2016–2017 Visitation Estimate Report

City of Boulder Open Space and Mountain Parks

2016–2017 Visitation Estimate Report

Monitoring Report

Prepared by:
Colin Leslie, Human Dimensions Coordinator

City of Boulder
Open Space and Mountain Parks Department
Boulder, Colorado

Published: August 2018
Updated: November 2018[1]

Suggested Citation:

Leslie, C. (2018). 2016-2017 Visitation Estimate Report. The City of Boulder, Open Space and Mountain Parks Department. Boulder, Colorado.

[1] See November 2018 Report Corrections at the end of this report for a description of updates.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This Visitation Estimate report is the collective work of many OSMP staff. We would like to thank Pete Lundskow, Zak Lance, Danielle Atton, Heidi Seidel, Saleh Dadjouy and Anna Kellogg for collecting, organizing and reviewing data; Brian Anacker for structure and content guidance; John Potter for project sponsorship; Tom Hodgson for assistance with database management; Katie Edwards, Emily Olivo and Kevin Pierce for conducting site mapping; Dustin Allard for assistance with infrastructure for equipment installations; Phillip Yates for editorial review and style guidance; Colin Leslie for contributions to methodology and analysis procedures; Deonne VanderWoude for project management; and numerous other internal contributors and reviewers.

Individually, and collectively, we thank you.

EXECUTIVE SUMMARY

The City of Boulder's Open Space and Mountain Parks (OSMP) Department manages over 45,000 acres of open space lands with around 155 miles of designated trails available for passive recreation activities. As of 2017, city-managed open space receives an estimated 6.26 (95% CI, 5.51 – 7.01) million annual visits. This is approximately a 34% increase from the 4.68 (95% CI, 4.38 – 5.00) million annual visits, estimated from the last system-wide study conducted in 2004-2005.

Understanding the level and distribution of visitation is important for improving and developing initiatives, services and policies that support high-quality visitor experiences and conservation of natural resources on city-managed open space. In the decade since the last system-wide estimate was completed, regional population growth, data from site-specific studies and a general sense of increasing visitation among both staff and the public prompted the department to obtain updated system-wide visitation estimates. Quantitatively understanding levels and patterns of visitation to city-managed open space allows the department to more effectively and efficiently deliver services to the public by evaluating the supply of department resources with the demands of recreation.

GOAL

The goal of this study – which is the largest visitation related data collection effort that the department has undertaken to date – is to develop a quantitative understanding of system-wide recreation visits[2] to city-managed open space[3] that can support the department and the public in making informed decisions relating to visitation.

Staff identified three primary objectives addressing fundamental components of visitation dynamics, which included:

- Estimate the total number of recreation visits to city-managed open space at 95% confidence interval.
- Evaluate annual, seasonal, monthly, daily and hourly patterns of visitation.
- Determine how visitation levels are distributed across sample locations.

Three secondary objectives were also identified:

- Evaluate changes in site-level visitation at the subset of locations that received repeat sampling between the 2004-2005 and 2016-2017 data collection periods.
- Estimate the number of recreation visits to select interior trails, including annual visitation to several popular destination areas.
- Estimate the number of annual dog visits to city-managed open space.

APPROACH

The Open Space and Mountain Parks system is geographically dispersed around the city, resulting in a highly porous boundary with many access locations to trails. To estimate the number of visits, staff installed automated

[2] A small number of counts collected during this study were known to be generated by staff, volunteers, contractors, or other non-recreation visits. Staff consider these to contribute minimally to the overall visitation estimates.

[3] Visitation data were only collected on trails or properties open to the public for recreational purposes.

trail counter equipment at strategic locations throughout the system. Counts of the number of people detected passing the trail counters at each location were then analyzed to estimate total system-wide visitation.

Between June 1, 2016, and May 31, 2017, staff deployed trail counters at 189 locations that were expected to receive at least 1,000 annual visits. Of the 189 locations, staff selected 45 locations as primary samples to receive continuous data collection for a minimum of one full year[4]. Staff conducted short-term data collections at the remaining 144 secondary sample locations for two to three weeks each to establish their visitation class. Staff established primary and secondary samples because installing automated trail counters at all 189 locations for a full year would have significantly exceeded project cost and personnel resources. During post-analysis, staff determined that 22 of the 144 secondary sample locations fell below the established minimum threshold of 1,000 annual visits. For the final analysis, staff classified the 167 valid sample locations into one of five visitation classes, ranging from Very Low to Very High. Visitation classes were based on ranges established during the 2004-2005 study.

Thirty-three of the 45 primary sample locations were direct repeats of sample locations included in the 2004-2005 study, which allowed staff to evaluate trends for these locations directly. Additionally, staff installed 16 trail counters at locations interior to the trail network system. These data will help staff better evaluate where and to what degree visitation levels measured at access locations (e.g. trailheads) is sustained across the interior of the trail system.

The following visitation estimate results detail one of two core components of the 2016-2017 Visitation Study conducted by the department's Human Dimensions Program. The other component consisted of an on-site visitor survey, which collected input from visitors on the types of recreational activities they were engaging in, experiences they had, and other key metrics designed to understand various dimensions of visitors to city-managed open space (VanderWoude & Kellogg, 2018). Results for the survey component can be found in the 2016-2017 Visitor Survey Report.

