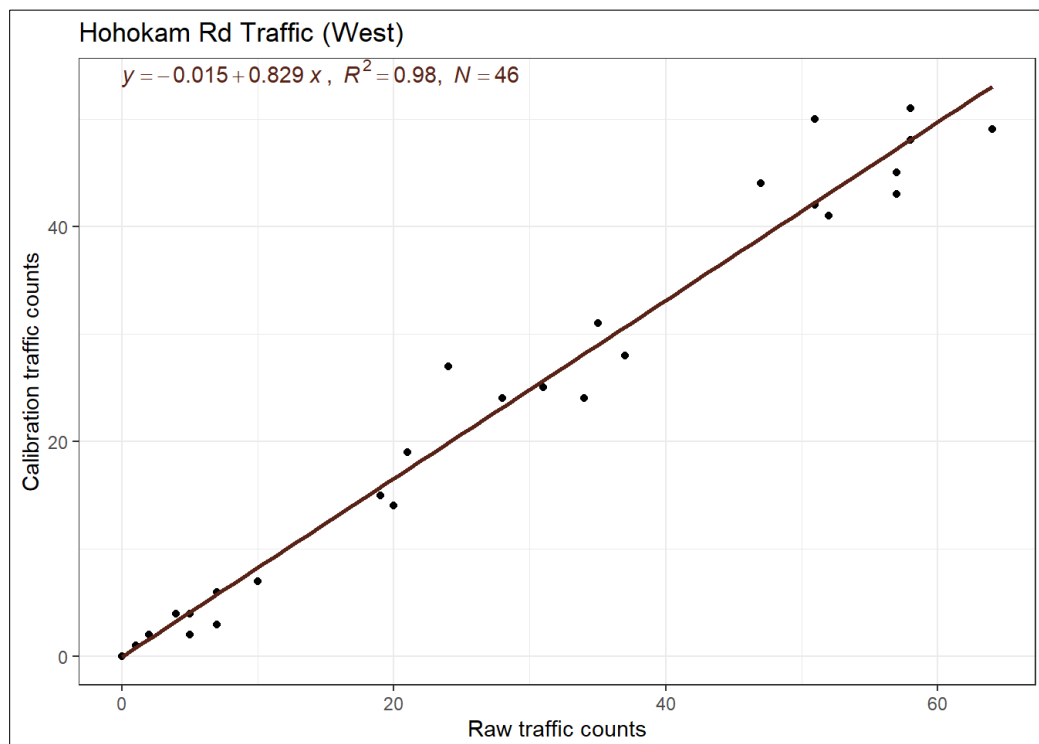


Figure 12. Roadway traffic counter calibration scatterplot with intercept and non-intercept regression models: Hohokam Road.

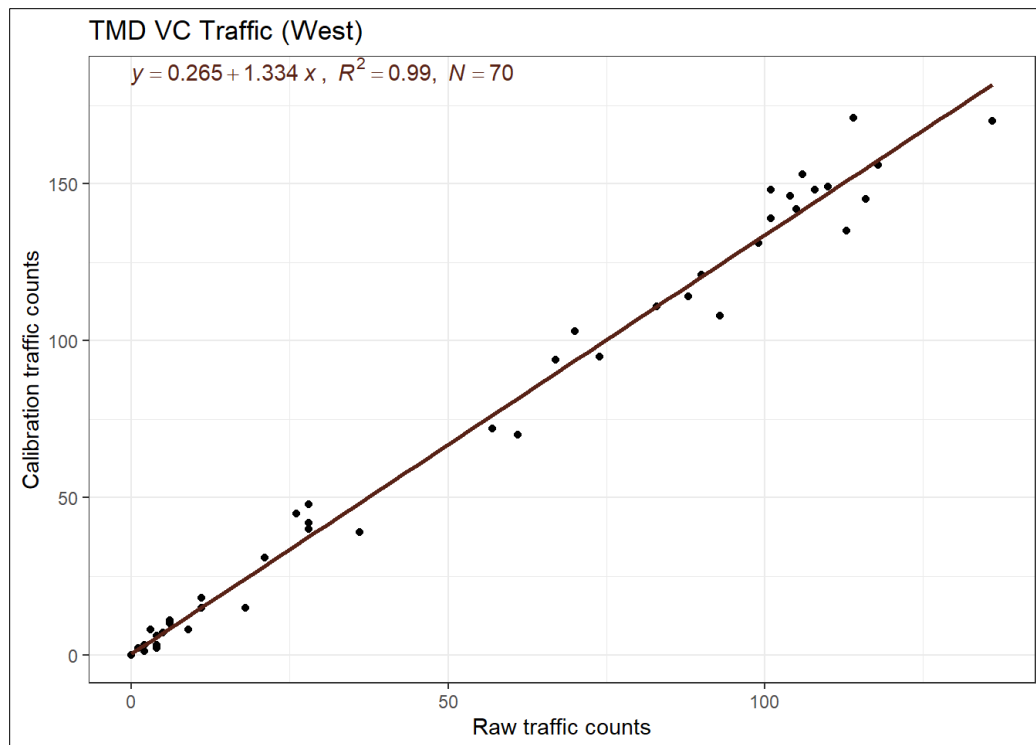


Figure 13. Roadway traffic counter calibration scatterplot with intercept and non-intercept regression models: Tucson Mountain District Visitor Center.

Traffic counter descriptive data results

Figure 14 through Figure 16 present total (inbound and outbound) calibrated daily traffic volumes for each counting location during the counting period. The yellow bars on each of the figures indicate dates for which the on-site parking accumulation data collection effort occurred. In the upper right corner of each figure, the mean daily traffic volume across the counting period and corresponding sample size, by day of week type (i.e., weekend day/holiday and weekday), are presented. These data suggest:

- Total daily traffic volumes at Golden Gate Road typically ranged from approximately 100 to around 425 vehicles per day. On Friday through Monday of President's Day Weekend, total daily traffic volumes reached or exceeded 375 vehicles. Total daily traffic volumes tended to be higher on weekend days and holidays compared to weekdays, and tended to be highest in late February through mid-March (Figure 14).
- Total daily traffic volumes at Hohokam Road typically ranged from approximately 175 to around 525 vehicles per day. On Saturday through Monday of President's Day Weekend, the total daily traffic volume exceeded 475 vehicles. Total daily traffic volumes tended to be higher on weekend days and holidays compared to weekdays, and tended to be highest in late February through mid-March (Figure 15).

- Total daily traffic volumes at the Tucson Mountain District Visitor Center (TMD VC)¹⁴ typically ranged from approximately 500 to just over 1,300 vehicles per day. On two days, both weekend days in early March, the total daily traffic volume exceeded 1,300 vehicles. Total daily traffic volumes tended to be slightly higher on weekend days and holidays compared to weekdays, and tended to be highest during the month of March (Figure 16).

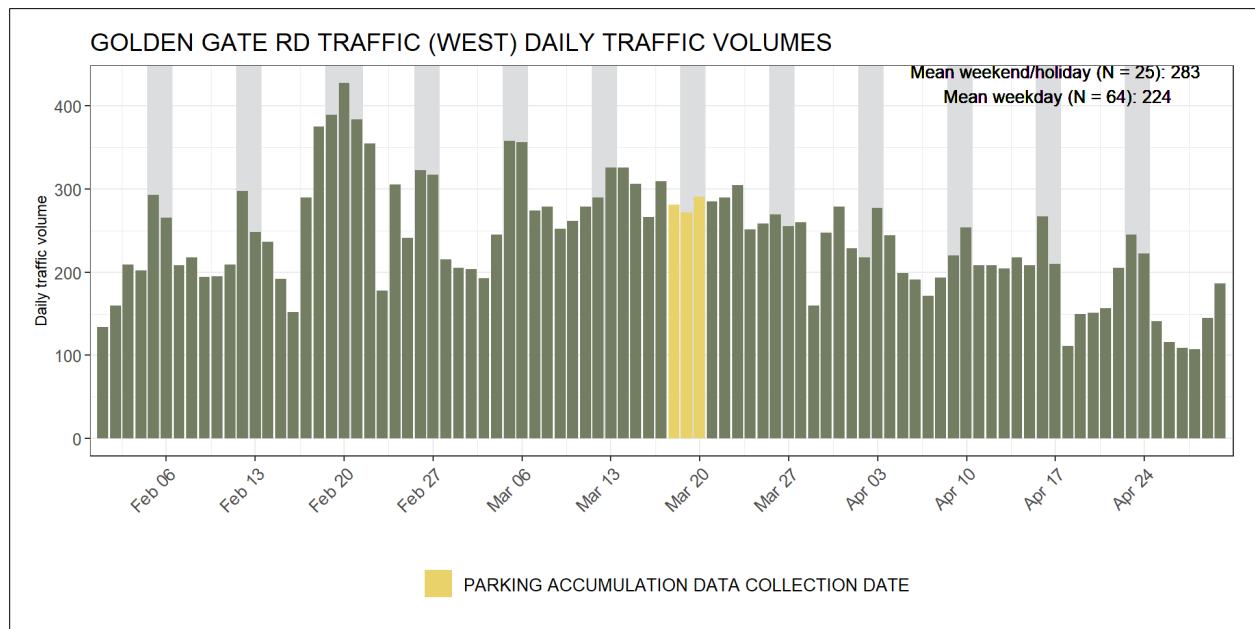


Figure 14. Daily traffic volumes: Golden Gate Road (gray shading indicates weekends/holidays).

¹⁴ Count data from DataNet between February 15 and March 4, 2022, were not available or missing.

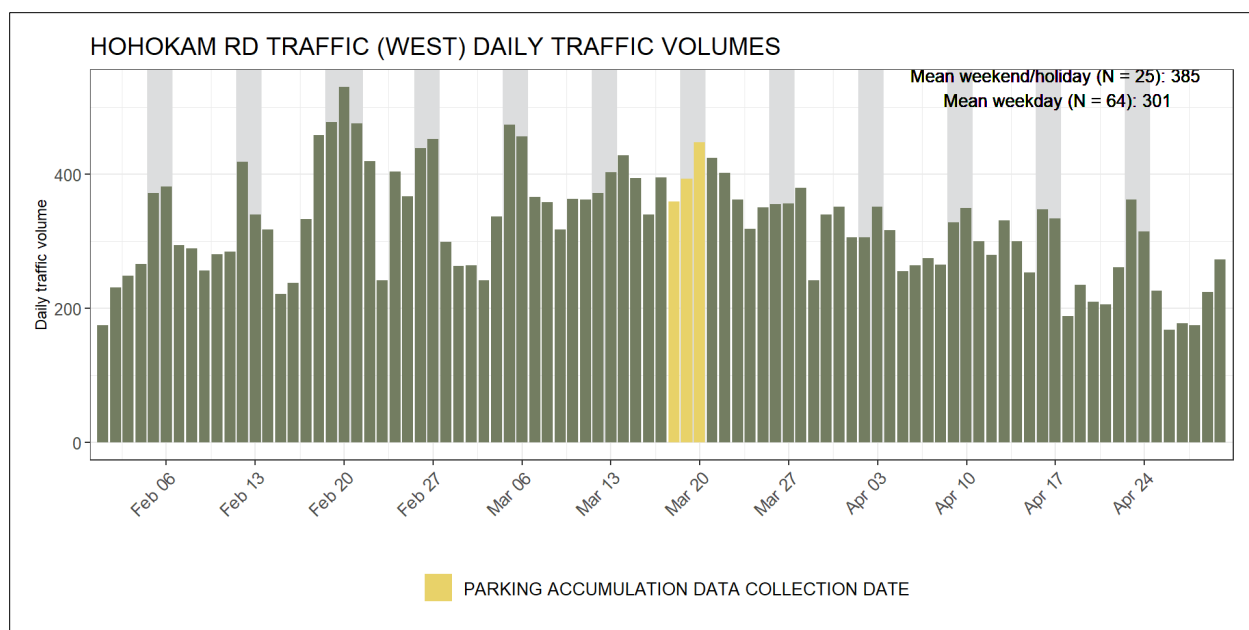


Figure 15. Daily traffic volumes: Hohokam Road (gray shading indicates weekends/holidays).

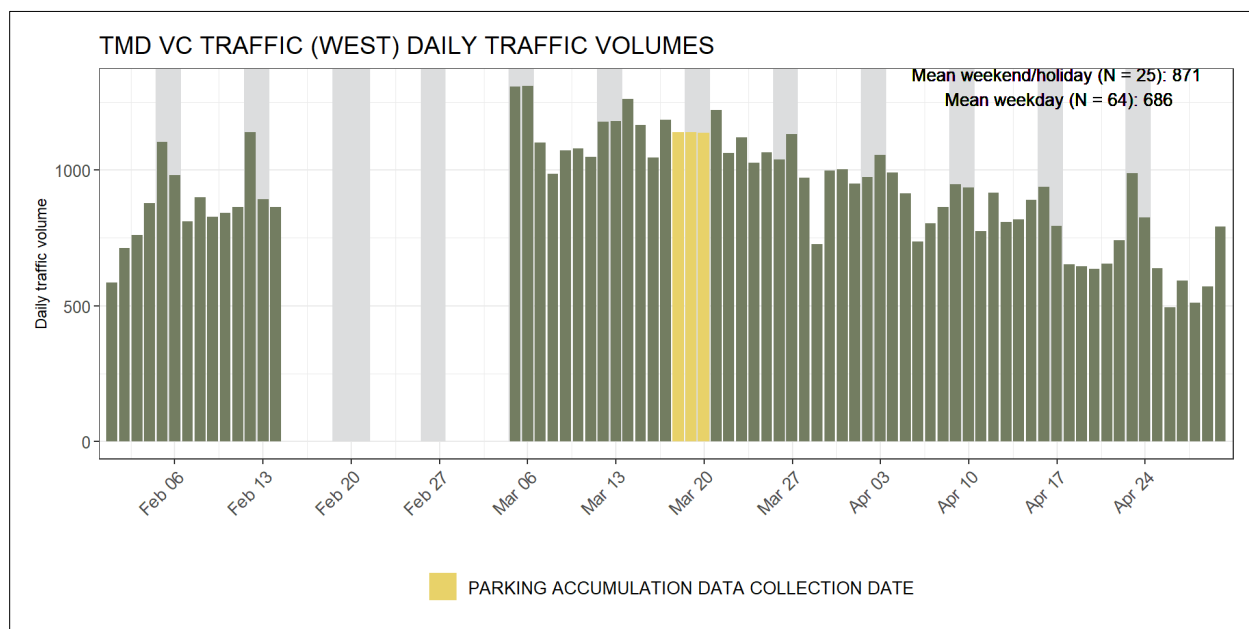


Figure 16. Daily traffic volumes: Tucson Mountain District Visitor Center (gray shading indicates weekends/holidays).¹⁵

¹⁵ Count data from DataNet between February 15 and March 4, 2022, were not available or missing.

Figure 17 through Figure 19 present mean calibrated hourly traffic volumes, by day of week type, for each counting location during the counting period. These data suggest:

- Mean hourly total traffic volumes at Golden Gate Road increased starting at around 7:00 a.m., until reaching a peak of approximately 33 vehicles at 1:00 p.m. on weekdays and 39 vehicles at 1:00 p.m. on weekend days and holidays. Mean hourly total traffic volumes decreased steadily from 1:00 p.m. until 8:00 p.m. (Figure 17).
- Mean hourly total traffic volumes at Hohokam Road increased gradually starting at around 5:00 a.m., and increased more sharply starting at 7:00 a.m. until reaching a peak of approximately 41 vehicles at 12:00 p.m. on weekdays, and 50 vehicles at 11:00 a.m. on weekend days and holidays. After reaching their peak, mean hourly total traffic volumes decreased steadily until 4:00 p.m., and decreased more sharply from 4:00 p.m. until 7:00 p.m. (Figure 18).
- Mean hourly total traffic volumes at the Tucson Mountain District Visitor Center (TMD VC) increased gradually starting at around 5:00 a.m., and increased more sharply starting at 7:00 a.m. until reaching a peak of approximately 120 vehicles at 12:00 p.m. on weekdays and 130 vehicles at 11:00 a.m. on weekend days and holidays. On weekdays, after reaching their peak, mean hourly total traffic volumes decreased steadily until 4:00 p.m., and decreased more sharply from 4:00 p.m. through 6:00 p.m. On weekend days and holidays, mean hourly total traffic volumes remained high until 1:00 p.m. before they decreased steadily until 4:00 p.m., and decreased more sharply from 4:00 p.m. through 6:00 p.m. (Figure 19).

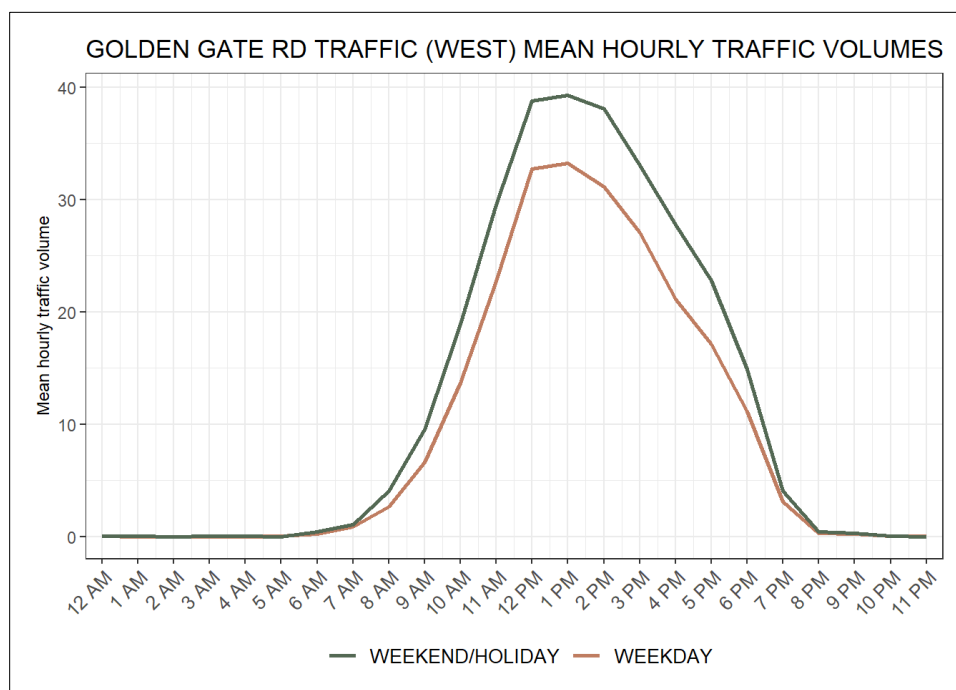


Figure 17. Mean hourly total (inbound and outbound) traffic volumes, by day-of-week type: Golden Gate Road.

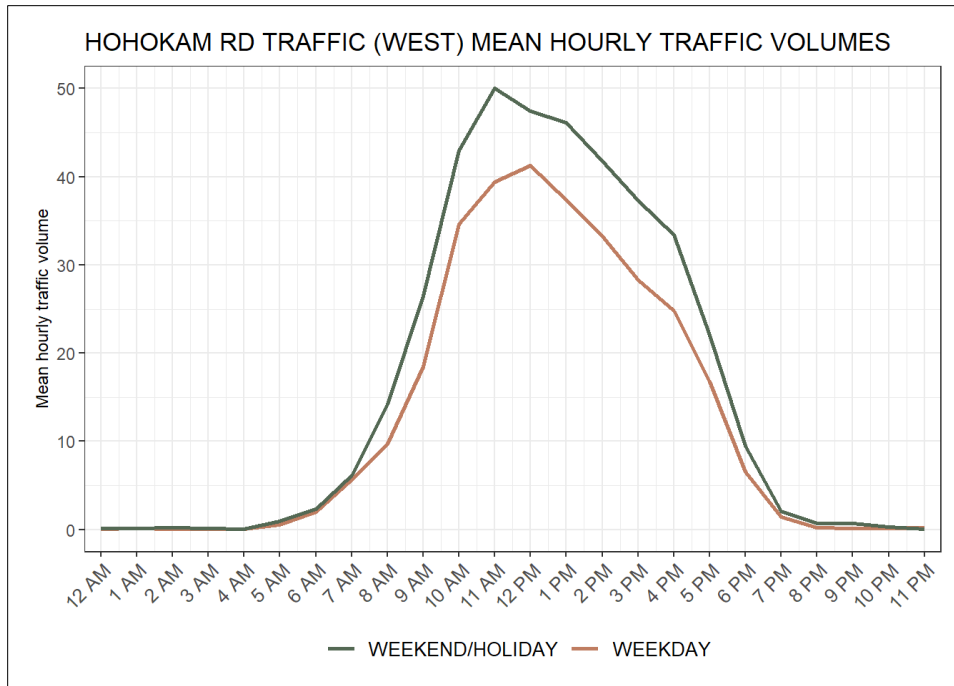


Figure 18. Mean hourly total (inbound and outbound) traffic volumes, by day-of-week type: Hohokam Road.