RESULTS

Staff were able to fully meet all the study objectives, and the department and public now have updated estimates that will offer a quantitative understanding of visitation. Following are some of the key findings from the visitation estimate study.

Annual Estimates

- City-managed open space received 6.26 (95% CI, 5.51 – 7.01) million annual visits, an increase of approximately 34% since the last visitation estimate of 4.68 (95% CI, 4.38 – 5.00) million conducted in 2004-2005, equivalent to a mean annual growth rate of 2.4%.
- Chautauqua, Sanitas, Wonderland Lake, South Mesa, Bobolink, and Marshall Mesa areas were some of the highest-visitation areas on city-managed open space, based on estimates from primary sample location data.
- Visitation to the Chautauqua Trail was the largest-measured increase in visitation since the 2005 study – growing from an estimated 111,479 to 349,050 annual visits, an increase of 213%, equivalent to a 10% mean annual growth rate.

[4] Due to technical issues with some counter installations at the beginning of the study, 5 of the 45 primary locations continued to receive data collection beyond the one-year mark (May 31, 2017) to ensure a minimum of 365 days of continuous data collection.

- Visitation increased at 22 of the 33 repeated primary sample locations, with 11 of those locations experiencing larger increases than the system-wide average of 34%.

Seasonal and Monthly Visitation Patterns

- Spring (1,658,202), summer (1,778,540) and fall (1,705,166) were the busiest seasons, with each season receiving 27% to 29% of annual visitation. Winter (1,104,829) is the lowest season, receiving 18% of annual visitation.
- March through November visitation was relatively consistent, with each month receiving between 8.5% and 10.1% of total annual visitation. In absolute terms, this equates to between roughly 526,000 and 636,000 visits each month. Sustained levels of visitation from March to November mean that the "off-season" is, at a minimum, much shorter on city-managed open space than comparative land agencies.
- June (635,979) and October (601,293) were the highest visitation months, accounting for 10.1% and 9.6% of annual visitation, respectively.
- December (313,640) was the lowest visitation month, accounting for 5% of annual visitation.

Daily and Hourly Visitation Patterns

- Forty percent of total annual visits occurred on the weekend, which was the same weekend/weekday proportion measured in 2004-2005.
- Sunday was the busiest day on average, accounting for 20.6% of total annual visitation.
- Tuesday was the least busy day on average, accounting for 11.3% of total annual visitation.
- Nearly all (98.8%) of visitation occurred between 6 a.m. and 9 p.m.
- Eleven to noon is the busiest hour on average, accounting for 10% of total annual visitation.
- Weekend visitation generally peaks around noon.
- Weekday visitation generally peaks two times during the day – first in the morning (between 9 a.m. and noon) and again in the late afternoon (between 4 p.m. and 6 p.m.). The two-peak pattern on weekdays was most pronounced during the summer and often absent during the winter.

Visitation at Interior Locations

- Chautauqua area interior locations received high levels of visitation, including the Chautauqua Upper Trail (219,257), the 1st/2nd Flatiron Trail (131,009) and Royal Arch (105,245).
- Bear Peak (10,428) and South Boulder Peak (9,075), mountain-peak destinations, both receive around 10,000 annual visits.

Annual Dog Visits

- City-managed open space received 1.79 (95% CI, 1.58 – 2.00) million annual dog visits.

1 INTRODUCTION

The City of Boulder's Open Space and Mountain Parks system supports a diverse array of charter purposes, including the preservation and provision of outstanding natural, scenic, and recreational qualities (City of Boulder, 2005), which are enjoyed by many local, regional, national and international visitors each year. The City of Boulder's Open Space and Mountain Parks (OSMP) Department last estimated system-wide visitation at 4.68 (95% CI, 4.38 – 5.00) million annual visits[5] in 2004-2005 (Vaske, Donnelly, & Shelby, 2009), up from 3 million annual visits in 1996 (City of Boulder, 2005). As of the publication of this report, it is now estimated that city-managed open space receives around 6.26 (95% CI, 5.51 – 7.01) million annual visits. Surveys conducted by the department over the last decade continue to indicate a high level of overall satisfaction with the services provided by OSMP (City of Boulder, 2017; Giolitto, 2012; VanderWoude & Kellogg, 2018). However, without a robust understanding of visitation dynamics, increasing levels of visitation may affect long-term goals to provide for high-quality visitor experiences while maintaining natural resource conditions (Anderson, Lime, & Wang, 1998; D'Antonio, Monz, Larson, & Rohman, 2016; Nickerson, 2016). It is therefore imperative that the department study and understand the complexities of visitation on city-managed open space so that future management opportunities can be evaluated in a comprehensive manner.

Reliable estimates on the level and distribution of visitation provide crucial data to improve and develop initiatives, services, and policies that support high-quality visitor experiences and ensure conservation of natural resources (City of Boulder, 2005). In the decade since the last system-wide estimate was completed, regional population growth (Colorado Department of Local Affairs, 2018), data from site-specific studies (VanderWoude & Anacker, 2016), and a general sense of increasing visitation among both staff and the public supported collecting updated system-wide visitation estimates. A quantitative and reliable understanding of visitation levels and patterns will allow the department to more effectively and efficiently deliver services to the public by evaluating the supply of department resources with the demands of passive recreation visitation.

Staff implemented a similar data collection method as the 2004-2005 study, using automated trail counters to detect the number of people entering and exiting city-managed open space at strategic locations throughout the system (Vaske et al., 2009). Data collection occurred between June 1, 2016 and May 31, 2017 for the majority of primary and secondary sample locations[6]. Several enhancements were made to the 2004-2005 methods, including more rigorous calibration methods for all trail counters installed at primary sample locations and the deployment of short-term trail counter installations at secondary sample locations, which greatly improved extrapolation procedures for system-wide visitation estimates. The specific implementation of these enhancements is covered in further detail in the Methods section of this report.

The visitation estimates presented in this report detail one of the two core components of the 2016-2017 Visitation Study conducted by the department's Human Dimensions Program. The other component consisted of an on-site visitor survey which collected input from visitors on the types of recreational activities they were engaging in, experiences they had, and other key metrics designed to understand various dimensions of visitors

[5] Visits refers to the number of distinct times that people visited city-managed open space. An individual person may contribute multiple visits over a period of time depending on how frequently they visit city-managed open space.

[6] Due to several delayed equipment installations, some locations continued to receive data collection beyond the one-year mark (May 31, 2017) to ensure a minimum of 365 days of continuous data collection.

to city-managed open space (VanderWoude & Kellogg, 2018). As of the release of this report, staff have compiled initial results for each core component separately, with a paired analysis planned.

Sections for this report have been laid out in a traditional scientific report format and include:

- An overview of the project goal and objectives.
- A review of the methods used to collect and analyze the data.
- A results section detailing the level and distribution of visitation on city-managed open space.
- A discussion section summarizing the current findings and future possibilities for analysis.
- An appendix section with additional information.

1.1 Goal and Objectives

The goal of this study was to develop a quantitative understanding of system-wide recreation visits[7] to city-managed open space[8] that can support the department and the public in making informed decisions relating to visitation. To accomplish this, staff identified three primary objectives addressing fundamental components of visitation dynamics, which included:

- Estimate the total number of recreation visits to city-managed open space at 95% confidence interval.
- Evaluate annual, seasonal, monthly, daily, and hourly patterns of visitation.
- Determine how visitation levels are distributed across sample locations.

Three secondary objectives were also identified:

- Evaluate changes in site-level visitation at the subset of locations that received repeat sampling between the 2004-2005 and 2016-2017 data collection periods.
- Estimate the number of recreation visits to select interior trails including annual visitation to several popular destination areas.
- Estimate the number of annual dog visits to city-managed open space.

1.2 Terminology

Throughout this report, there are some key terms used to describe visitation that have specific meanings within the context of this visitation study. All results are reported in terms of recreational *visits*, which is different from recreational *visitors*. Visits refer to the *distinct number of times* that people access city-managed open space as opposed to visitor, which refers to the *individual people* who are visiting, regardless of how frequently they access open space. For example, if the same visitor goes for a hike one day and then goes for another hike the following day, the occurrences are counted as *two distinct visits* but are still only a *single visitor*. Estimating the number of individual visitors that generated all the distinct visits to city-managed open space during the study period is a multilayered analysis, requiring the integration of differential visitation frequencies among visitor sub-groups and is beyond the scope of this report.

---

[7] A small number of counts collected during this study were known to be generated by staff, volunteers, contractors, or other non-recreation visits. Staff consider these to contribute minimally to the overall visitation estimates.

[8] Visitation data were only collected on trails or properties open to the public for recreational purposes.

2 METHODS

The primary goal of this study was to estimate visitation to city-managed open space in a comprehensive manner, such that visitation can be assessed at varying geographic and temporal scales. Public land-management agencies utilize a variety of methods to collect visitation data, including entrance station or ticket/pass counts, vehicle-based roadway counts, visitor-center counts and trail-based person counts (Turner, Lasley, & Pourteau, 2013; Ziesler & Singh, 2018). City-managed open space is geographically dispersed around the City of Boulder, with many locations where visitors can enter onto the system. Only a minority of trails originate at or near OSMP managed parking lots or visitor centers, severely limiting the potential coverage of vehicle or visitor-center count methods.

To estimate the number of people who visit city-managed open space, staff conducted trail-based person counts. This approach allowed for the broadest geographic coverage of locations as almost all recreation areas are accessed by roads or trails. To collect Person counts, automated trail counters were strategically placed on trails in proximity to locations where people can access city-managed open space. Trail counters operate on the primary principle of using a sensor to detect when a person passes by the counter, which is recorded as a timestamped record to the automated trail counter's memory. The following section provides an outline of the methods employed by the department to collect, manage and analyze visitation data on city-managed open space. A more comprehensive protocol document, with detailed procedures used to conduct visitation estimates, is available upon request.