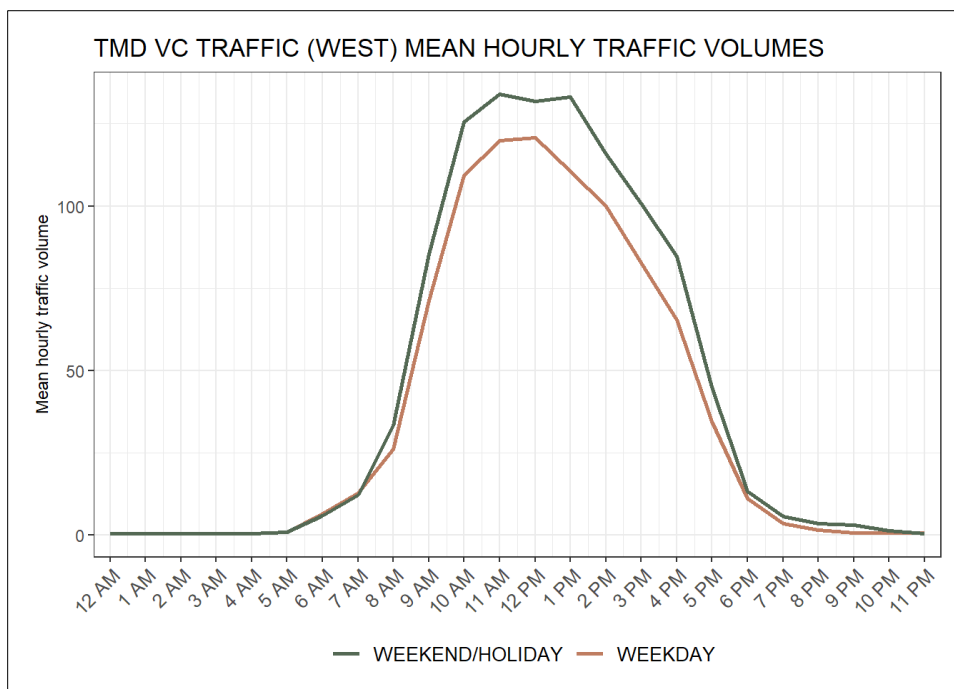


Figure 19. Mean hourly total (inbound and outbound) traffic volumes, by day-of-week type: Tucson Mountain District Visitor Center.

Trail use conditions

This subsection of the report presents calibration and descriptive results of trail use volumes. The trail counting locations are depicted in Figure 8 and Figure 9 and include:

- Broadway Trailhead
- Camino Loma Alta Trailhead
- Douglas Spring Trailhead
- El Camino del Cerro Trailhead
- King Canyon Trailhead
- Scenic Loop Trailhead

Trail counter calibration

Table 5 reports the calibration regression model specifications for trail counter data from the six trail counting locations. Coefficients from regression models with intercepts were used to calibrate the trail counter data for each location. Figure 20 through Figure 25 contain trail counter calibration scatterplots with intercept and non-intercept linear regression models plotted.

Table 5. Trail counter calibration regression model results.

Location	Intercept	Coefficient	Intercept p-value	Coefficient p-value	R²	N
Broadway Trailhead	0.4723509	0.9749368	0.41	< 0.001	0.98	69
Camino Loma Alta Trailhead	0.1122892	0.9669772	0.80	< 0.001	0.89	70
Douglas Spring Trailhead	-0.8464081	1.2701320	0.20	< 0.001	0.97	69
El Camino del Cerro Trailhead	0.0407291	0.8728570	0.85	< 0.001	0.90	61
King Canyon Trailhead	-0.3978448	0.7916696	0.67	< 0.001	0.78	42
Scenic Loop Trail Trailhead	0.1850533	0.9650476	0.45	< 0.001	0.94	70

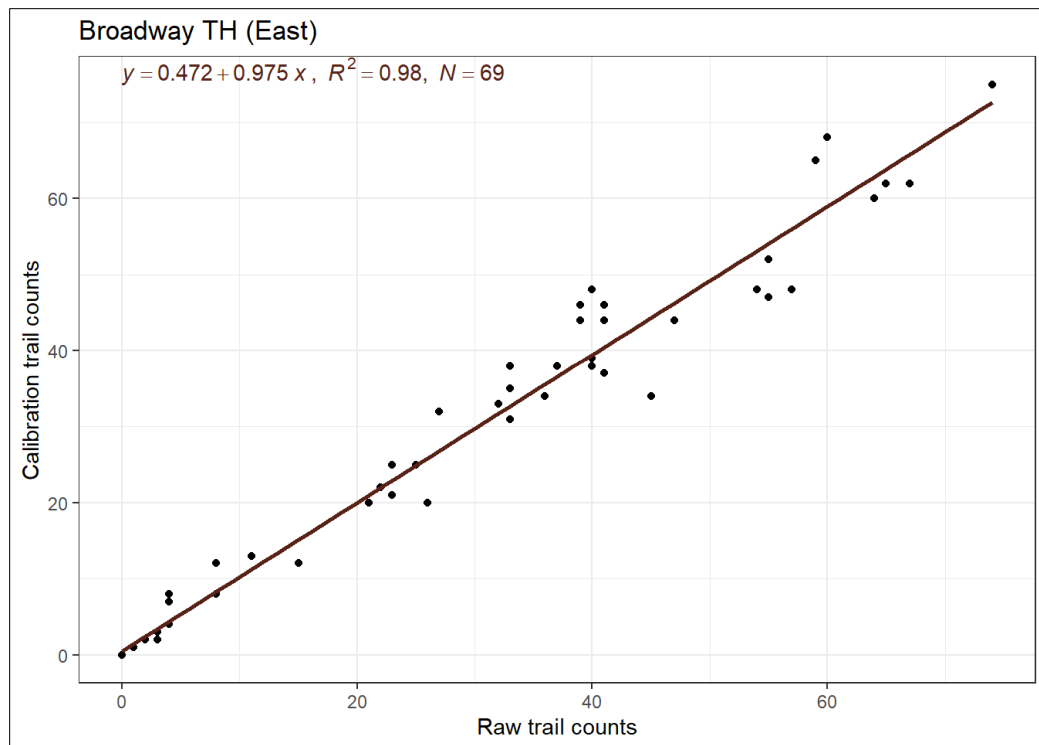


Figure 20. Trail counter calibration scatterplot with intercept and non-intercept regression models: Broadway Trailhead.

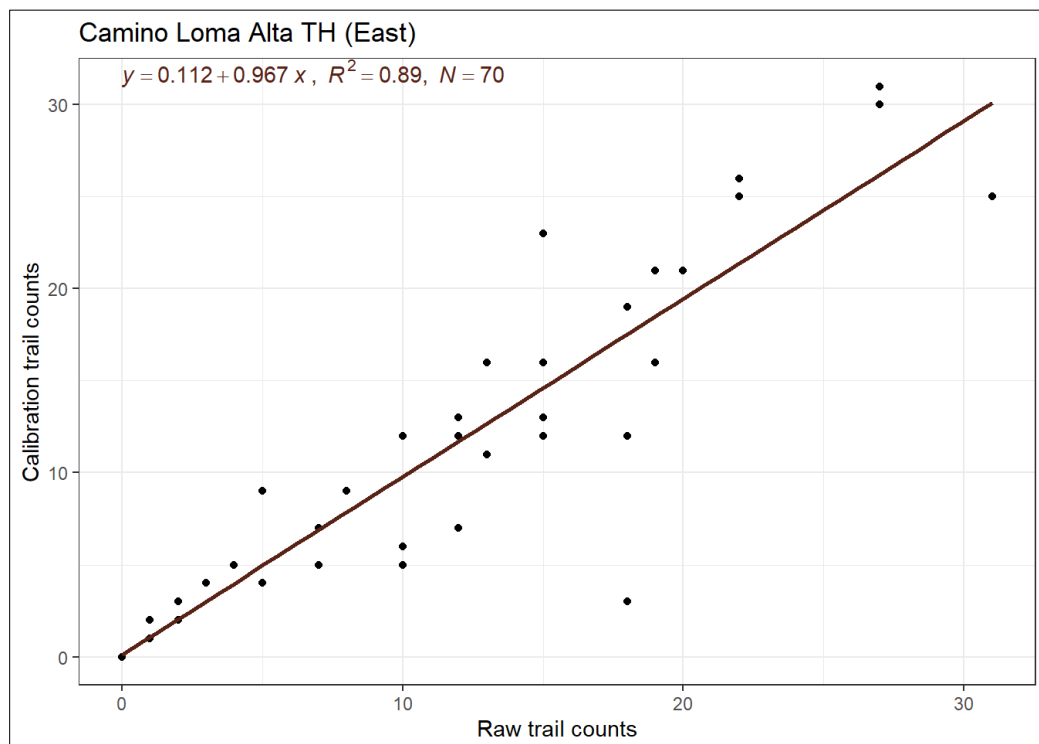


Figure 21. Trail counter calibration scatterplot with intercept and non-intercept regression models: Camino Loma Alta Trailhead.

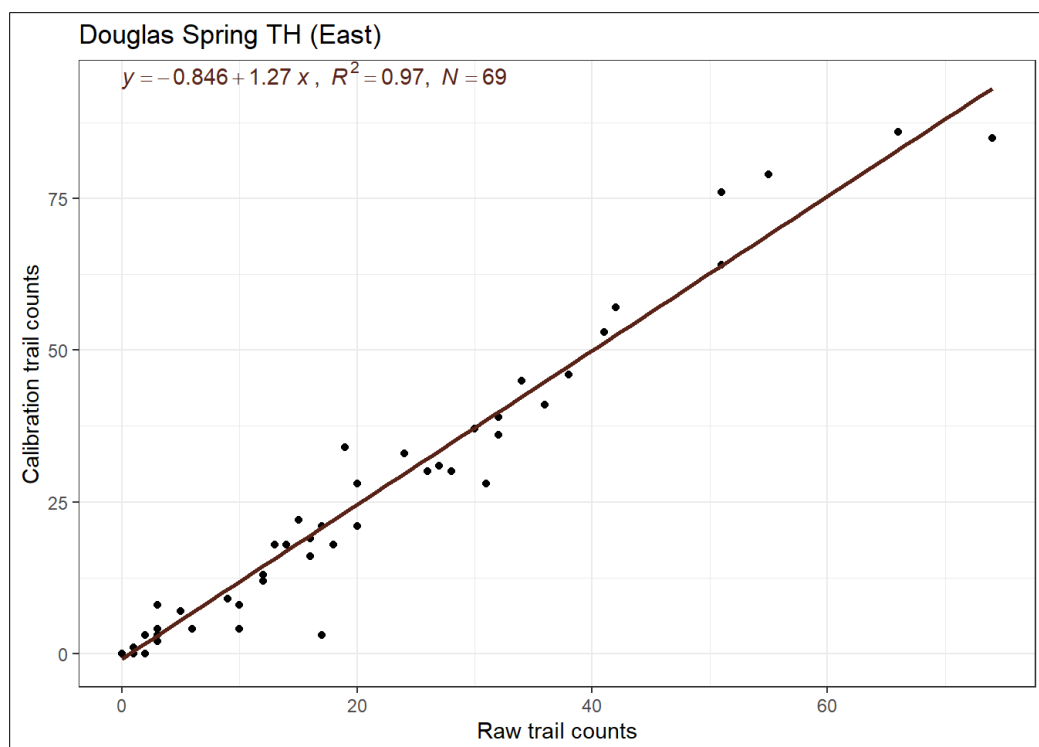


Figure 22. Trail counter calibration scatterplot with intercept and non-intercept regression models: Douglas Spring Trailhead.

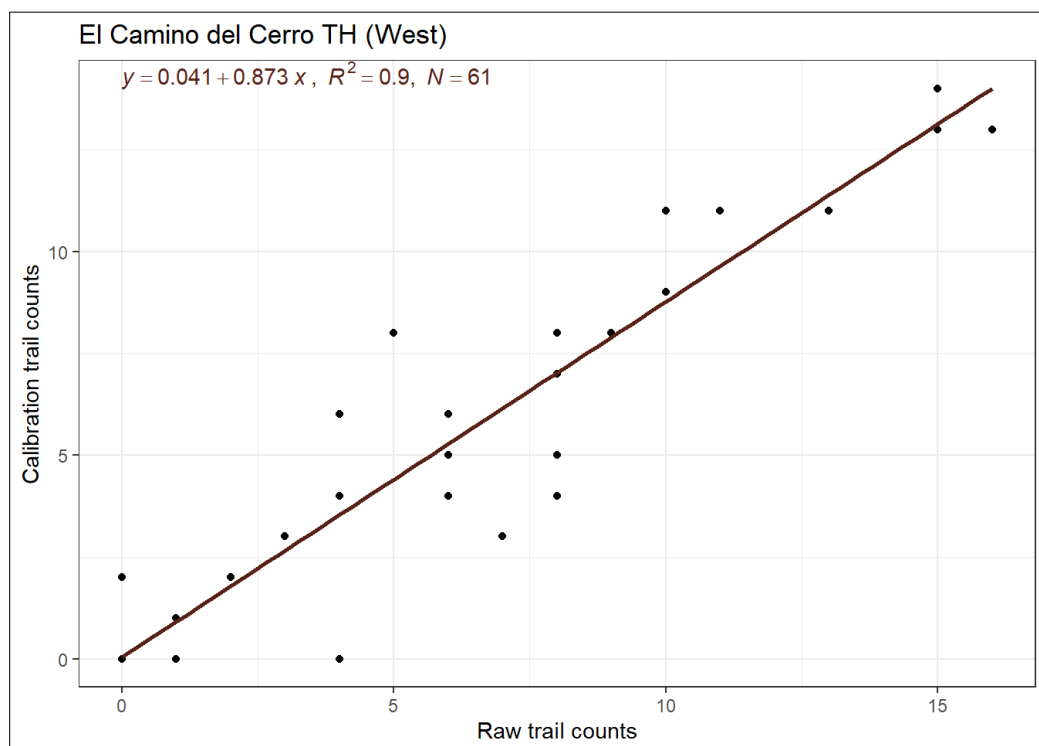


Figure 23. Trail counter calibration scatterplot with intercept and non-intercept regression models: El Camino del Cerro Trailhead.

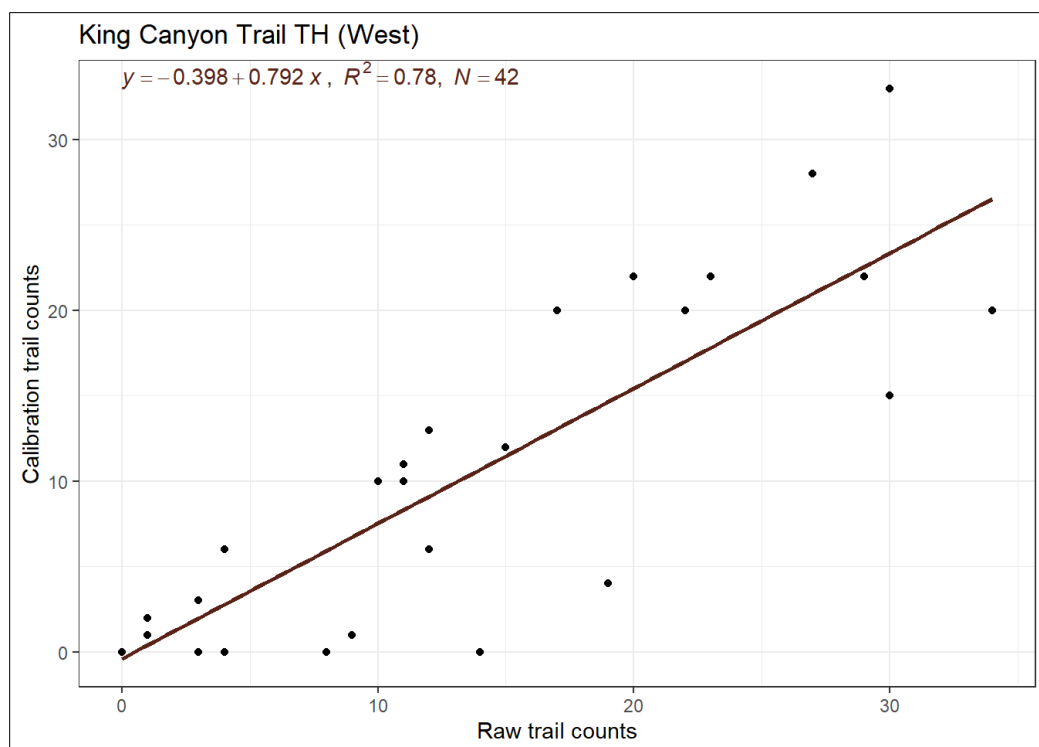


Figure 24. Trail counter calibration scatterplot with intercept and non-intercept regression models: King Canyon Trailhead.

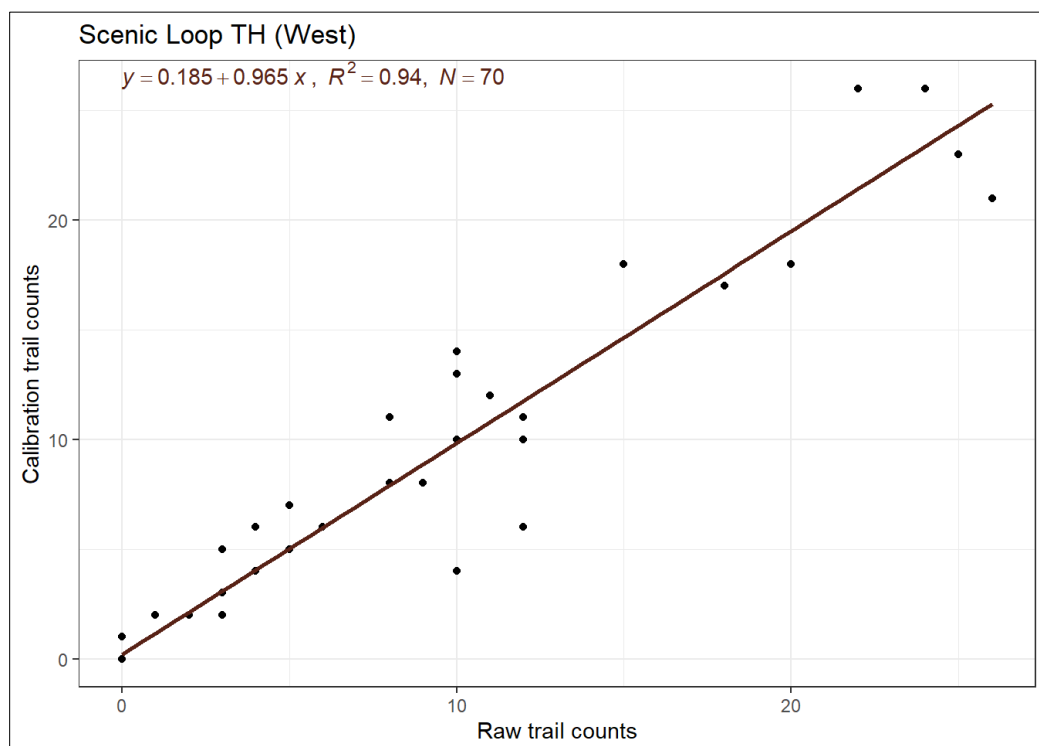


Figure 25. Trail counter calibration scatterplot with intercept and non-intercept regression models: Scenic Loop Trailhead.