2.1 Sample Location Selection

To select sample locations for this study, staff first conducted a review of locations where trails (both designated and undesignated) allow people to enter onto city-managed open space. During the summer and fall of 2015, staff conducted a mapping inventory to confirm previous locations and record new locations (both designated and undesignated). About 340 locations were identified and recorded in the field using Trimble GPS units. Staff then reviewed the GPS points to filter out locations where staff expected fewer than 1,000 annual visits, or about 3 per day. A few locations were further excluded due to a high probability of double counting at two locations. Ultimately, staff selected 189 sample locations for inclusion in the study. Forty-five locations were selected as primary sample locations and had automated trail counter equipment installed for the duration of the study period (full-year). The remaining 144 locations were selected as secondary sample locations and received short-term (minimum of two weeks) installations to establish their visitation class (Figure 1).

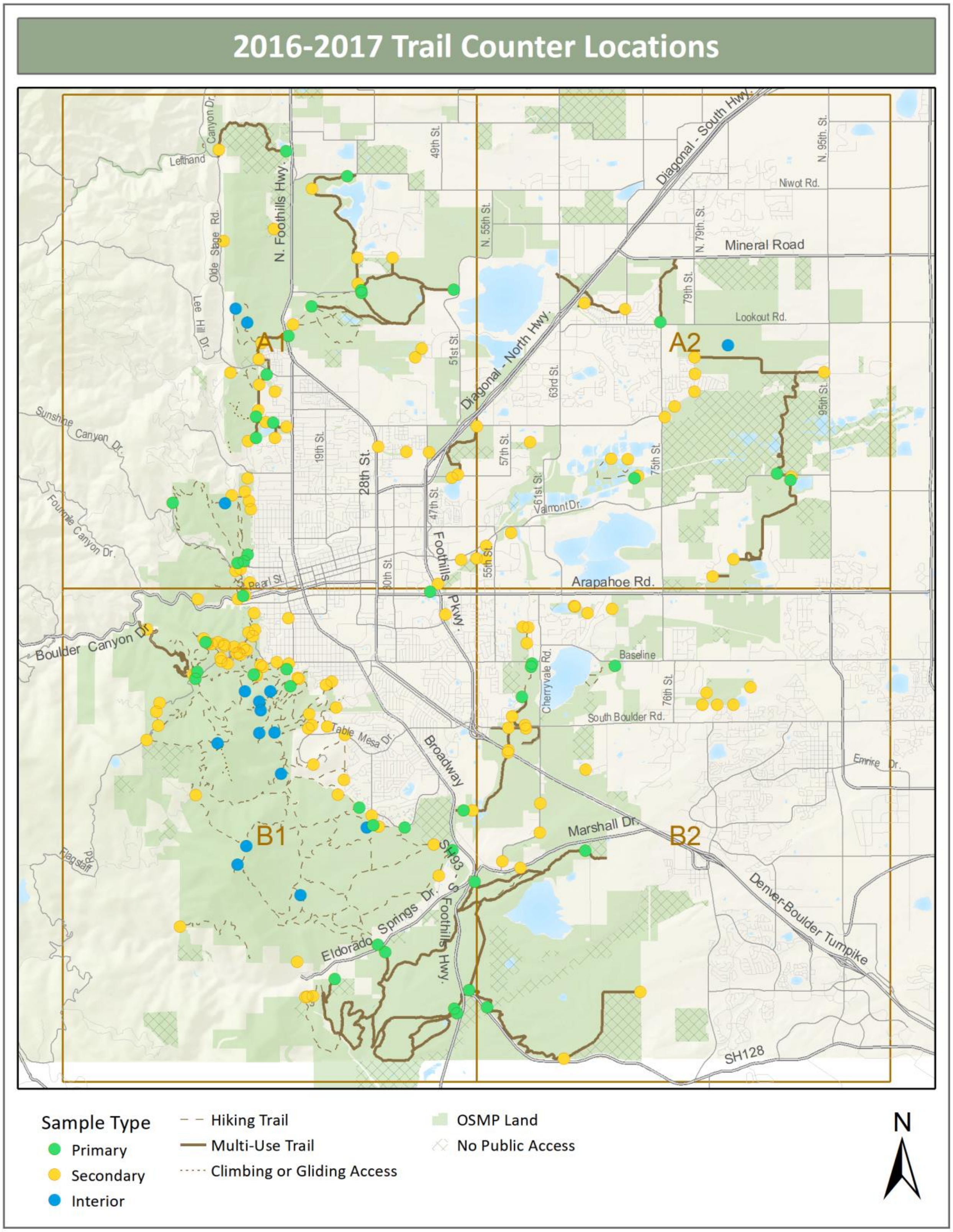


Figure 1. Sample locations for the 2016-2017 Visitation Estimate.

The 45 primary sample locations were selected based on a combination of where past sampling had occurred (to facilitate trend analysis) and other locations where robust visitation data will support current and future projects, such as trail construction. Of the 144 secondary sample locations, post-analysis of the data estimated that 23 of the locations fell below the minimum threshold of 1,000 annual visits and were excluded from further analysis. In the end, 166 sample locations were used to calculate the final system-wide visitation estimates.