Trail counter descriptive data results

Figure 26 through Figure 31 present total (inbound and outbound) calibrated daily trail use volumes for each trail counter location during the counting period. The yellow bars on each of the figures indicate dates for which the on-site parking accumulation data collection effort occurred. In the upper right corner of each figure, the mean total daily trail use volume across the counting period and corresponding sample size, by day of week type (i.e., weekend day/holiday and weekday), are presented. These data suggest:

- Total daily trail use volumes at the Broadway Trailhead typically ranged from approximately 200 to 1,000 per day. On four days, three of which were weekend days or holidays, total daily trail use volumes exceeded 750. Daily trail use volumes tended to be higher on weekend days and holidays compared to weekdays (Figure 26).
- Total daily trail use volumes at the Camino Loma Alta Trailhead typically ranged from approximately 25 to 300 per day. On two days, both weekend days or holidays in March, total daily trail use volumes exceeded 250. Daily trail use volumes tended to be higher on weekend days and holidays compared to weekdays (Figure 27).
- Total daily trail use volumes at the Douglas Spring Trailhead typically ranged from approximately 200 to 1,000 per day. On five days, all weekend days or holidays, total daily trail use volumes exceeded 800. Daily trail use volumes tended to be higher on weekend days and holidays compared to weekdays (Figure 28).
- Total daily trail use volumes at the El Camino del Cerro Trailhead typically ranged from approximately 25 to around 250 per day. On three days, all of which were weekdays, the total daily trail use volume exceeded 200. Daily trail use volumes tended to be higher on weekend days and holidays compared to weekdays, with the exception of the last week in April (Figure 29).
- Total daily trail use volumes at the King Canyon Trailhead typically ranged from approximately 100 to 1,100 per day. On six days, five of which were weekdays, total daily trail use volumes met or exceeded 800. Trail use volumes tended to be highest during mid-to-late February and April. There were no discernable patterns between daily trail use volumes on weekend days and holidays versus weekdays (Figure 30).
- Total daily trail use volumes at the Scenic Loop Trailhead typically ranged from approximately 50 to around 450 per day. On six days, five of which were weekend days or holidays, total daily trail use volumes met or exceeded 200. Daily trail use volumes tended to be higher on weekend days and holidays compared to weekdays (Figure 31).

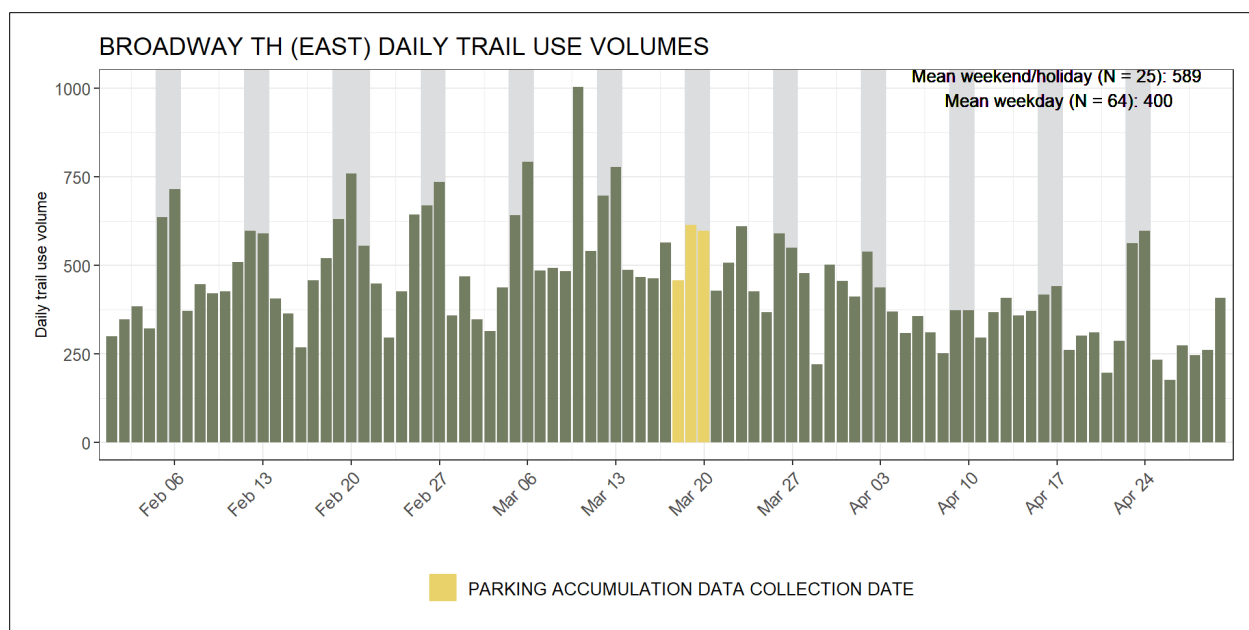


Figure 26. Total (inbound and outbound) daily trail use volumes: Broadway Trailhead (gray shading indicates weekends/holidays).

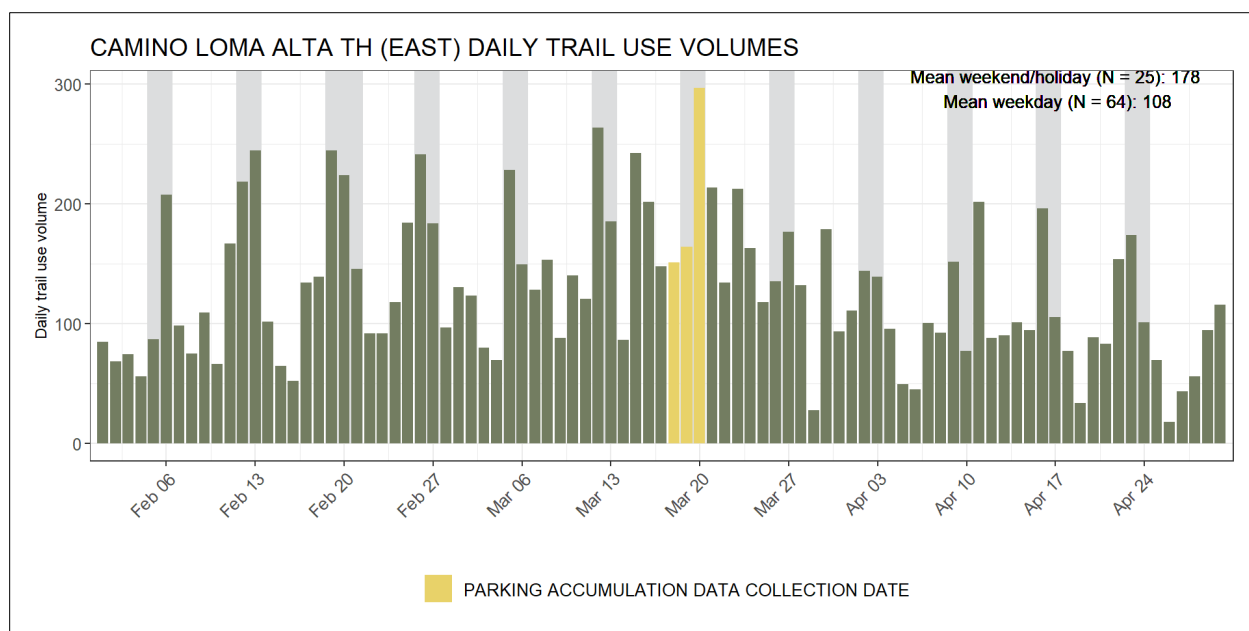


Figure 27. Total (inbound and outbound) daily trail use volumes: Camino Loma Alta Trailhead (gray shading indicates weekends/holidays).

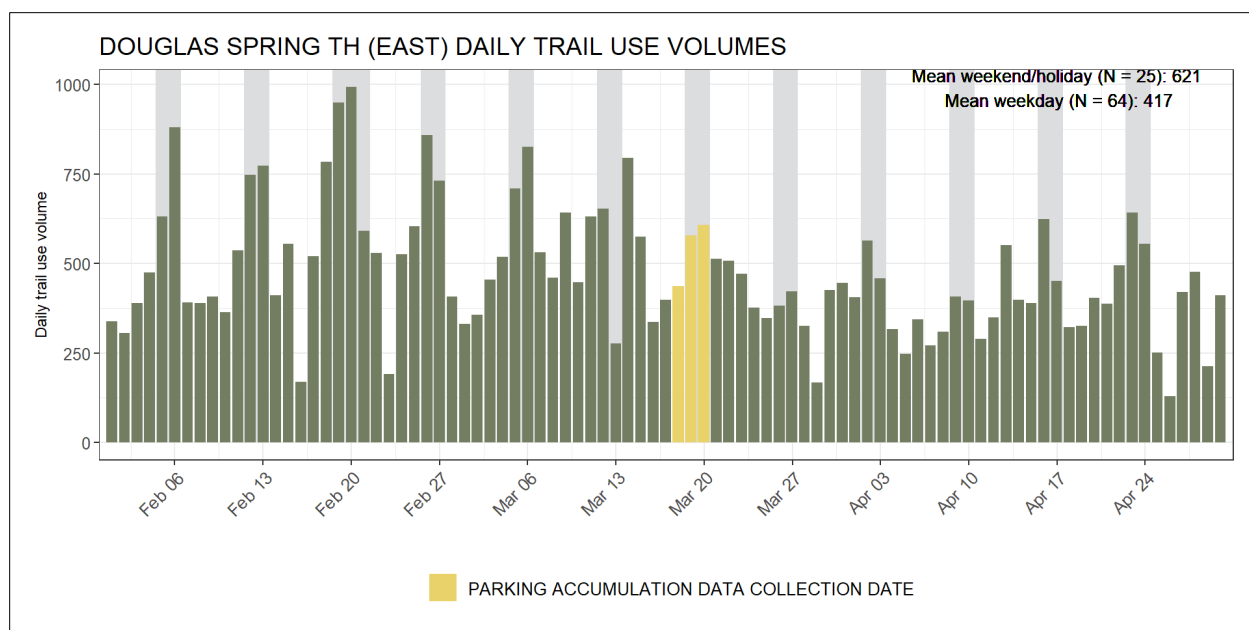


Figure 28. Total (inbound and outbound) daily trail use volumes: Douglas Spring Trailhead (gray shading indicates weekends/holidays).

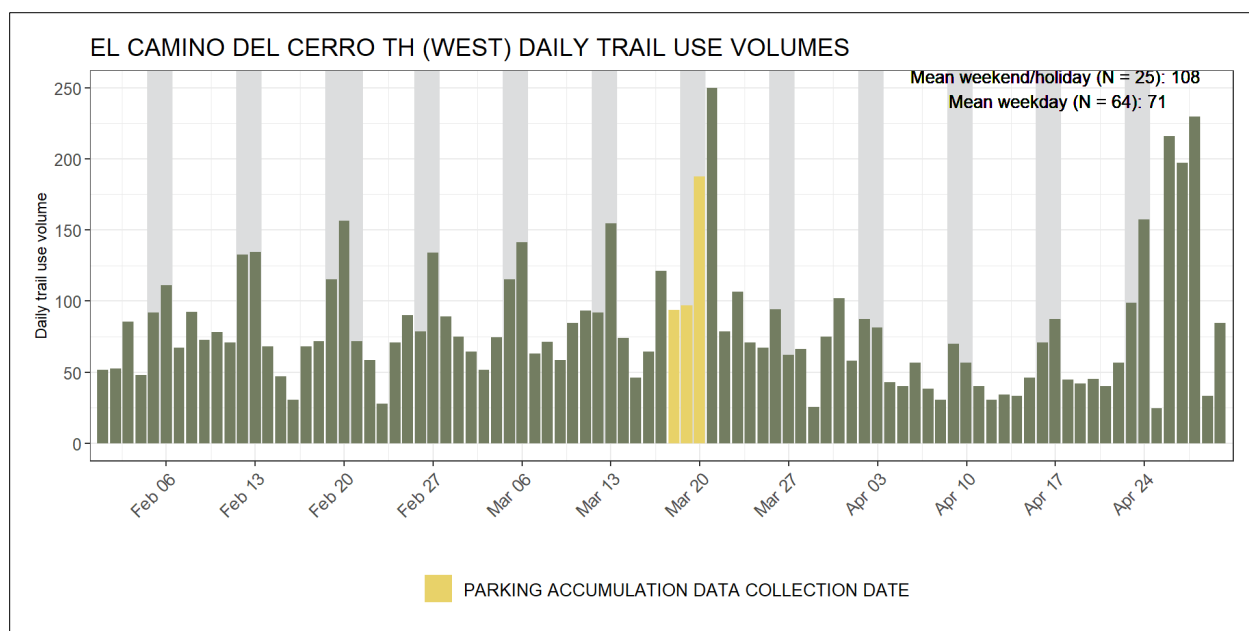


Figure 29. Total (inbound and outbound) daily trail use volumes: El Camino del Cerro Trailhead (gray shading indicates weekends/holidays).

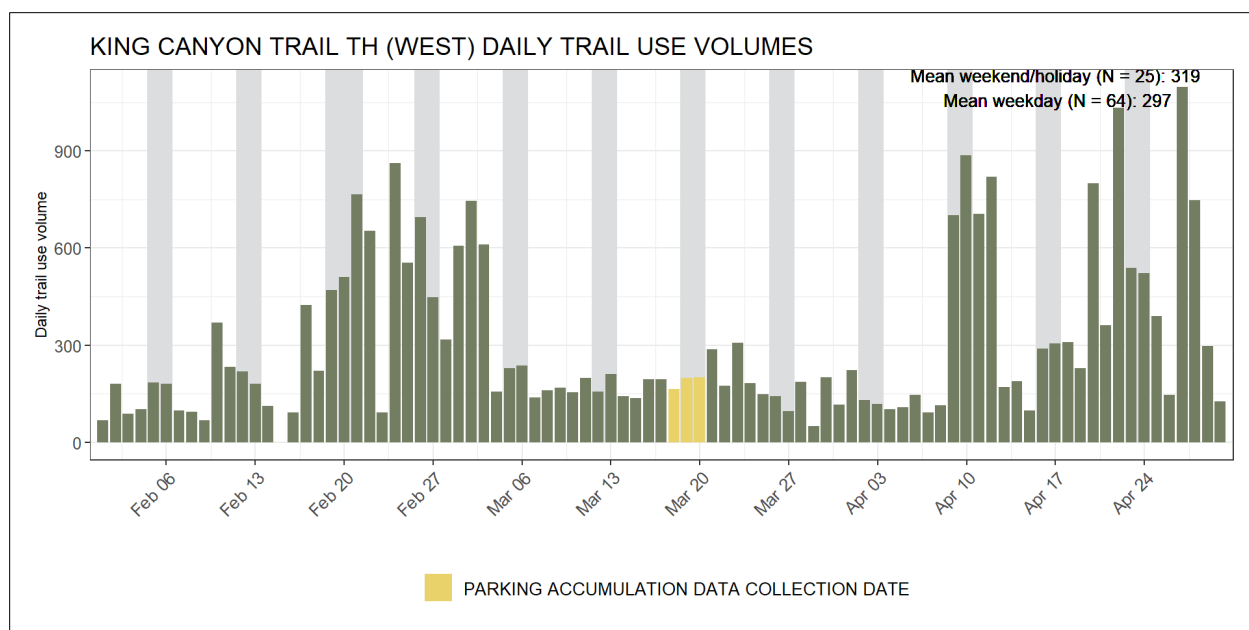


Figure 30. Total (inbound and outbound) daily trail use volumes: King Canyon Trailhead (gray shading indicates weekends/holidays).¹⁶

¹⁶ There is a gap in the data on February 15, 2022, because 50% or more of the hourly counts during the visitor use day from 5:00 a.m. through 6:59 p.m. were outlier counts.

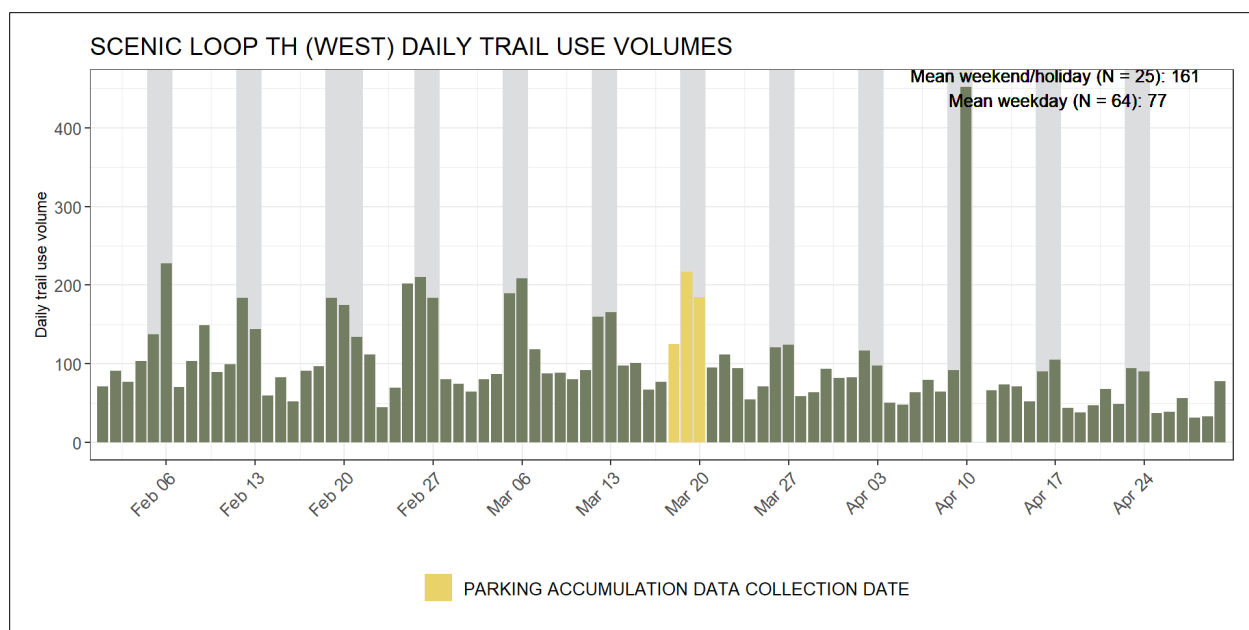


Figure 31. Total (inbound and outbound) daily trail use volumes: Scenic Loop Trailhead (gray shading indicates weekends/holidays).¹⁷

¹⁷ There is a gap in the data on April 11, 2022, because 50% or more of the hourly counts during the visitor use day from 5:00 a.m. through 6:59 p.m. were outlier counts. Although April 10 was identified as a potential outlier day, it was not removed from the analysis as the number of hours classified as outliers did not surpass the 50% threshold.