2.2 Data Collection

2.2.1 Automated Trail Counter Equipment

Three brands of trail counters were used to count visitors for this study: TRAFx G3, Eco-Counter Pyro, and TrailMaster 1550 (Figure 2). Both the TRAFx G3 and Eco-Counter Pyro count pedestrians using a passive infrared sensor, which operates by detecting sudden changes in temperature, such as the heat signature generated by a person (or animal) as they pass by the counter relative to the background thermal field. TrailMaster 1550 units, by contrast, employ an active infrared sensor where a transmitter unit emits a low-energy invisible beam which is received by the sensor in the receiving unit. Detections for active infrared sensors are made when an object, such as a person, temporarily breaks the invisible infrared beam.

TRAFx Generation III (G3) passive infrared counter | Eco-Counter Pyro mounted in a recycled post passive infrared counter | TrailMaster TM1550 active infrared counter receiver (left) and transmitter (right).

Figure 2. Passive and active infrared trail counters used on city-managed open space.

Passive infrared sensors have the major advantage that the equipment only needs to be installed on one side of the trail or travel corridor (Figure 2). Since the heat generated by a person operates as the transmission component of the detection circuit, these units provide more installation flexibility than units requiring both a transmitter and receiver. Most locations for this study were monitored using TRAFx G3 trail counters However, the reliable detection range on passive infrared sensors is typically limited to 15 to 20 feet.

The TrailMaster 1550 units use active infrared sensors and, while they are an older technology (no longer in production), they have the advantage of being able to detect over greater distances, typically up to 200 feet. The TrailMaster 1550 units have a significantly lower memory capacity (less suitable for high-visitation locations), but their ability to reliably detect visitors over greater ranges make them ideal for complex situations, such as where two trails run parallel to each other or where a wide travel corridor, such as a road, exceeded the detection range of a TRAFx G3 unit.

All trail counters recorded detections as time-stamped records, which were downloaded in the field using a portable data retrieval unit. Depending on the location and type of trail counter, staff downloaded the trail counter data every one to two weeks. This download frequency allowed staff to check on the status of the installation, ensuring that the counters were operating correctly, clear of any vegetation that may have grown up in front of the scope and, although rare, repair any equipment vandalism.

2.2.2 Measurement Error

There were several error sources that were accounted for when estimating the actual number of visits from detections made by the trail counters. The following sections describe some of the error sources and how they were accounted for in this study.

Detection Error

Detection error is when the trail counter either under or over counts relative to the actual number of times a person passed by the sensor and can be either systematic or random in origin. Systematic errors tend to be slightly easier to correct for as they are generally a result of physical characteristics of the location where the trail counter is installed and are therefore relatively stable over time, making them easier to measure (Turner et al., 2013). Systematic errors include:

- People walking side-by-side on wide trails, resulting in only a single detection and thus an undercount of *person passes*.
- People passing through the far edge of the detection zone on wide trails where the detection zone is largest, resulting in multiple detections per person and thus an overcount of *person passes*.
- Presence of non-humans, such as dog or horses, that register as detections.

All the systematic errors mentioned above were reduced greatly by calibrating the trail counters through direct observation where the actual number of person passes, recorded by a human observer, were compared with the number of detections made by the trail counter (Pettebone, Newman, & Lawson, 2010; Turner et al., 2013). By comparing the ratio of observed person passes to the number of detections made by the counter, a correction factor was calculated to adjust for any systematic under or over-counting. Calibration data for the primary sample location calibrations was also used to calculate 95% confidence interval estimates at each location.

In addition to systematic errors, random errors also cause the trail counter to over or under detect the actual number of person passes and include:

- Vegetation blowing back and forth in front of the sensor, resulting in erroneous counts.
- Insects, vegetation or vandalism, which either partially or fully block the sensor, resulting in an undercount of person passes.
- Severe weather events, such as snow, that either block the sensor, resulting in an undercount or, in rare circumstances, causes false detections that result in erroneous counts.

Random errors – such as from insects, vegetation or vandalism – were largely avoided through regular field visits, such that when they did occur, staff were able to rectify them in a timely manner and minimize any data impacts. When erroneous periods of high or low counts occurred, they were identified through post-collection quality control procedures and corrected as necessary in post-processing of the data (Turner et al., 2013).

Estimation error

Estimation error is primarily related to how differential travel patterns influence the number of times the same person passes by a specific counter during their visit. By placing trail counters proximate to the beginning of a trail, an individual person will typically produce two counts at that location, one as they enter the area and one as they leave. This can be easily corrected for through an adjustment factor by reducing the number of counts detected by the trail counter by half (Turner et al., 2013).

However, in some cases an individual person may make a “through trip”, entering at one location and leaving an another. While this is still only counted as one visit to city-managed open space, it will generate multiple site-level visits. In these circumstances, an individual would only be expected to produce one count at each location per visit.

Reducing the number of trail counter detections by half would slightly underestimate the number of unique visits if the location in question has a considerable number of through trips. Because trail counters cannot differentiate whether detections occurred from the same or different individuals, this phenomenon was explored through the on-site visitor survey. The survey included a question asking respondents to indicate if they had entered at the same location where they were exiting (the surveys were conducted as exit surveys). If the respondent indicated they had not entered at the current location, they were provided a map so that they could indicate where they had entered, thus providing origin-destination information for their visit.

For the 2004-2005 study (Vaske et al., 2009), different site-level adjustment factors were established for each visitation class. Analysis of the 2016-2017 survey data revealed that, while there is a percentage of visitors that make through trips, the probability of a given percentage of visitors making though trips at a location (i.e. trail) is not positively correlated with visitation class. Staff hypothesize that the occurrence of through trips is more likely a spatial phenomenon, where certain trail network configurations are more conducive to these types of trips. Testing this hypothesis will require additional data collection and analysis beyond the scope of this current study. Therefore, staff have elected to use an adjustment factor of .5 for both system-wide and site-level estimates. Since the survey data show that some through trips do occur, using an adjustment factor of .5 may slightly underestimate visitation at the site-level for some locations but greatly reduces the risk of overestimating visitation.

2.3 Data Management and Analysis

Sample location attribute data were managed using Geographic Information System (GIS) feature classes. A Structured Query Language (SQL) database was used to manage all data related to the installation, maintenance, and calibration of trail counter samples, including records of all field visits (downloads, maintenance issues, etc.) and any potential quality issues spotted in the data during periodic spot checks by staff. Hourly count data from the trail counters was also transferred into the SQL database once it had undergone initial processing to standardize the data formatting from each of the various counter types. The majority of data processing and analysis was conducted using R (R Development Core Team, 2017) with some initial quality-control conducted using Excel.

2.3.1 Data Processing

To prepare count data for analysis, it was run through a series of processing levels to take it from its raw (Level 0) to cleaned and calibrated (Level 5) state. Figure 3 shows the general processing pipeline to advance data from a Level 0 to Level 5 data product.

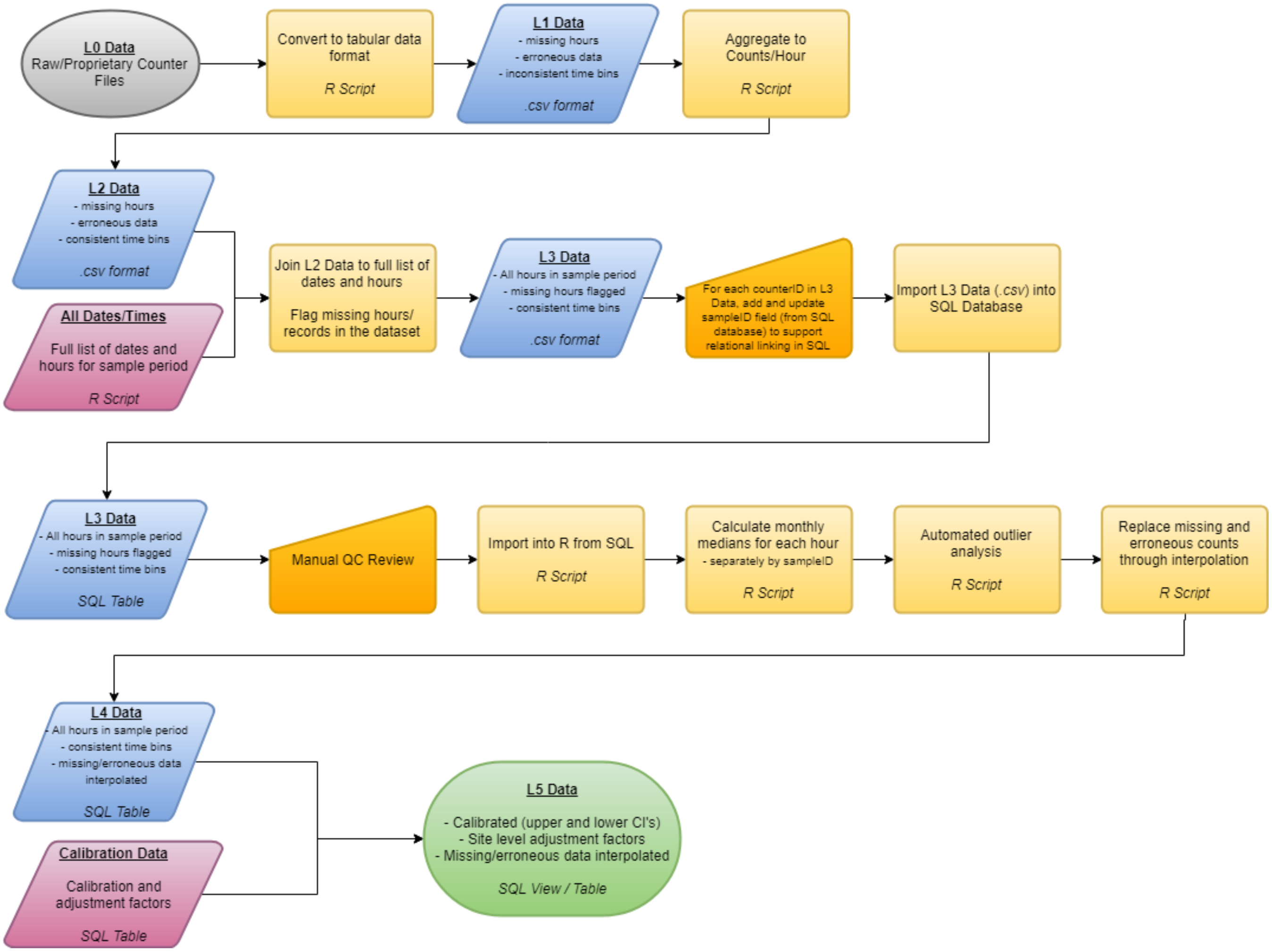


Figure 3. Flow chart of trail counter data processing from Level 0 (raw) to Level 5 (final) data products