Figure 32 through Figure 37 present total (inbound and outbound) mean hourly trail use volumes, by day of week type, for each trail counter location during the counting period. These data suggest:

- Mean hourly total trail use volumes at the Broadway Trailhead increased starting at 5:00 a.m. until reaching a peak of approximately 46 at 10:00 a.m. on weekdays, and 70 at 10:00 a.m. on weekend days and holidays. On weekdays, after 10:00 a.m., mean hourly total trail use volumes decreased steadily from 10:00 a.m. through 3:00 p.m., increased from 3:00 p.m. until 5:00 p.m., and then decreased sharply from 5:00 p.m. through 7:00 p.m. On weekend days and holidays, mean hourly total trail use volumes decreased from 10:00 a.m. until 1:00 p.m., then varied between 30 and 40 through 5:00 p.m. before decreasing sharply through the 7:00 p.m. hour (Figure 32).
- Mean hourly total trail use volumes at the Camino Loma Alta Trailhead increased starting at 5:00 a.m. until reaching a peak of approximately 14 at 10:00 a.m. on weekdays and 23 at 10:00 a.m. on weekend days and holidays. After the 10:00 a.m. peak, mean hourly total trail use volumes varied between 5 and 15 on weekdays and between approximately 10 and 20 on weekend days and holidays before decreasing sharply at 6:00 p.m. (Figure 33).
- Mean hourly total trail use volumes at the Douglas Spring Trailhead increased starting at around 4:00 a.m. until reaching a peak of approximately 50 at 10:00 a.m. on weekdays, and just over 80 at 11:00 a.m. on weekend days and holidays. On weekdays, mean hourly total trail use volumes decreased steadily from 10:00 a.m. through 8:00 p.m. On weekend days and holidays, mean hourly total trail use volumes decreased sharply from 11:00 a.m. through noon, at which point they decreased more steadily through 8:00 p.m. (Figure 34).
- Mean hourly total trail use volumes at the El Camino del Cerro Trailhead increased from 4:00 a.m. until 9:00 a.m. on weekdays, at which point they varied between 7 and 8 through the 2:00 p.m. hour and decreased sharply through the 8:00 p.m. hour. Mean hourly total trail use volumes on weekend days and holidays increased starting at 4:00 a.m. until reaching a peak of approximately 13 at 10:00 a.m. Mean hourly total trail use volumes on weekend days and holidays decreased steadily starting at 1:00 p.m. (Figure 35).
- Mean hourly total trail use volumes at the King Canyon Trailhead increased starting at 5:00 a.m. until reaching a peak of approximately 36 at 2:00 p.m. on weekdays and 40 at 2:00 p.m. on weekend days and holidays. After the 2:00 p.m. peak, mean hourly total trail use volumes decreased steadily through the end of the day (Figure 36).
- Mean hourly total trail use volumes at the Scenic Loop Trailhead increased from 5:00 a.m. through 7:00 a.m. on weekdays, at which point they varied between approximately 5 and 12 through the 4:00 p.m. hour. Mean hourly total trail use volumes on weekend days and holidays increased starting at 5:00 a.m. until reaching a peak of approximately 18 at 11:00 a.m. Mean hourly total trail use volumes on weekend days and holidays decreased from 11:00 a.m. until 3:00 p.m., increased from 3:00 p.m. to 5:00 p.m., and then decreased again from 5:00 p.m. through 8:00 p.m. (Figure 37).

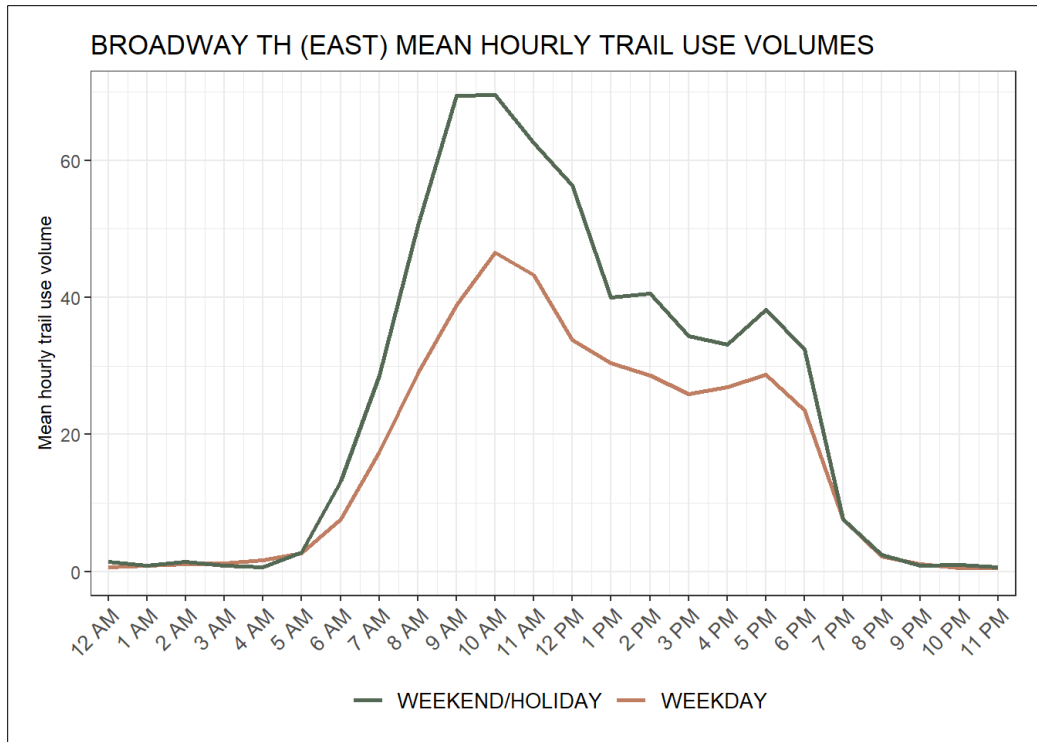


Figure 32. Total (inbound and outbound) mean hourly trail use volumes: Broadway Trailhead.

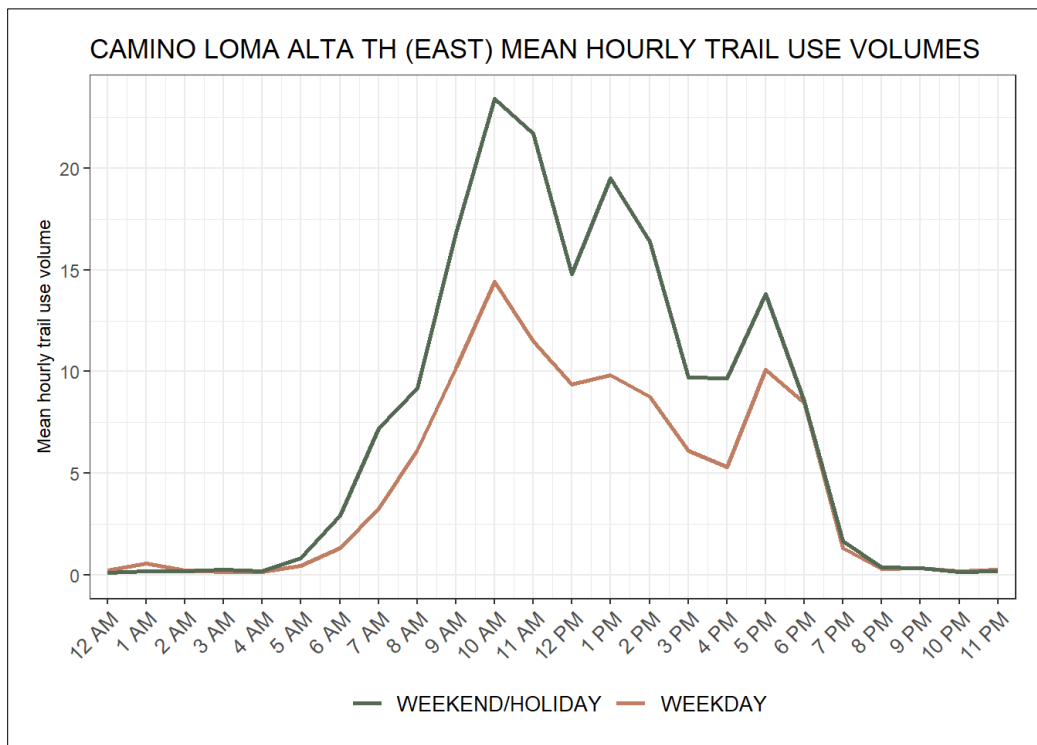


Figure 33. Total (inbound and outbound) mean hourly trail use volumes: Camino Loma Alta Trailhead.

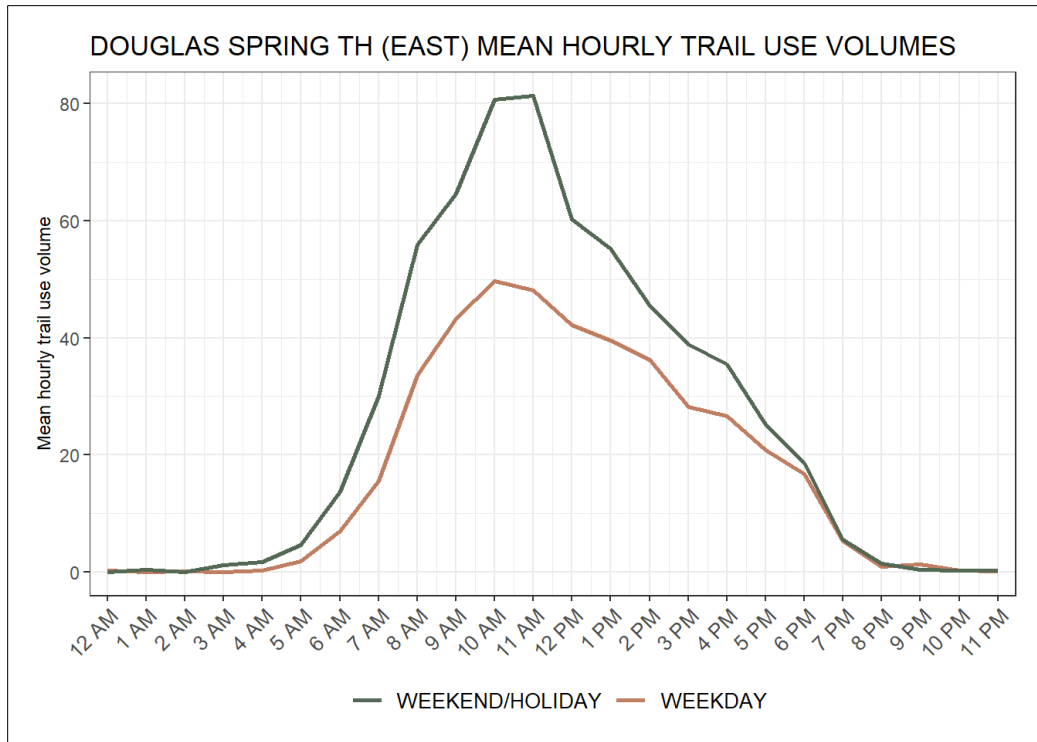


Figure 34. Total (inbound and outbound) mean hourly trail use volumes: Douglas Spring Trailhead.

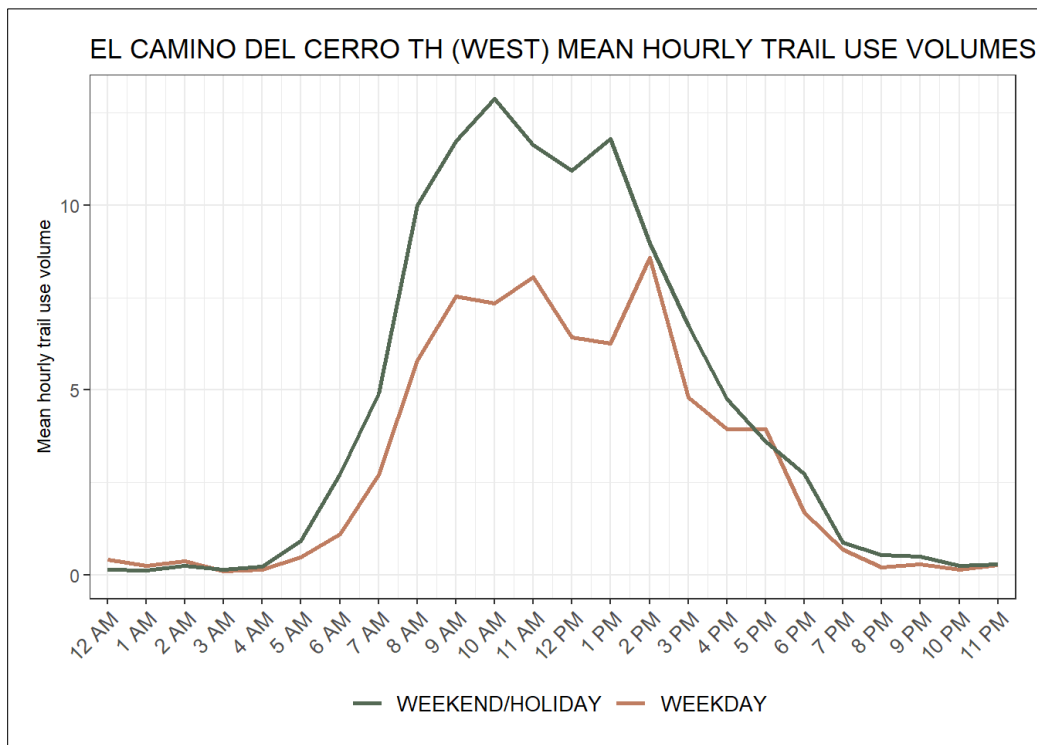


Figure 35. Total (inbound and outbound) mean hourly trail use volumes: El Camino del Cerro Trailhead.

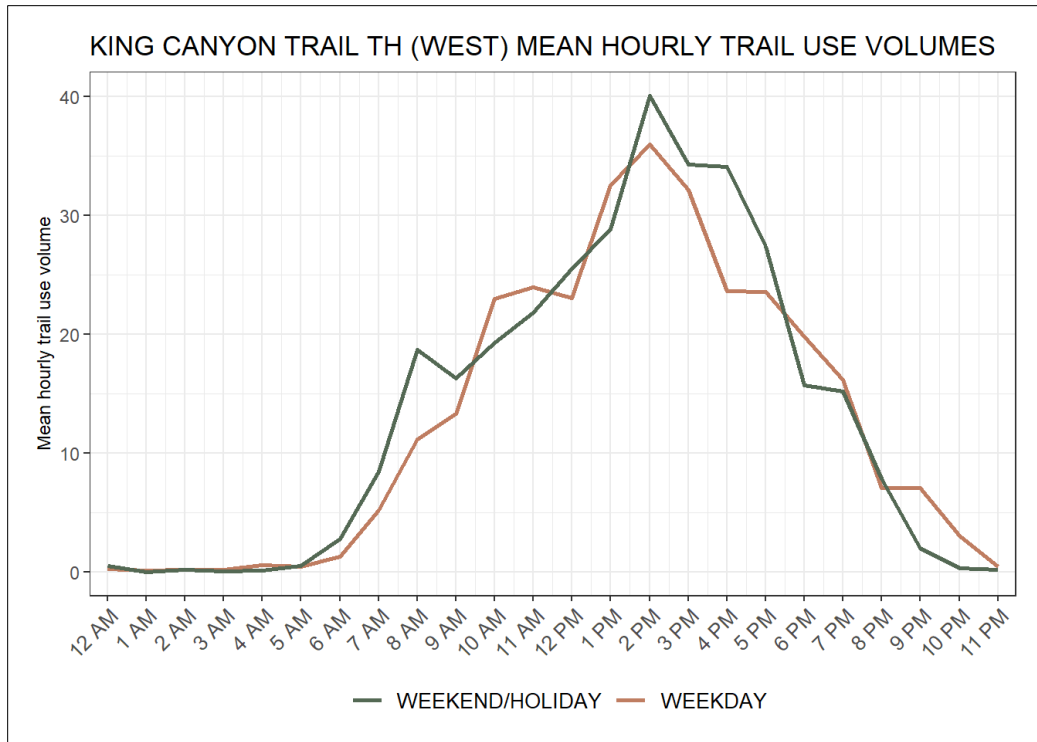


Figure 36. Total (inbound and outbound) mean hourly trail use volumes: King Canyon Trailhead.

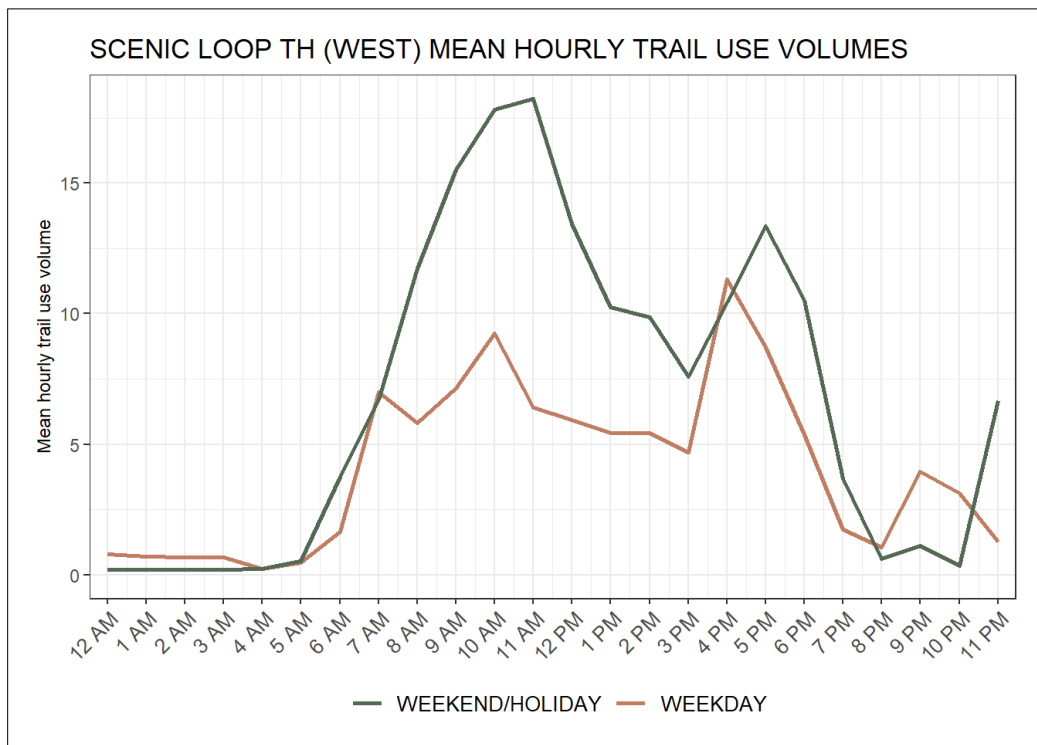


Figure 37. Total (inbound and outbound) mean hourly trail use volumes: Scenic Loop Trailhead.

Parking conditions

This subsection of the report presents descriptive results of parking accumulation as well as estimates of parking duration and parking turnover for the 11 parking areas. The parking areas are depicted in Figure 8 and Figure 9 and include:

- Broadway Trailhead
- Cam-Boh Picnic Area
- Comino Loma Alta Trailhead
- Douglas Spring Trailhead
- Hugh Norris Trailhead
- Rincon Mountain District Visitor Center (RMD VC)
- Scenic Loop Trailhead
- Signal Hill Picnic Area
- Tanque Verde Ridge Trailhead
- Tucson Mountain District Visitor Center (TMD VC)
- Valley View

This subsection also presents vehicle queue length count summaries for the Rincon Mountain District entrance gate.

Parking accumulation

Figure 38 through Figure 48 present hourly parking accumulation, by sampling date for each of the 11 parking areas. These data suggest:

- At the Broadway Trailhead parking area, parking accumulation was highest in the morning on all three days. Peak parking accumulation was higher on Saturday and Sunday (34 and 31, respectively) than on Friday (17). The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 38).
- At the Cam-Boh Picnic parking area, peak parking accumulation was highest on Sunday (8) compared to Friday and Saturday (6 and 4, respectively). The time at which the peak parking accumulation count occurred varied across each of the three days, and the hourly parking accumulation trend was not consistent from day to day during the sampling period (Figure 39).