Once data were processed to a Level 3 data product, the structure of the data had been standardized such that counts were aggregated into hour bins (Turner et al., 2013). If any hours were missing from the original downloaded counter data, a blank record for that hour was created and flagged as missing values in the record set. This created a continuous time series such that the dataset contained all dates and hours between the beginning and end of the sample window. However, each Level 3 record still only represented the number of detections made by the counter during each hour. In order to process the data to a Level 5 data product, representing the number of actual visits to each location, several additional steps were completed, including missing data and outlier identification, data interpolation/replacement, calculation of calibration factors, and application of an adjustment factor to account for multiple detections of the same person during a visit.

2.3.2 Missing Data and Outlier Identification

Missing Data Identification

Missing data were identified during Level 2 to Level 3 data product processing by comparing the date-time stamped records (in hour bins) from the original downloaded trail counter data against a template list of all date-times for the sample period. First, a template list of date-time stamps was generated between the start and end date of the sample period for the counter data being process. Next, the original counter data was joined to the template list, keeping all date-times from the generated list. Finally, if no matching date-time was found in the original counter data during the join, a new variable was calculated indicating that the date-time was missing. Figure 4 illustrates the join process.

Input

Template date-times
2016-08-02 08:00
2016-08-02 09:00
2016-08-02 10:00
2016-08-02 11:00
2016-08-02 12:00

↔

Input

Data file date-times
2016-08-02 08:00
2016-08-02 09:00
2016-08-02 11:00
2016-08-02 12:00

=

Output

All date-times	Missing
2016-08-02 08:00	FALSE
2016-08-02 09:00	FALSE
2016-08-02 10:00	TRUE
2016-08-02 11:00	FALSE
2016-08-02 12:00	FALSE

Figure 4. Join process to combine original time-stamp data from the trail counter to a template list of date-times to create a continuous dataset and identify any periods of missing records.

Missing data could result from a number of sources, including counter malfunction, vandalism, or other maintenance issues. For the TRAFx G3 units, which automatically aggregated data into hour bins internally, the download process would automatically result in the hour of the download being dropped from the dataset due to the default programming of the software.

Outlier Identification

In statistical terms, an outlier is a data point that falls outside of the overall or expected distribution of the data (Vaske, 2008). If a data point falls outside the expected distribution, it does not mean it is necessarily invalid nor does a data point falling within the expected distribution necessarily mean that it is valid.

For example, a branch that drooped down in front of one of the Boulder Valley Ranch counters resulted in upwards of 500 hourly counts for a couple days until the situation was corrected, which was clearly outside the normal distribution of 10 – 40 hourly counts. The counter at Boulder Creek and Arapaho also had several periods of greater than 500 hourly counts where the normal distribution for those hours was between 100 – 200 counts. Upon further examination, however, it was discovered that the Boulder Creek at Arapaho and Foothills counter was part of the Ironman Boulder race course and the high counts occurred during the race period and thus were valid counts. At the other end of the spectrum, it can often be difficult to statistically identify periods of erroneously low counts since count data can only be non-negative (i.e. never falling below zero). If the trail counter sensor became obstructed, resulting in zero detections during a given period, the error could often only be detected through a visual inspection of the data or by having knowledge of when the obstruction or other issue was present.

Outlier identification occurred in two phases. First, a visual inspection of the Level 3 data was conducted by staff. To facilitate identification of potential issues, a detailed calendar and log of any significant events, such as vandalism or weather that could have impacted the counter's ability to detect visitors, was maintained by staff throughout the project. If periods of potentially high or low counts were identified, they were flagged in the dataset. Next, the data were analyzed using a median based outlier identification procedure. The median is a useful statistic for evaluating non-normal distributions or datasets with a small number of observations where other outlier tests, based on means and standard deviations, cannot be reliably computed (Vaske et al., 2009). The median value for each hour period of the day was calculated separately for each counter at the monthly level such that the count value for an hour time period could be compared to the values of that same hour time period for all other days in a given month. For the 2004-2005 visitation estimate, Vaske et. al. (2009) found that 20 times the median value provided a reasonable threshold for outlier identification. An examination of outlier values identified by this median test, compared against values identified through the visual inspection, confirmed that this test provided a reasonable approach.

2.3.3 Data Interpolation/Replacement

To maintain a continuous time series of data and provide for flexibility in later analysis, missing and invalid data (outliers) were replaced using one of two strategies.

1. Where only 1 hour of invalid data existed, with valid count data in the preceding and subsequent hours, a new value was interpolated using the average of the values on either side of the missing data. For example, if the data on either side of the invalid hour were 10 and 20, the invalid hour would be replaced with the interpolated value of 15.
2. Where the number of continuous hours of invalid data was greater than 2 hours, the invalid data were replaced using a seasonal mean. Seasonal means were calculated separately for each counter by season, day-of-week and hour.