- At the Camino Loma Alta parking area, parking accumulation was highest at both 10:00 a.m. and 1:00 p.m. on Friday, highest at 9:00 a.m. on Saturday, and highest at 11:00 a.m. on Sunday. Peak parking accumulation was higher on Saturday and Sunday (16 and 15, respectively) than on Friday (7). The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 40).
- At the Douglas Spring Trailhead parking area, peak parking accumulation was higher on Saturday and Sunday (59 and 68, respectively) than on Friday (39). The hourly parking accumulation trend was relatively consistent from day to day during the sampling period, increasing in the early morning, peaking during the 9:00 a.m. hour on Sunday and during the 10:00 a.m. hour on Friday and Saturday, and decreasing during the late morning and early afternoon. In the last hour of the analysis period (i.e., the 2:00 p.m. hour), there were still 33 vehicles parked at the Douglas Spring Trailhead on Saturday and Sunday, but no vehicles parked there on Friday (Figure 41).
- At the Hugh Norris Trailhead parking area, parking accumulation was highest at 10:00 a.m. on both Friday and Saturday, and highest at 12:00 p.m. and 1:00 p.m. on Sunday. Peak parking accumulation was highest on Saturday (14) compared to Friday and Sunday (9 and 12, respectively). The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 42).
- At the Rincon Mountain District Visitor Center (RMD VC) parking area, parking accumulation was highest during the last hour of the analysis period (i.e., the 2:00 p.m. hour) on both Friday and Sunday, and highest at 8:00 a.m. on Saturday. Peak parking accumulation was highest on Sunday (34) compared to Friday and Saturday (27 and 25, respectively). The hourly parking accumulation trend was somewhat consistent from day to day during the sampling period, increasing in the morning and remaining relatively constant from late morning through the early afternoon (Figure 43).
- At the Scenic Loop Trailhead parking area, parking accumulation was highest in the morning (either at 9:00 a.m. or 10:00 a.m.) on all three sampling days. Peak parking accumulation was highest on Sunday (13) compared to Friday and Saturday (11). The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 44).
- At the Signal Hill Picnic parking area, parking accumulation was highest at noon on Friday and Sunday, and during the last hour of the analysis period (i.e., the 3:00 p.m. hour) on Saturday. Peak parking accumulation was highest on Sunday (21) compared to Friday and Saturday (15 and 14, respectively). The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 45).

- At the Tanque Verde Ridge Trailhead parking area, parking accumulation was highest at 11:00 a.m. on Friday, at noon on Saturday, and at 1:00 p.m. on Sunday. Peak parking accumulation was highest on Sunday (33) compared to Friday and Saturday (27 and 24, respectively). For each of the three sampling days, hourly parking accumulation rose steadily early in the day, reached a peak mid-day (i.e., between 11:00 a.m. and 1:00 p.m.), and then steadily declined through the last hour of the analysis period (i.e., the 3:00 p.m. hour). (Figure 46).
- At the Tucson Mountain District Visitor Center (TMD VC) parking area, parking accumulation peaked at 27 at 1:00 p.m. on Friday, at 34 at 10:00 a.m. on Saturday, and at 47 at 3:00 p.m. on Sunday. The hourly parking accumulation trend was somewhat similar from day to day during the sampling period, remaining relatively constant from 9:00 a.m. through 2:00 p.m., and decreasing in the last hour of the analysis period (i.e., the 4:00 p.m. hour) (Figure 47).
- At the Valley View parking area, parking accumulation peaked at 7 at 10:00 a.m. and 11:00 a.m. on Friday, at 18 at 2:00 p.m. on Saturday, and at 12 at 11:00 a.m. and 12:00 p.m. on Sunday. The hourly parking accumulation trend was not consistent from day to day during the sampling period, but instead varied across each of the three days (Figure 48).

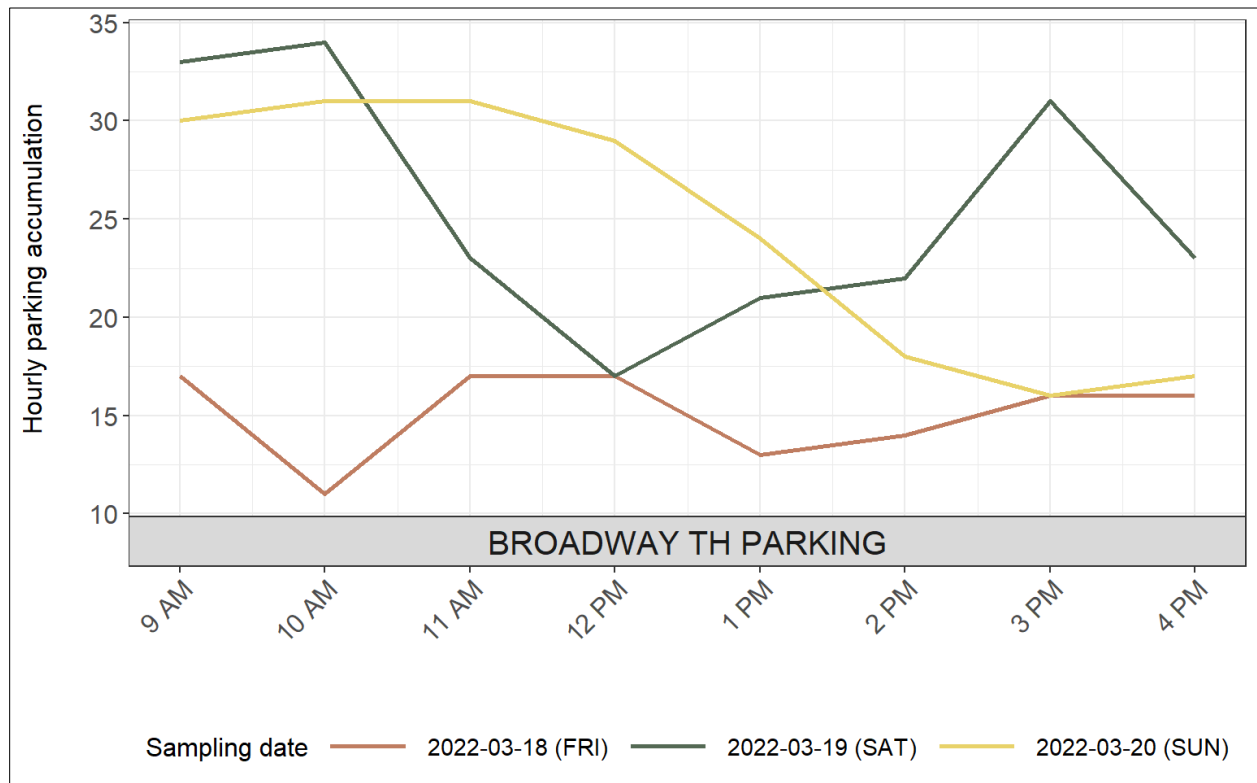


Figure 38. Hourly parking accumulation, by sampling date: Broadway Trailhead Parking.

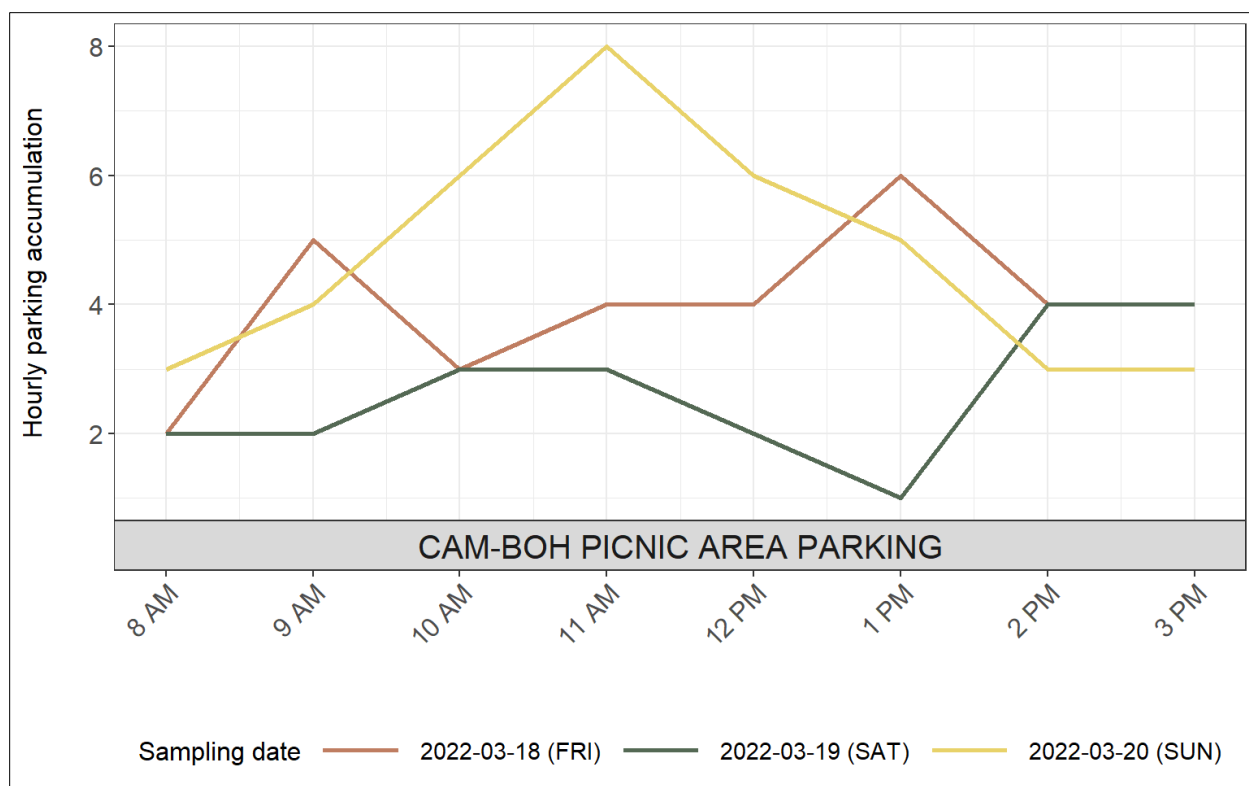


Figure 39. Hourly parking accumulation, by sampling date: Cam-Boh Picnic Area.

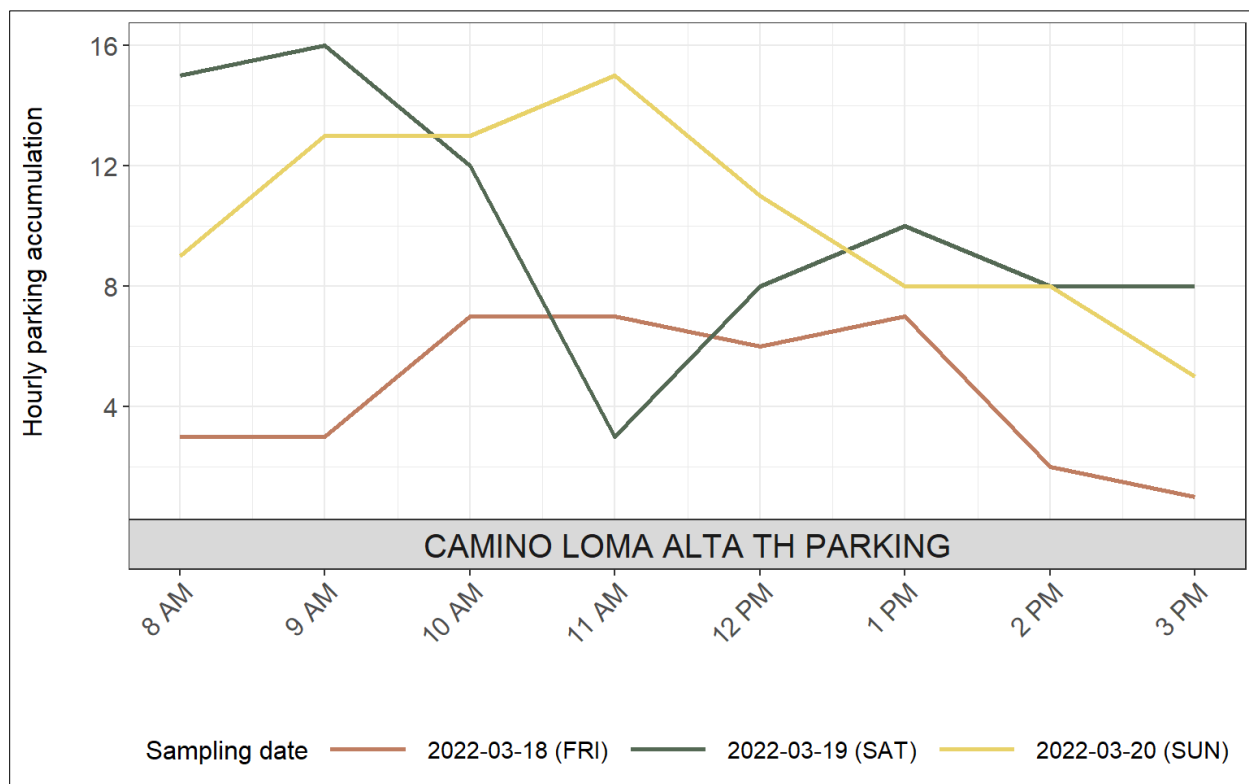


Figure 40. Hourly parking accumulation, by sampling date: Camino Loma Alta Trailhead Parking.

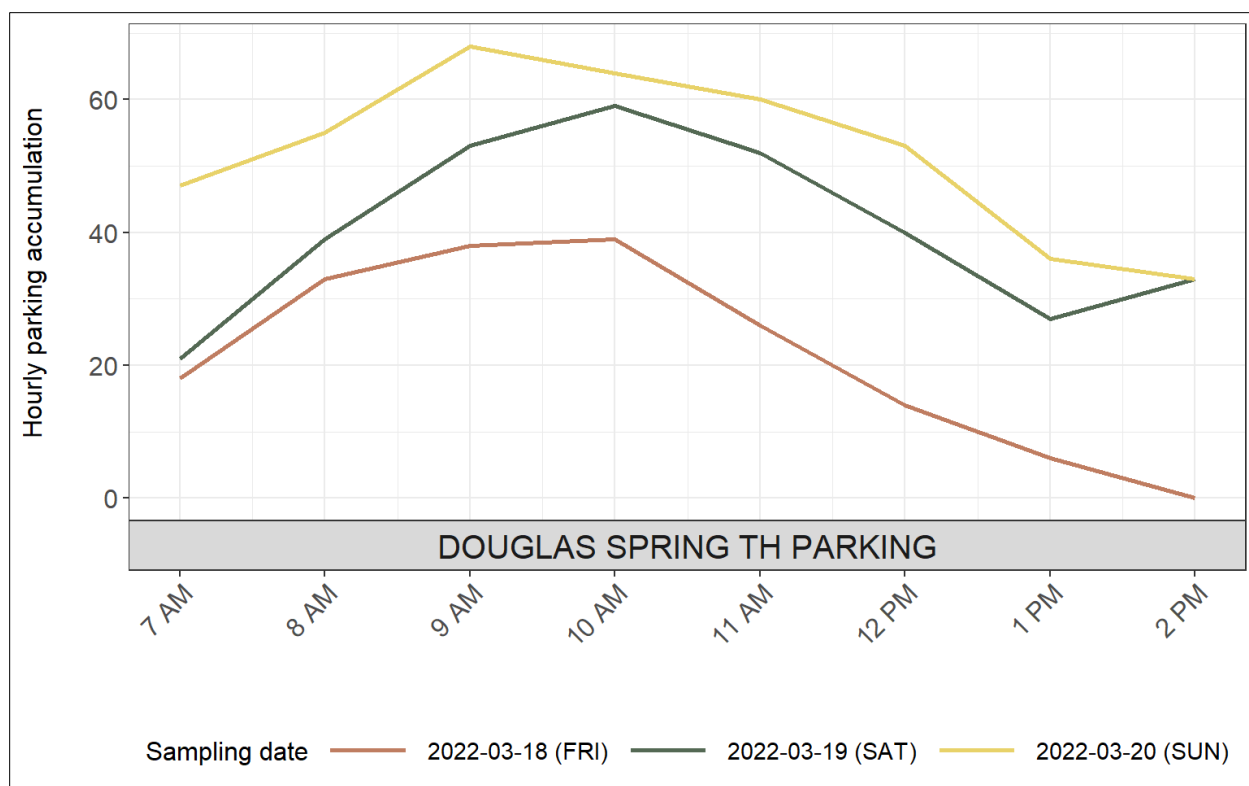


Figure 41. Hourly parking accumulation, by sampling date: Douglas Spring Trailhead.

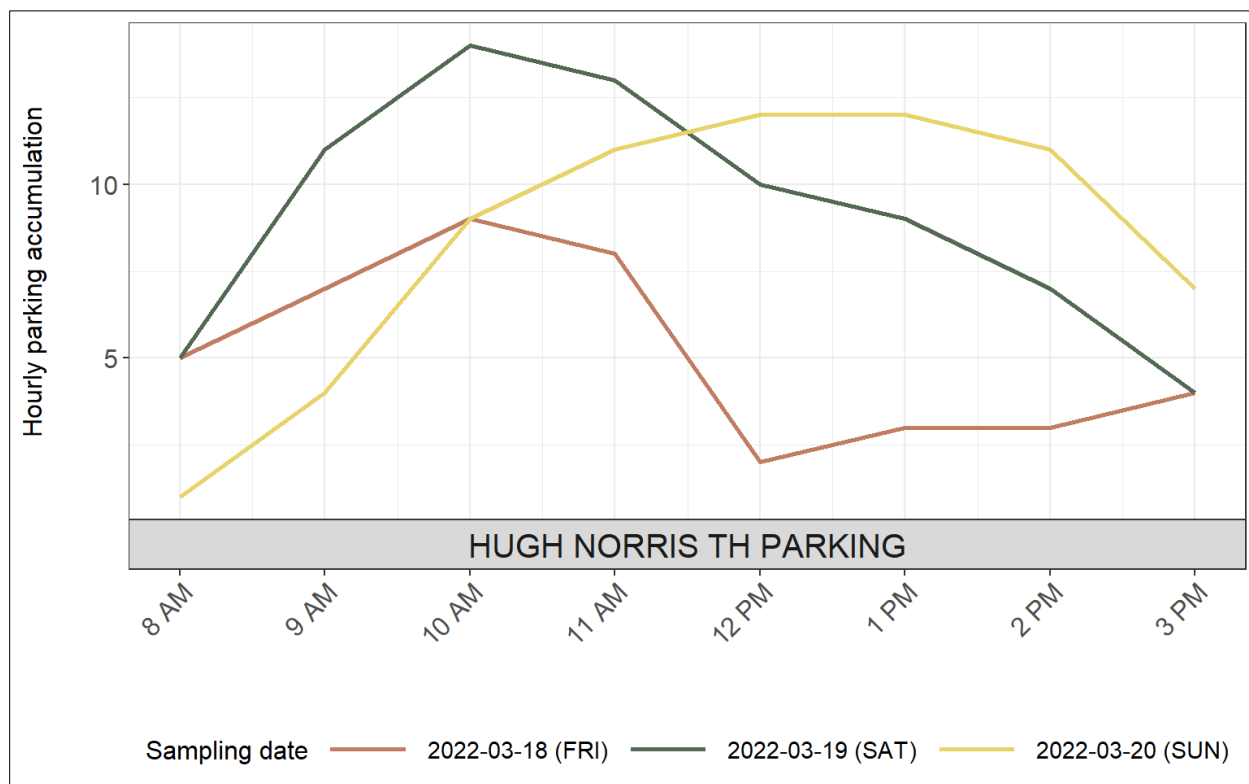


Figure 42. Hourly parking accumulation, by sampling date: Hugh Norris Trailhead Parking.

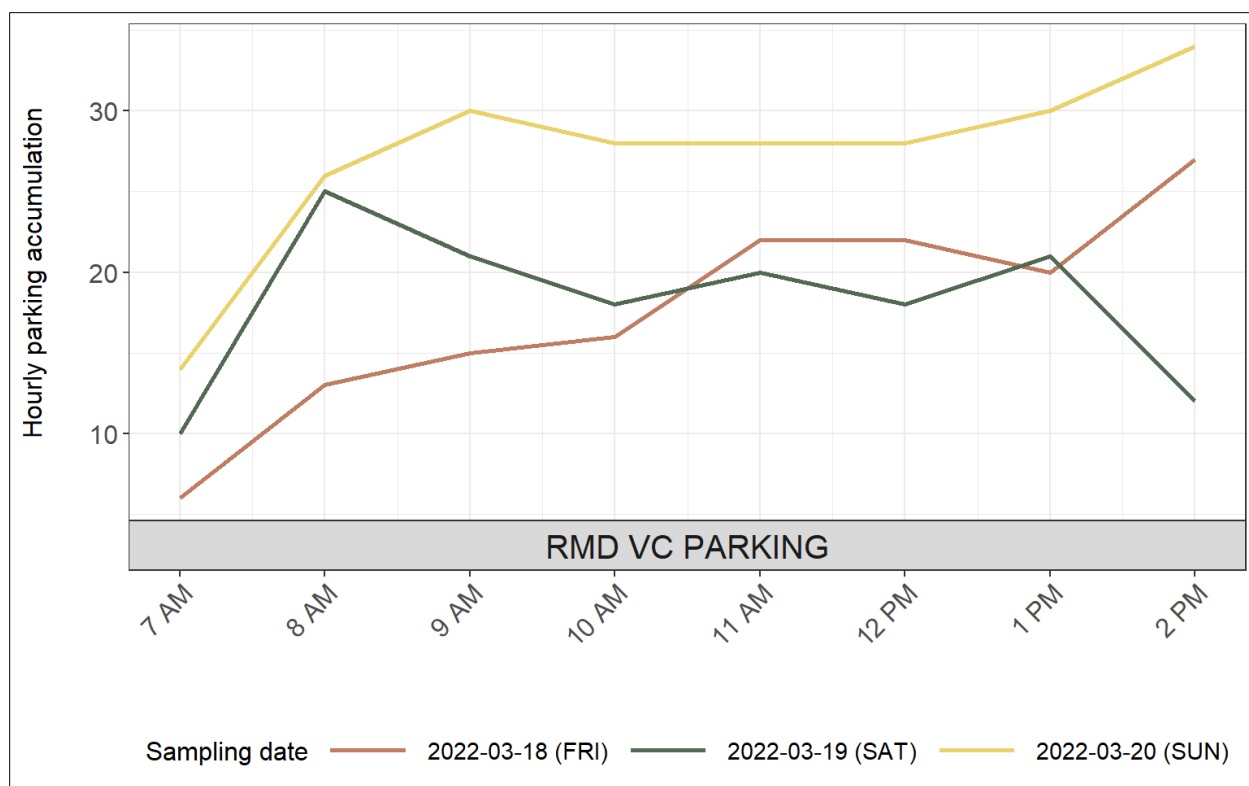


Figure 43. Hourly parking accumulation, by sampling date: Rincon Mountain District Visitor Center Parking.

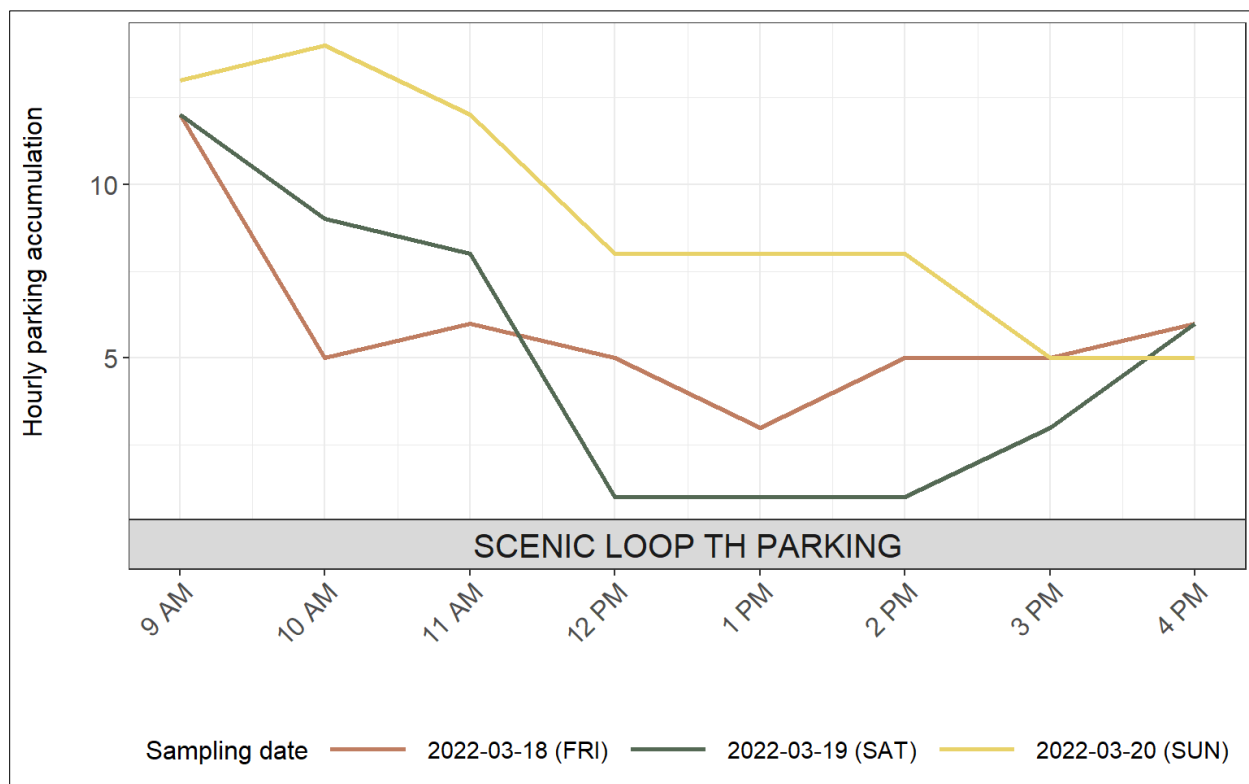


Figure 44. Hourly parking accumulation, by sampling date: Scenic Loop Trailhead Parking.

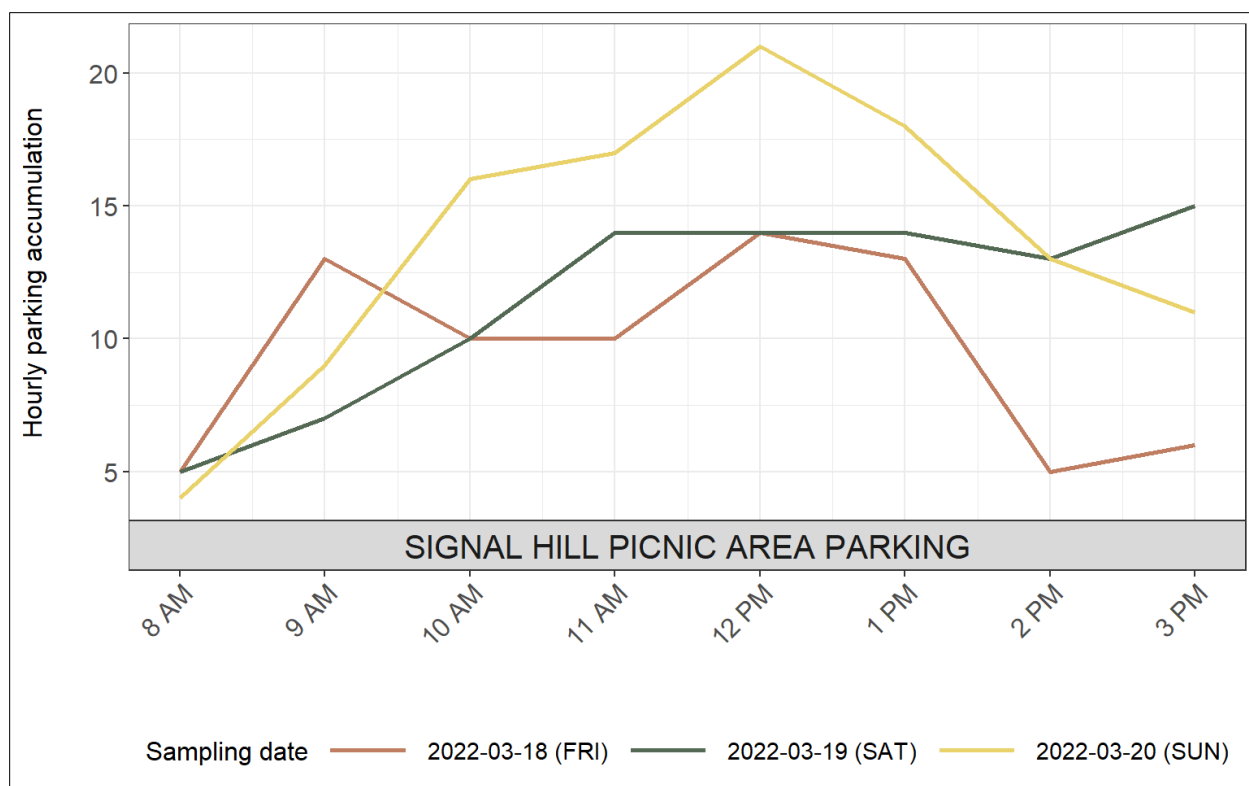


Figure 45. Hourly parking accumulation, by sampling date: Signal Hill Picnic Area Parking.

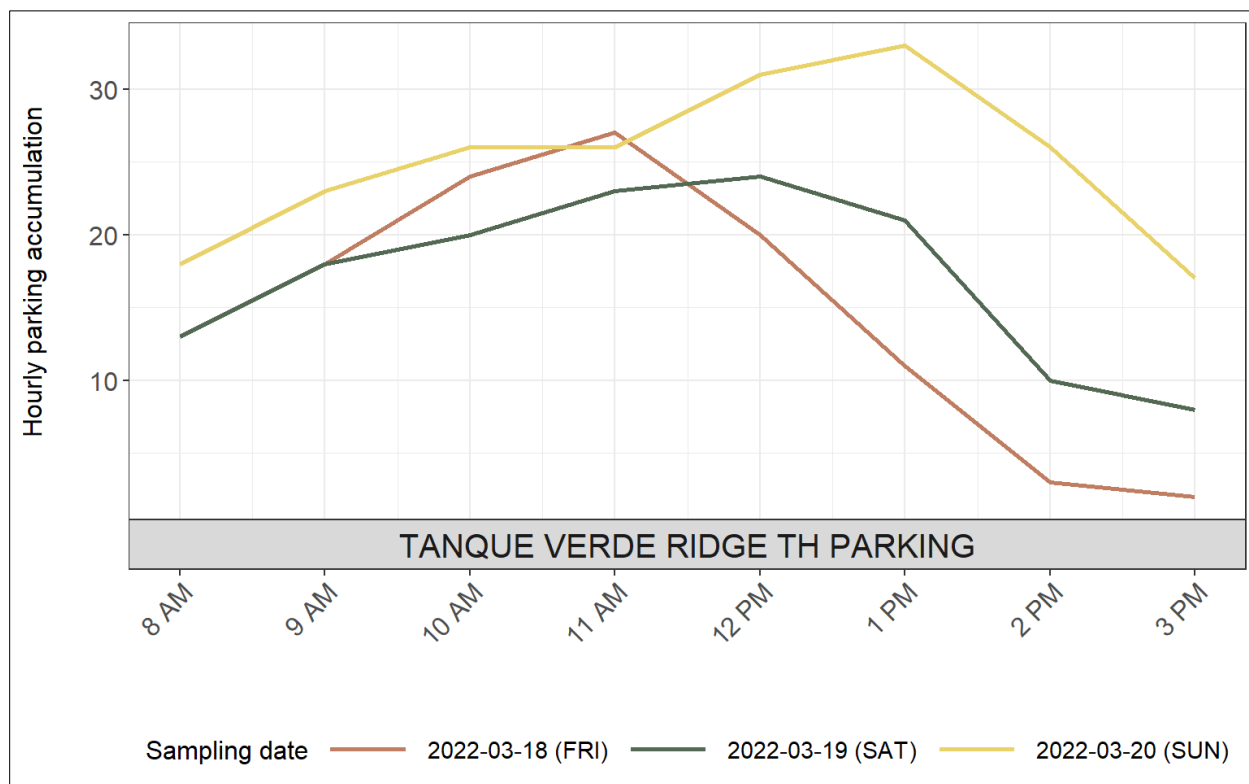


Figure 46. Hourly parking accumulation, by sampling date: Tanque Verde Ridge Trailhead Parking.

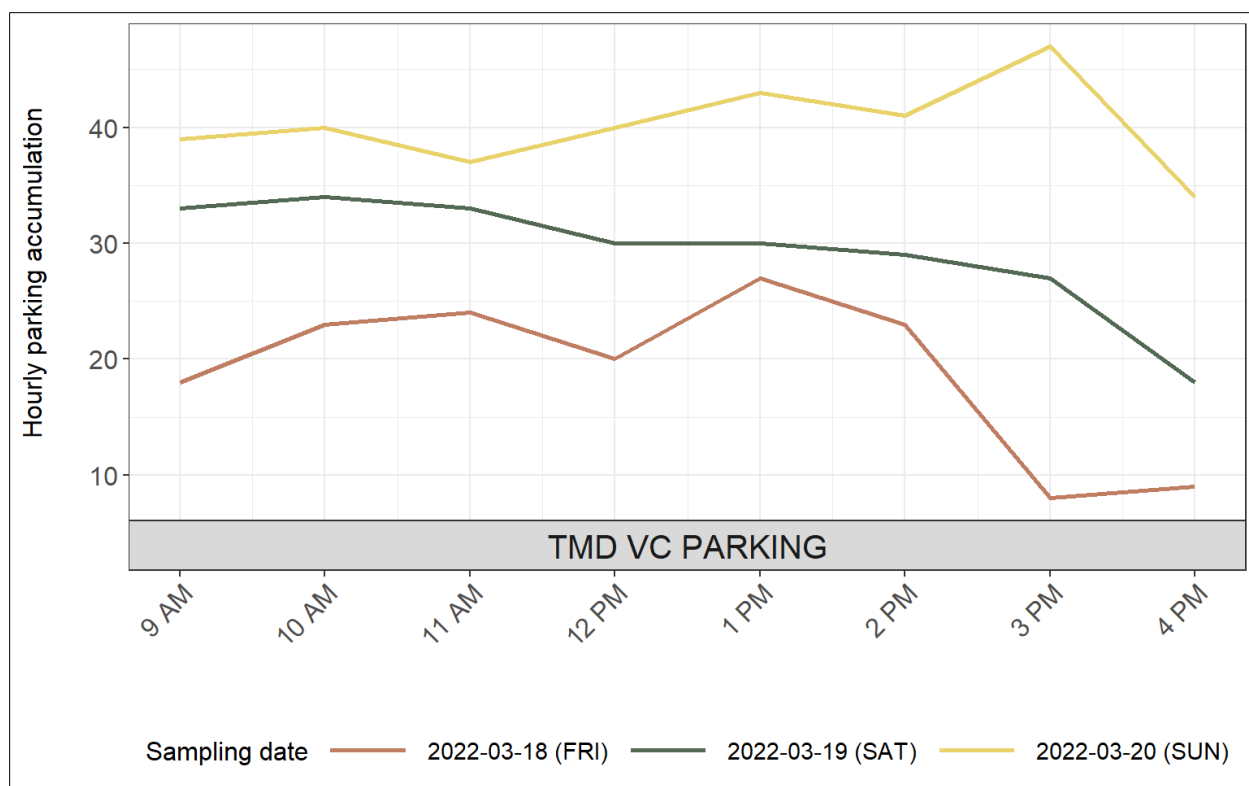


Figure 47. Hourly parking accumulation, by sampling date: Tucson Mountain District Visitor Center Parking.

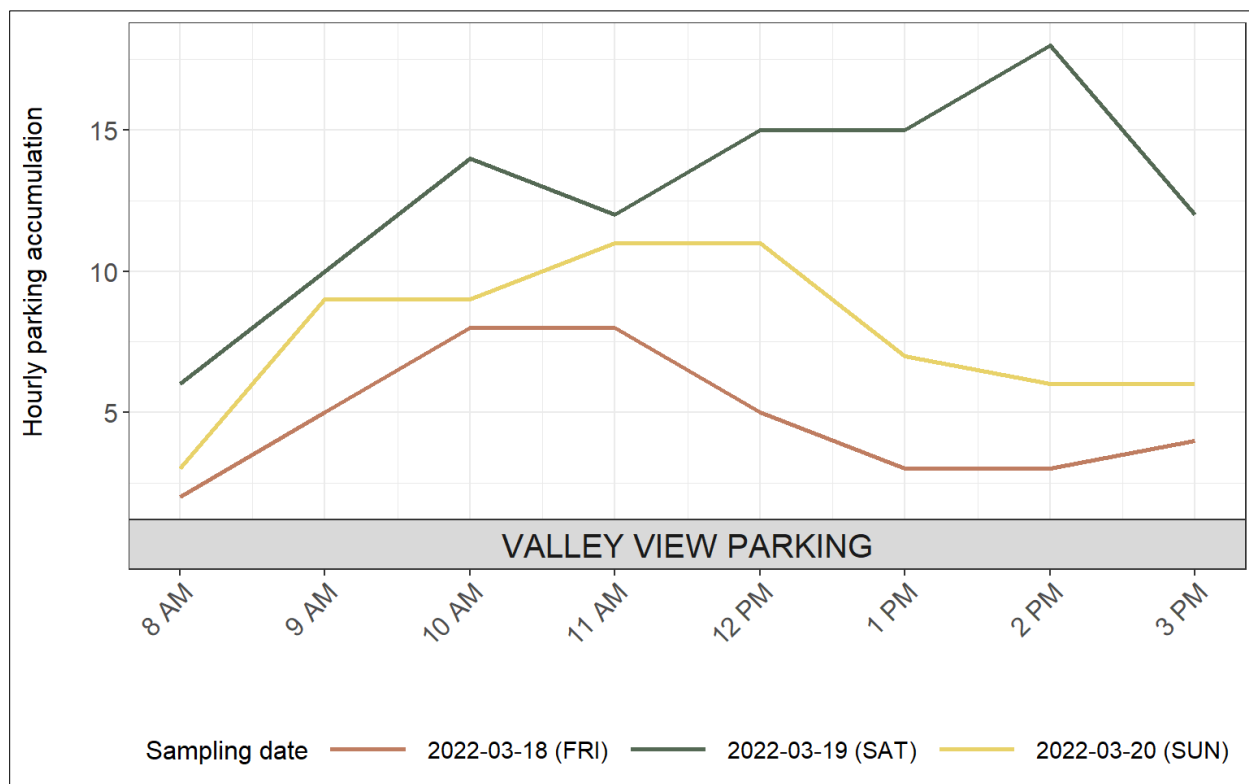


Figure 48. Hourly parking accumulation, by sampling date: Valley View Parking.

Parking area duration

Table 6 presents the estimated average parking duration (i.e., the average extent of time each vehicle parked), by date and location during the parking sampling period. These data suggest:

- On average, parking durations for the Rincon Mountain District Visitor Center, Signal Hill Picnic Area, Tucson Mountain District Visitor Center, and Valley View parking areas were less than one hour.
- On average, parking durations for the Camino Loma Alta Trailhead and Douglas Spring Trailhead parking areas were greater than two hours.
- Average parking duration was highest for the Douglas Spring Trailhead at 168 minutes. Average parking duration was lowest for the Rincon Mountain District Visitor Center at 30.6 minutes.

Table 6. Estimated parking duration (minutes) by location and date.

Location	Saturday March 18, 2022	Sunday March 19, 2022	Monday March 20, 2022	Average
Broadway Trailhead	82.5	112	110	101.9
Cam-Boh Picnic Area	64.0	70.0	71.3	68.4
Camino Loma Alta Trailhead	108.0	154.8	136.7	133.17
Douglas Spring Trailhead	128.9	154.3	220.9	168.0
Hugh Norris Trailhead	60.0	125.1	78.8	88.0
Rincon Mountain District Visitor Center	28.6	26.4	36.7	30.6
Scenic Loop Trailhead	97.2	91.1	121.7	103.3
Signal Hill Picnic Area	45.6	54.7	60.6	53.6
Tanque Verde Ridge Trailhead	90.8	124.5	115.4	110.2
Tucson Mountain District Visitor Center	25.8	37.3	50.0	37.7
Valley View	42.2	81.6	45.9	56.6

Parking area turnover

Table 7 presents hourly parking turnover rates (i.e., the number of vehicles per parking space throughout the sampling day),¹⁸ by date and location. Turnover rates were only calculated for the three parking areas with a striped parking capacity. These data suggest:

- The Rincon Mountain District Visitor Center parking turnover rate ranged from 1.23 to 1.48 times per hour during the three-day sampling period, with an average hourly turnover rate of 1.36. An hourly turnover rate of 1.36 suggests that there are approximately one to two different vehicles parked in each parking space per hour.
- The Tanque Verde Ridge Trailhead parking turnover rate ranged from 0.36 to 0.57 times per hour during the three-day sampling period, with an average hourly turnover rate of 0.45. An hourly turnover rate of 0.45 suggests that there are approximately zero to one vehicles parked in each parking space per hour.
- The Tucson Mountain District Visitor Center parking turnover rate ranged from 0.57 to 0.83 times per hour during the three-day sampling period, with an average hourly turnover rate of 0.80. An hourly turnover rate of 0.80 suggests that there are approximately zero to one vehicles parked in each parking space per hour.

Table 7. Estimated hourly parking turnover rate, by location and date.

Location	Saturday March 18, 2022	Sunday March 19, 2022	Monday March 20, 2022	Average
Rincon Mountain District Visitor Center	1.23	1.38	1.48	1.36
Tanque Verde Ridge Trailhead	0.42	0.36	0.57	0.45
Tucson Mountain District Visitor Center	0.57	0.81	0.83	0.80

¹⁸ The sampling days for each of the parking areas consisted of eight hours. Table 2 reports the specific eight-hour time periods for which parking data were recorded and post-processed for each parking area.

Queue Length at Rincon Mountain District Visitor Center

Figure 49 presents five-minute instantaneous vehicle queue length count summaries for the Rincon Mountain District entrance gate¹⁹ just beyond the visitor center and parking area for each of the three parking sampling days. These results suggest:

- Across all three sampling days, the maximum observed queue length was 10 vehicles, which occurred on Sunday, March 20, at 10:50 a.m. On Sunday, March 20, queue length observations ranged from one to 10 vehicles between 10:30 a.m. and 12:00 p.m., but there were four observations of queue length at or above nine vehicles. On Friday, March 18, the maximum queue length of six vehicles occurred twice during the 10:00 a.m. hour. Meanwhile, on Saturday, March 19, the maximum daily queue length of seven vehicles occurred at 2:00 p.m.
- For each of the three sampling days, it was common to observe no queue or a queue length of one vehicle between 7:00 a.m. through 9:00 a.m. Vehicle queue length typically increased starting around 9:00 a.m. and did not steadily decrease until approximately 12:30 p.m. In general, vehicle queue length counts spiked in the afternoon between 1:30 to 2:30 p.m.

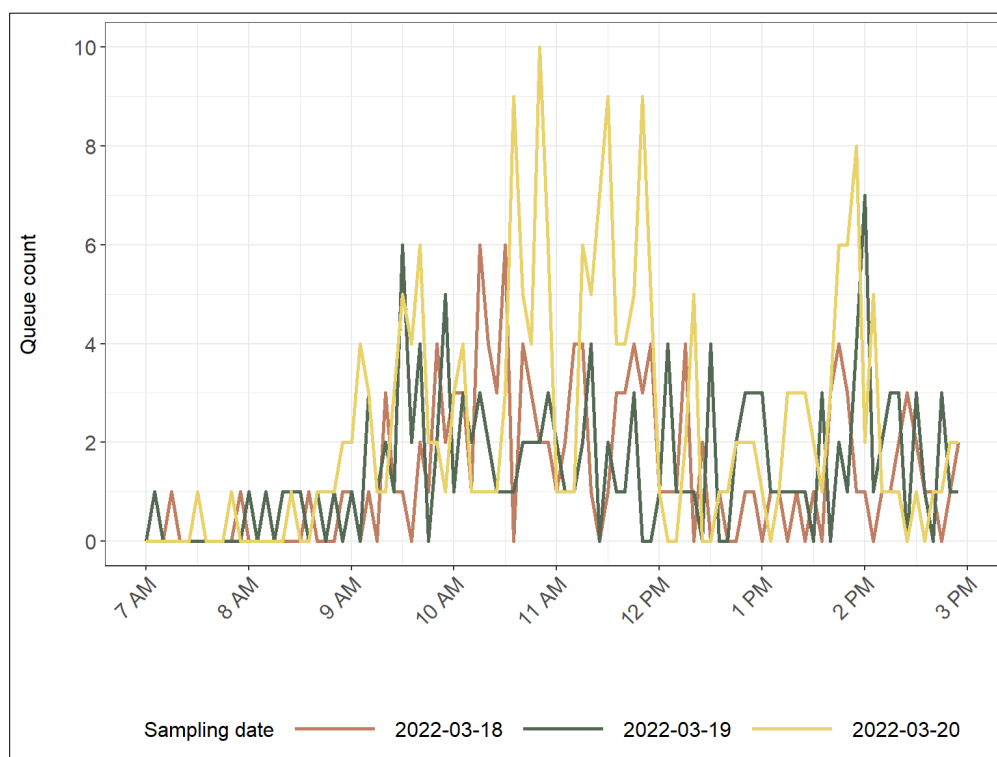


Figure 49. Five-minute queue length count: Rincon Mountain District entrance gate.

¹⁹ Figure 59 in [Appendix 3](#) contains a screen capture of the Rincon Mountain District's camera viewscape area, which shows the extent of roadway for which the vehicle queue length was counted.

Share of recreation traffic on park roads

This section of the report presents descriptive summaries of PMD and estimated proportions of recreation traffic on the three park-maintained roads. Table 8 provides a summary of the cleaned dataset used for subsequent analyses.

Table 8. Description and summary statistics for the cleaned PMD sample.

Dataset	Analysis Period	Number of sightings	Number of unique vehicles
Cleaned PMD	March 1, 2022 – February 28, 2023 (12 months)	1,065,383	15,206

Table 9 summarizes additional characteristics derived from the cleaned PMD sample. The mean time interval between consecutive sightings (292.9 seconds) is much higher than the median (9 seconds), suggesting that a substantial number of vehicles have longer time gaps between sightings.

Table 9. Summary of characteristics derived from the from the cleaned PMD sample.

Variable of interest	Mean	Median
Number of sightings per vehicle	70.1	28
Time interval between consecutive sightings (second)	292.9	9
Median speed (mph)	36.0	40.5

Table 10 presents the estimated percentages of daily recreation traffic on three park roads in the West District: West Picture Rocks Road, North Sandario Road, and North Kinney Road. The results are presented for a series of stop duration thresholds ranging from two minutes to 15 minutes, which were used to identify vehicles that made recreation stops with durations longer than the specified threshold value (see Methods for more details). These results suggest that:

- For West Picture Rocks Road, the proportion of daily recreation traffic ranges from 14.9% to 16.8% during the 12-month analysis period. A share of 16.8% suggests that out of every 100 vehicles on the West Picture Rocks Road per date, approximately 17 vehicles can be attributed to recreation visitors.
- For North Sandario Road, the proportion of daily recreation traffic ranges from 15.8% to 19.4% during the 12-month analysis period. A share of 19.4% suggests that out of every 100 vehicles on the North Sandario Road per date, approximately 19 vehicles can be attributed to recreation visitors.
- For North Kinney Road, the proportion of daily recreation traffic ranges from 57.4% to 69.9% during the 12-month analysis period. A share of 69.9% suggests that out of every

100 vehicles on the North Kinney Road per date, approximately 70 vehicles can be attributed to recreation visitors.

- Across the different stop duration thresholds, North Kinney Road consistently has the highest proportion of recreation traffic, followed by North Sandario Road and West Picture Rocks Road. This pattern aligns with the fact that North Kinney Road provides direct access to prominent recreation facilities or attractions, such as the Red Hills Visitor Center, attracting a larger share of visitors engaged in recreation activities within the park.
- As the stop duration threshold increases, the proportion of recreation traffic shows a gradual decrease across all roads. This is because only longer stops were considered when calculating the number of vehicles that made recreation stops. It is important to note that using a larger stop duration threshold may result in an underestimation of the proportion of recreation visitors, while a smaller threshold may inflate the proportion. It's a matter for NPS to judge which threshold is acceptable based on management knowledge and expertise of visitor use patterns and trends.

Table 10. Estimated percentages of recreation traffic on park roads based on stop duration thresholds.

Minimum stop duration (minute)	West Picture Rocks Road	North Sandario Road	North Kinney Road
2	16.8%	19.4%	69.9%
3	16.4%	19.2%	69.3%
5	16.0%	18.5%	67.7%
10	15.4%	17.2%	63.6%
15	14.9%	15.8%	57.4%

Passive mobile data comparison with visitor survey data

This section of the report presents the results of a comparison between PMD and visitor survey data. The visitor survey data utilized for this comparison came from the 2023 SAGU on-site visitor survey,²⁰ which collected information about visitor demographics, experiences, and visitation patterns in the East and West districts of the park from late January to early February 2023. To validate PMD, five specific questions related to visitor use patterns were selected in consultation with NPS. Responses from survey question 21 to a portion of question 25 were retrieved and summarized in frequency tables.

To create comparable frequency tables using the PMD, vehicles that made recreation stops in the park were considered to determine the number of vehicles that matched the descriptions in each

²⁰ The analysis period of the PMD, spanning from March 1, 2022, through February 28, 2023, generally aligns with the visitor survey sampling period (January to February 2023). The results of the SAGU visitor survey are summarized in a separate report document.

selected survey question (this is because all survey respondents had made recreation visits to the park on the day they were intercepted for the survey). For instance, the results from survey question 21 could be summarized as the percentage of visitors who left and re-entered the East District. To obtain a comparable metric from the PMD, the number of daily vehicles that made recreation stops in the East District and re-entered the East District was divided by the total number of daily vehicles that made recreation stops in the East District.²¹ These results are presented in the same order as the survey questions and include the question number, text, and frequency comparison tables (Table 11 through Table 18). It should also be noted that the survey data sample size varies by question due to item non-response (i.e., one or more questions left blank by a respondent). These results suggest that:

- PMD indicated a slightly lower proportion of visitors (6.6%) re-entering the East District on the same day compared to the survey data (9.4%) (Table 11).
- PMD showed a slightly higher proportion of visitors that re-entered the East District once on the same day and a slightly lower proportion of visitors that re-entered twice. There were no instances of visitors re-entering the East District three times in the survey data, while 2.2% of visitors did so in the PMD (Table 12).
- PMD showed a slightly lower percentage of visitors (5.0%) who left the East District and entered the West District on the same day compared to the survey data (8.3%) (Table 13).
- PMD showed a slightly higher proportion of visitors (6.4%) re-entering the West District compared to the visitor survey data (3.5%) (Table 14).
- PMD showed a notably higher proportion of visitors (93.7%) re-entering the West District once compared to the visitor survey data (72.0%). In contrast, the visitor survey data showed a considerably higher proportion of visitors (28.0%) re-entering the West District twice compared to the PMD (6.3%). Note that this comparison result should be interpreted with caution due to the small sample size of survey responses (N = 25) (Table 15).
- PMD showed a lower percentage of visitors (3.3%) who left the West District and entered the East District on the same day compared to the survey data (10%) (Table 16).
- In terms of visitation patterns among park points of interest (POIs),²² the comparisons between PMD and survey data reveal a substantial difference. Specifically, PMD showed a notably lower proportion of visitors (18.7%) to Red Hills Visitor Center compared to the survey data (52.2%) (Table 17). Conversely, the PMD reveals a substantially higher proportion of visitors (28.1%) to West Pictured Rocks Road east of the Cam-Boh Picnic Area compared to the survey data (0.8%) (Table 18).

²¹ The validation analysis was conducted using a 15-minute stop duration threshold.

²² The percentage of visitors visiting a park point of interest (POI) was calculated as the proportion of daily vehicles that stopped in the corresponding POI polygon out of the total number of daily vehicles that made recreation stops within the refined SAGU park boundary. The POI polygons and refined park boundary are shown in Figure 71 in [Appendix 4](#).

Question 21A:

Did you, or do you plan to, leave and re-enter Saguaro East (Rincon Mountain District) today?

Table 11. Frequency comparisons between PMD and survey data for re-entry into the East District.

Category	Visitor survey (N = 588)	PMD (N = 682)
Yes	9.4%	6.6%
No	90.6%	93.4%

Question 21B:

How many times did you, or do you plan to, leave and re-enter Saguaro East (Rincon Mountain District) today?

Table 12. Frequency comparisons between PMD and survey data for the number of times re-entering the East District.

Times	Visitor survey (N = 55)	PMD (N = 45)
1	92.7%	95.6%
2	7.3%	2.2%
3	—	2.2%

Question 22:

Did you, or do you plan to, leave Saguaro East (Rincon Mountain District) and enter Saguaro West (Tucson Mountain District) today?

Table 13. Frequency comparisons between PMD and survey data for visitors leaving East District and entering West District.

Category	Visitor survey (N = 588)	PMD (N = 682)
Yes	8.3%	5.0%
No	91.7%	95.0%

Question 23A:

Did you, or do you plan to, leave and re-enter Saguaro West (Tucson Mountain District) today?

Table 14. Frequency comparisons between PMD and survey data for re-entry into the West District.

Category	Visitor survey (N = 709)	PMD (N = 991)
Yes	3.5%	6.4%
No	96.5%	93.6%

Question 23B:

How many times did you, or do you plan to, leave and re-enter Saguaro West (Tucson Mountain District) today?

Table 15. Frequency comparisons between PMD and survey data for the number of times re-entering the West District.

Times	Visitor survey (N = 25)	PMD (N = 63)
1	72.0%	93.7%
2	28.0%	6.3%

Question 24:

Did you, or do you plan to, leave Saguaro West (Tucson Mountain District) and enter Saguaro East (Rincon Mountain District) today?

Table 16. Frequency comparisons between PMD and survey data for visitors leaving West District and entering East District.

Category	Visitor survey (N = 709)	PMD (N = 991)
Yes	10.0%	3.3%
No	90.0%	96.7%

Question 25:

Considering your visit today, have you been to or do you plan to, visit any of the following locations within Saguaro National Park?

Table 17. Frequency comparisons between PMD and survey data for visitation to Red Hills Visitor Center.

Category	Visitor survey (N = 1284)	PMD (N = 1648)
Yes	52.2%	18.7%
No	47.8%	81.3%

Table 18. Frequency comparisons between PMD and survey data for visitation to West Pictured Rocks Road east of Cam-Boh Picnic Area.

Category	Visitor survey (N = 1284)	PMD (N = 1648)
Yes	0.8%	28.1%
No	99.2%	71.9%

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Appendix 1. Hourly outlier and missing values replaced with imputed values for daily-level roadway traffic and trail use volume summaries

Table 19. Hourly outliers and missing values replaced with imputed values for daily-level roadway traffic and trail use volume summaries.²³

Data type	Location name	Timestamp	Missing or outlier value	Imputed value
Traffic	Golden Gate Road	2022-02-03 10:00:00	2	12
Traffic	Golden Gate Road	2022-02-10 10:00:00	--	12
Traffic	Golden Gate Road	2022-02-10 11:00:00	--	21
Traffic	Golden Gate Road	2022-03-04 15:00:00	--	32
Traffic	Golden Gate Road	2022-04-01 09:00:00	--	10
Traffic	Hohokam Road	2022-02-10 10:00:00	--	28
Traffic	Hohokam Road	2022-03-04 15:00:00	--	30
Traffic	Hohokam Road	2022-04-01 09:00:00	--	19
Traffic	Tucson Mountain District Visitor Center	2022-02-10 10:00:00	--	70
Traffic	Tucson Mountain District Visitor Center	2022-02-14 13:00:00	--	90
Traffic	Tucson Mountain District Visitor Center	2022-02-14 14:00:00	--	104
Traffic	Tucson Mountain District Visitor Center	2022-02-14 15:00:00	--	106
Traffic	Tucson Mountain District Visitor Center	2022-02-14 16:00:00	--	74
Traffic	Tucson Mountain District Visitor Center	2022-02-14 17:00:00	--	32
Traffic	Tucson Mountain District Visitor Center	2022-02-14 18:00:00	--	6
Traffic	Tucson Mountain District Visitor Center	2022-02-14 19:00:00	--	2
Traffic	Tucson Mountain District Visitor Center	2022-02-14 20:00:00	--	0
Traffic	Tucson Mountain District Visitor Center	2022-02-14 21:00:00	--	0
Traffic	Tucson Mountain District Visitor Center	2022-02-14 22:00:00	--	0
Traffic	Tucson Mountain District Visitor Center	2022-02-14 23:00:00	--	0
Traffic	Tucson Mountain District Visitor Center	2022-03-05 09:00:00	--	97
Traffic	Tucson Mountain District Visitor Center	2022-03-05 10:00:00	--	150
Traffic	Tucson Mountain District Visitor Center	2022-03-11 15:00:00	--	79
Traffic	Tucson Mountain District Visitor Center	2022-04-02 15:00:00	--	86
Trail	Broadway Trailhead	2022-03-08 11:00:00	--	40
Trail	Broadway Trailhead	2022-03-14 07:00:00	136	21
Trail	Broadway Trailhead	2022-03-16 10:00:00	138	51
Trail	Broadway Trailhead	2022-04-05 11:00:00	--	22
Trail	Broadway Trailhead	2022-04-13 17:00:00	83	23
Trail	Camino Loma Alta Trailhead	2022-02-14 17:00:00	33	2
Trail	Camino Loma Alta Trailhead	2022-02-22 13:00:00	55	5

²³ Tucson Mountain District Visitor Center count data from DataNet between February 15 and March 4, 2022, that were not available or missing are not included in this table.

Data type	Location name	Timestamp	Missing or outlier value	Imputed value
Trail	Camino Loma Alta Trailhead	2022-03-08 11:00:00	--	17
Trail	Camino Loma Alta Trailhead	2022-03-14 08:00:00	151	6
Trail	Camino Loma Alta Trailhead	2022-03-18 17:00:00	55	4
Trail	Camino Loma Alta Trailhead	2022-04-05 11:00:00	--	4
Trail	Camino Loma Alta Trailhead	2022-04-13 09:00:00	32	8
Trail	Camino Loma Alta Trailhead	2022-04-15 09:00:00	61	12
Trail	Douglas Spring Trailhead	2022-03-08 12:00:00	--	32
Trail	Douglas Spring Trailhead	2022-03-14 07:00:00	140	18
Trail	Douglas Spring Trailhead	2022-03-16 09:00:00	154	45
Trail	Douglas Spring Trailhead	2022-04-05 12:00:00	--	11
Trail	Douglas Spring Trailhead	2022-04-10 18:00:00	106	14
Trail	El Camino del Cerro Trailhead	2022-02-10 13:00:00	--	6
Trail	El Camino del Cerro Trailhead	2022-02-27 17:00:00	102	5
Trail	El Camino del Cerro Trailhead	2022-03-04 13:00:00	--	13
Trail	El Camino del Cerro Trailhead	2022-03-08 16:00:00	63	2
Trail	El Camino del Cerro Trailhead	2022-03-13 17:00:00	75	4
Trail	El Camino del Cerro Trailhead	2022-03-16 17:00:00	349	7
Trail	El Camino del Cerro Trailhead	2022-03-18 13:00:00	46	13
Trail	El Camino del Cerro Trailhead	2022-03-28 10:00:00	31	15
Trail	El Camino del Cerro Trailhead	2022-04-01 12:00:00	--	3
Trail	El Camino del Cerro Trailhead	2022-04-01 13:00:00	--	2
Trail	El Camino del Cerro Trailhead	2022-04-10 08:00:00	24	10
Trail	El Camino del Cerro Trailhead	2022-04-26 06:00:00	114	2
Trail	El Camino del Cerro Trailhead	2022-04-26 07:00:00	219	5
Trail	El Camino del Cerro Trailhead	2022-04-26 08:00:00	133	5
Trail	El Camino del Cerro Trailhead	2022-04-27 10:00:00	155	5
Trail	El Camino del Cerro Trailhead	2022-04-27 11:00:00	105	4
Trail	El Camino del Cerro Trailhead	2022-04-27 12:00:00	148	2
Trail	El Camino del Cerro Trailhead	2022-04-27 13:00:00	175	5
Trail	El Camino del Cerro Trailhead	2022-04-28 13:00:00	139	2
Trail	King Canyon Trailhead	2022-02-10 14:00:00	--	42
Trail	King Canyon Trailhead	2022-02-10 19:00:00	134	73
Trail	King Canyon Trailhead	2022-02-10 20:00:00	277	58
Trail	King Canyon Trailhead	2022-02-11 16:00:00	133	32
Trail	King Canyon Trailhead	2022-02-19 08:00:00	547	10
Trail	King Canyon Trailhead	2022-02-21 11:00:00	271	19
Trail	King Canyon Trailhead	2022-02-21 12:00:00	513	12
Trail	King Canyon Trailhead	2022-02-21 13:00:00	356	4
Trail	King Canyon Trailhead	2022-02-22 08:00:00	273	13
Trail	King Canyon Trailhead	2022-02-23 08:00:00	761	1
Trail	King Canyon Trailhead	2022-02-23 09:00:00	419	5
Trail	King Canyon Trailhead	2022-02-23 10:00:00	934	7

Data type	Location name	Timestamp	Missing or outlier value	Imputed value
Trail	King Canyon Trailhead	2022-02-23 11:00:00	1102	4
Trail	King Canyon Trailhead	2022-02-23 12:00:00	399	10
Trail	King Canyon Trailhead	2022-02-24 17:00:00	364	16
Trail	King Canyon Trailhead	2022-02-27 08:00:00	120	35
Trail	King Canyon Trailhead	2022-02-27 16:00:00	360	34
Trail	King Canyon Trailhead	2022-02-27 18:00:00	533	4
Trail	King Canyon Trailhead	2022-02-27 19:00:00	354	1
Trail	King Canyon Trailhead	2022-03-01 08:00:00	399	9
Trail	King Canyon Trailhead	2022-03-01 15:00:00	310	11
Trail	King Canyon Trailhead	2022-03-01 16:00:00	322	13
Trail	King Canyon Trailhead	2022-03-03 08:00:00	232	11
Trail	King Canyon Trailhead	2022-03-04 08:00:00	1237	9
Trail	King Canyon Trailhead	2022-03-04 09:00:00	548	18
Trail	King Canyon Trailhead	2022-03-04 10:00:00	1059	22
Trail	King Canyon Trailhead	2022-03-04 11:00:00	1557	18
Trail	King Canyon Trailhead	2022-03-04 12:00:00	861	20
Trail	King Canyon Trailhead	2022-03-04 13:00:00	--	9
Trail	King Canyon Trailhead	2022-03-16 18:00:00	355	45
Trail	King Canyon Trailhead	2022-04-01 13:00:00	--	65
Trail	King Canyon Trailhead	2022-04-22 14:00:00	403	11
Trail	King Canyon Trailhead	2022-04-22 15:00:00	337	15
Trail	King Canyon Trailhead	2022-04-22 16:00:00	562	12
Trail	King Canyon Trailhead	2022-04-22 17:00:00	364	4
Trail	King Canyon Trailhead	2022-04-27 12:00:00	288	46
Trail	King Canyon Trailhead	2022-04-27 14:00:00	311	79
Trail	King Canyon Trailhead	2022-04-28 12:00:00	330	22
Trail	King Canyon Trailhead	2022-04-28 13:00:00	436	35
Trail	Scenic Loop Trailhead	2022-02-10 11:00:00	--	6
Trail	Scenic Loop Trailhead	2022-03-04 09:00:00	53	13
Trail	Scenic Loop Trailhead	2022-03-04 14:00:00	--	6
Trail	Scenic Loop Trailhead	2022-03-08 17:00:00	91	9
Trail	Scenic Loop Trailhead	2022-03-16 15:00:00	57	4
Trail	Scenic Loop Trailhead	2022-03-16 16:00:00	269	7
Trail	Scenic Loop Trailhead	2022-03-21 14:00:00	76	7
Trail	Scenic Loop Trailhead	2022-04-01 11:00:00	--	1
Trail	Scenic Loop Trailhead	2022-04-10 11:00:00	684	8
Trail	Scenic Loop Trailhead	2022-04-10 12:00:00	836	4
Trail	Scenic Loop Trailhead	2022-04-10 13:00:00	946	1
Trail	Scenic Loop Trailhead	2022-04-10 14:00:00	909	4
Trail	Scenic Loop Trailhead	2022-04-10 15:00:00	96	1
Trail	Scenic Loop Trailhead	2022-04-10 16:00:00	305	5
Trail	Scenic Loop Trailhead	2022-04-12 00:00:00	117	0

Data type	Location name	Timestamp	Missing or outlier value	Imputed value
Trail	Scenic Loop Trailhead	2022-04-12 01:00:00	29	0
Trail	Scenic Loop Trailhead	2022-04-12 02:00:00	175	0
Trail	Scenic Loop Trailhead	2022-04-12 03:00:00	27	0
Trail	Scenic Loop Trailhead	2022-04-12 06:00:00	36	2

Appendix 2. Cactus Forest Drive total camera calibration counts

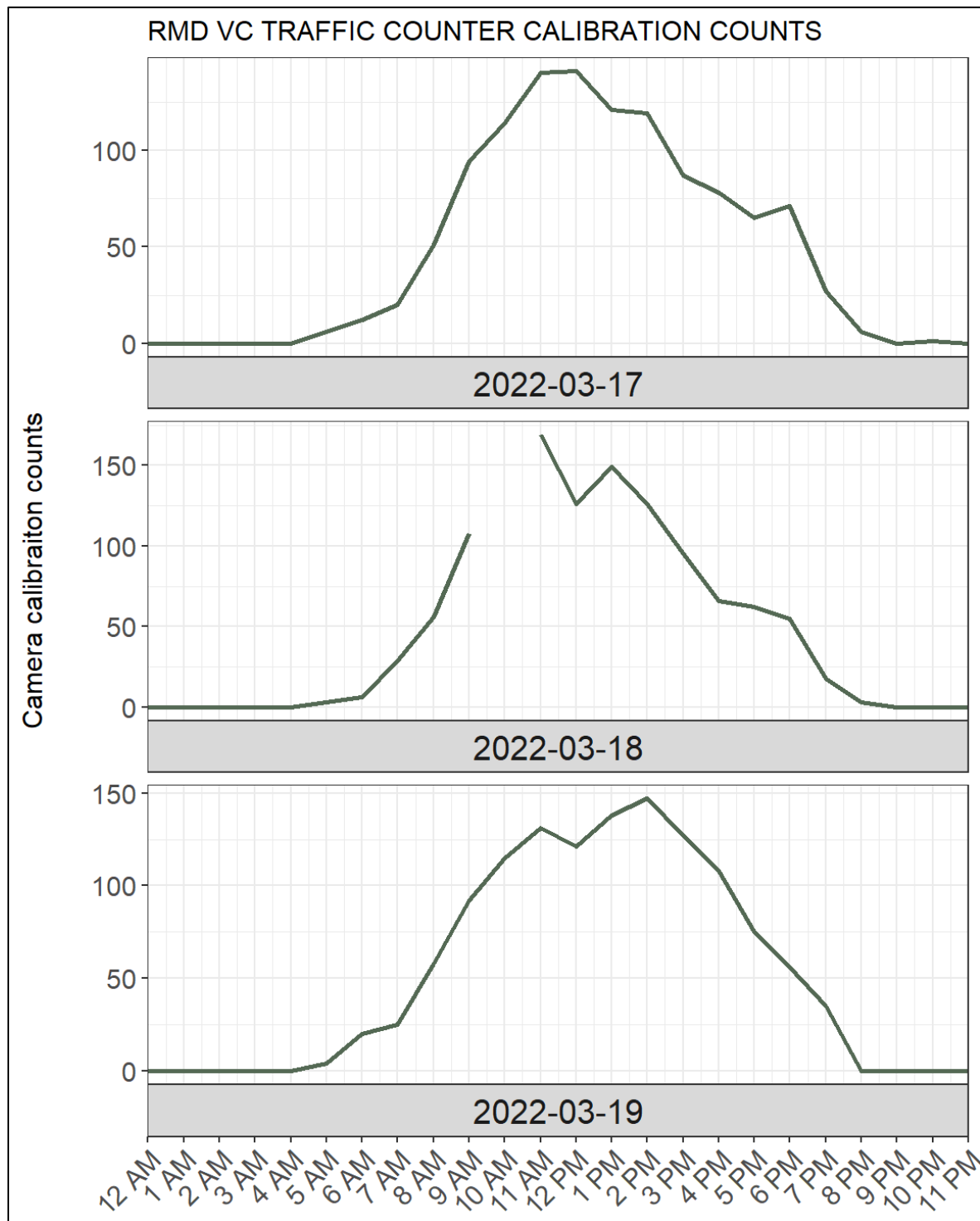


Figure 50. Hourly total (arrivals and departures) calibration counts of vehicles, by sampling date, from the Cactus Forest Drive counting location west of the Rincon Mountain District Visitor Center.²⁴

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Appendix 3. Parking video camera viewscape areas



Figure 51. Broadway Trailhead parking video camera #1 viewscape area.



Figure 52. Broadway Trailhead parking video camera #2 viewscape area.



Figure 53. Cam-Boh Picnic Area Trailhead parking video camera #1 viewscape area.



Figure 54. Camino Loma Alta Trailhead parking video camera #1 viewscape area.



Figure 55. Douglas Spring Trailhead parking video camera #1 viewscape area.



Figure 56. Douglas Spring Trailhead parking video camera #2 viewscape area.



Figure 57. Hugh Norris Trailhead parking video camera #1 viewscape area.



Figure 58. Hugh Norris Trailhead parking video camera #2 viewscape area.



Figure 59. Rincon Mountain District Visitor Center Trailhead parking video camera #1 viewscape area.



Figure 60. Scenic Loop Trailhead parking video camera #1 viewscape area.



Figure 61. Scenic Loop Trailhead parking video camera #2 viewscape area.



Figure 62. Signal Hill Trailhead parking video camera #1 viewscape area.



Figure 63. Signal Hill Trailhead parking video camera #2 viewscape area.



Figure 64. Signal Hill Trailhead parking video camera #3 viewscape area.



Figure 65. Tanque Verde Trailhead parking video camera #1 viewscape area.



Figure 66. Tanque Verde Trailhead parking video camera #2 viewscape area.



Figure 67. Tucson Mountain District Visitor Center parking video camera #1 viewscape area.



Figure 68. Tucson Mountain District Visitor Center parking video camera #2 viewscape area.



Figure 69. Tucson Mountain District Visitor Center parking video camera #3 viewscape area.



Figure 70. Valley View parking video camera #1 viewscape area.

Appendix 4. Methods for addressing time gaps and identifying recreation stops

To address the challenges posed by time gaps, an additional method for identifying recreation stops during time gaps was developed, alongside the stop duration method used under normal circumstances. The analysis considered two separate situations: vehicles without time gaps and vehicles with time gaps. For vehicles without time gaps, different stop duration thresholds ranging from two minutes to 15 minutes were set to identify recreation stops. For vehicles with time gaps, the gaps themselves were used as a criterion to detect stops. If a time gap was significantly longer than the anticipated travel time between the locations before and after the gap, a stop must have occurred during the gap. However, it's important to note that time gaps could also arise from signal blockage or data stream discontinuity, potentially leading to overcounting of recreation stops if a stop was flagged but no actual stop occurred within the park. To account for potential overcounting and improve the accuracy of estimating the proportion of recreation traffic, various filters were applied to the time gaps associated with a potential stop.

The identification of recreation stops was approached differently based on the two aforementioned situations. The specific criteria and filters applied in each situation are specified as follows:

1. Vehicles without time gaps:²⁵ In a situation where there were no time gaps, sightings with a rolling average speed²⁶ of no greater than 0.03 mph (miles per hour) were considered stopped sightings. The spatial collection of the stopped sightings was filtered to identify a stop with a duration longer than a specified threshold value. The threshold value varied between two minutes and 15 minutes. Among the remaining stopped sightings, the spatial center²⁷ of those located within the refined SAGU park boundary was designated as the location of a recreation stop. Figure 71 depicts the refined park boundary, which excludes peripheral regions that do not provide direct access to recreational activities but instead offer access to urban facilities.

²⁵ Vehicles were grouped into two categories based on the presence or absence of time gaps, which are periods where no data is recorded. In this study, vehicles with time gaps were identified when there was a time gap of at least two minutes. In contrast, vehicles without time gaps were those that didn't have any gaps longer than two minutes.

²⁶ "Rolling average speed" refers to the average speed of a vehicle calculated using a one-minute window. This means that speed measurements are collected at regular intervals along the vehicle's trajectory, and the average speed is calculated by considering the speed values within a one-minute time frame. As new speed measurements are obtained, the window "rolls" along the trajectory, continuously updating the average speed value to provide a smoothed representation of the vehicle's speed over short intervals of time.

²⁷ The spatial center of the stopped sightings is determined by taking the mean coordinates of the stopped sightings.

2. Vehicles with time gaps: To identify additional stops for vehicles with time gaps, the time gaps were compared with the anticipated travel time it should have taken to travel the distance during the gap. Assuming that the driving pattern remained consistent before, during, and after the time gap, the vehicle's speed is expected to remain relatively stable. To determine if a stop occurred during the time gap, the anticipated travel time was estimated by considering the driving distance from the last sighting before the gap to the first sighting after the gap, along with the rolling average speeds before and after the gap. Next, the anticipated travel time was compared with the duration of the time gaps. If the time gap exceeded the anticipated travel time by more than a threshold value, ranging from two minutes to 15 minutes, it was inferred that a potential recreation stop occurred during the gap. The sighting before the time gap was then identified as a potential stop location. For each threshold, a subset of potential stops was identified. To ensure that these potential stops are relevant to recreation activities (i.e., longer stops within the park), successive filters were applied to reduce the possibility of falsely identifying additional recreation stops:
 - a. The first filter excluded time gaps when a vehicle appeared to be leaving the park without stopping. If a vehicle was actively moving and exiting the park before the time gap, it was highly unlikely to have made a stop within the park during that gap. Therefore, time gaps were excluded if the vehicles were heading out of the park at a rolling average speed of at least 5 mph. These excluded time gaps were not considered in the subsequent filtering step.
 - b. The second filter removed time gaps where the sightings before and after the gaps were both located near the park boundary. If a vehicle was approaching at a very low speed near the park boundary before the gap, and the sighting immediately after the gap was also near the boundary, it indicated that the vehicle likely exited and re-entered the park, making it highly unlikely for a stop to occur in the park during the gap. Therefore, these time gaps were not considered potential recreation stops.

The recreation stops identified in both situations were combined to estimate the share of recreation traffic on each road based on the share of daily vehicles that were both detected within the corresponding road corridor polygon and made recreation stops among the daily vehicles recorded within that polygon.

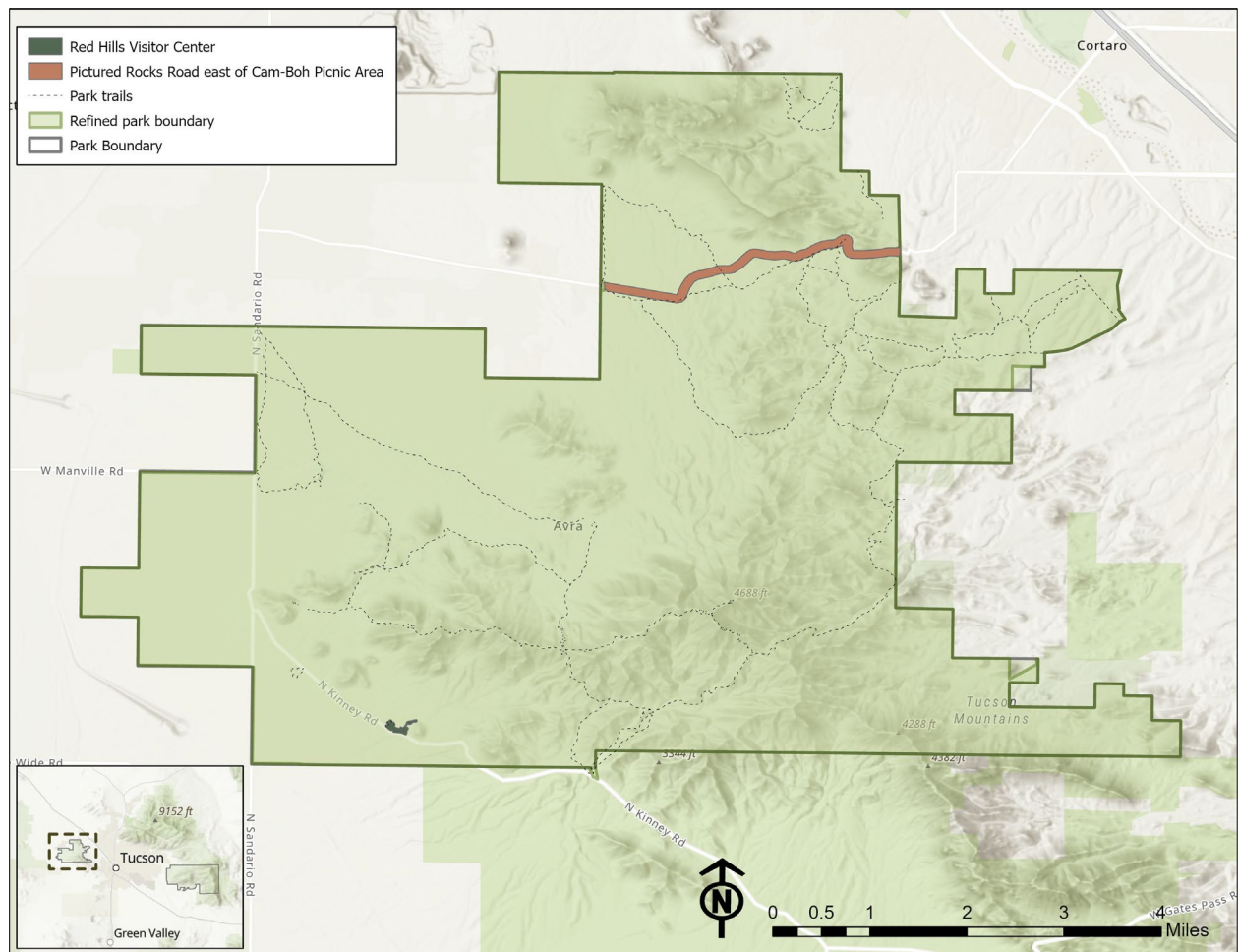


Figure 71. Refined park boundary and POI polygons.

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