The number of invalid records varied by the counter (Table 1), with an average of 3.6% data replacement across all primary trail counter installations due to outlier (0.7%) and missing (2.9%) records. For a full breakout of data replacement for all primary counters, see Table 12 in Appendix C: Data Cleaning Summary

Table 1. Data quality control results for 10 of the 45 primary sample locations.

		Valid		Outlier		Missing		Replaced	
ID	Site Name	Records	Percent	Records	Percent	Records	Percent	Records	Percent
54	Settlers Trailhead West	8572	97.9	48	0.5	140	1.6	188	2.1
60	Mount Sanitas Trail	8087	92.3	31	0.4	642	7.3	673	7.7
61	Sanitas Valley Trail	8602	98.2	18	0.2	140	1.6	158	1.8
63	Sanitas Valley View	8401	95.9	55	0.6	304	3.5	359	4.1
66	Wonderland Trail Poplar Ave	8518	97.2	47	0.5	195	2.2	242	2.8
68	Foothills Trail Locust Pl	8509	97.1	14	0.2	237	2.7	251	2.9
70	Wonderland Utica East	8465	96.6	8	0.1	287	3.3	295	3.4
74	Fourmile Trailhead	8526	97.3	16	0.2	218	2.5	234	2.7
79	Foothills Trail Near US 36	8523	97.3	40	0.5	197	2.2	237	2.7
81	Eagle Trail West	8540	97.5	7	0.1	213	2.4	220	2.5

2.3.4 Calibrations

All primary trail counter installations received a minimum of 9 hours of calibration each to ensure accurate and reliable estimates. During the calibration session, staff recorded the actual number of people that passed by the counter, along with the number of detections made by the trail counter. Observations were recorded in 15-minute increments for a total duration of 3 hours per calibration session (Pettebone et al., 2010; Turner et al., 2013). Calibration sessions were conducted across varying times of the day, days of the week, and months of the year. Once a trail counter was installed, any calibrations conducted on it remained applicable so long as the trail counter was not physically repositioned. If a trail counter did need to be repositioned (such as to replace the post it was mounted to) new calibrations were conducted and the previous calibrations were used only for the data collected up to the time of repositioning.

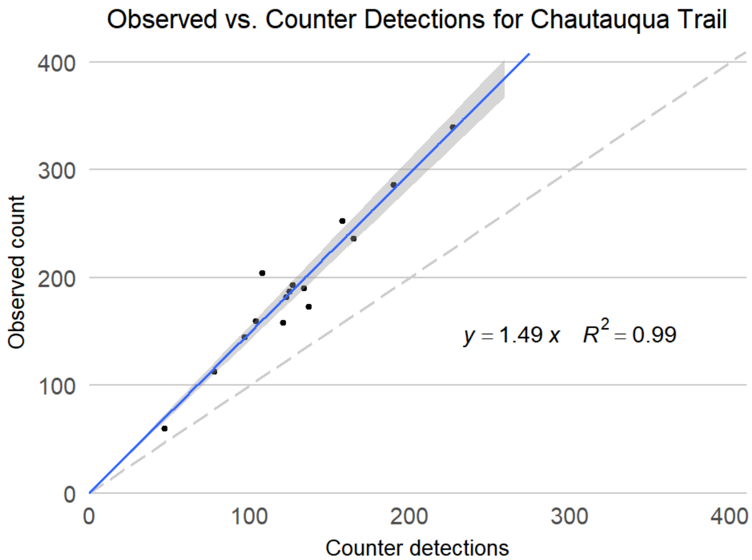


Figure 5. Regression plot showing the relationship between observed counts (*y*) and counter detections (*x*) for the Chautauqua Trail sample location. Dashed line represents a theoretical perfect detection rate of 1:1.

Calibration data were aggregated into hour bins for analysis. Since multiple paired observations (observed vs. detected) were collected for each trail counter, linear regression modeling was used to estimate the correction factor for each trail counter (Pettebone et al., 2010). For each linear regression model, the estimated regression coefficient or slope (β) provided the correction factor while the coefficient of determination (r^2) provided an estimate of how consistently the trail counter is detecting people at varying levels (Figure 5). Using this method, it was also possible to calculate 95% confidence intervals for the regression coefficient, thus providing an upper and lower correction factor with which to parameterize the estimates of counts to visits. For a full list of calibration model results, see Appendix D: Calibration Results.

The remaining 144 secondary sample locations received a simplified calibration, where 60 person-passes were recorded in three groups of 20 at the time of installation. A simple ratio was calculated for each of the three groups of 20, which were then averaged to compute a final calibration factor for each secondary sample location.

2.3.5 Estimating Visitation Class

Each sample location was categorized into one of five visitation classes, from Very Low to Very High (Table 2). Sample locations were classified based on the estimated number of visits for the location. Visitation classes are based on ranges established during the 2004-2005 study. The lower breakpoint for the Very High visitation was modified based on a post analysis of data from the primary sample locations. Results from the 2004-2005 study revealed that no sample locations met the prior minimum visitation threshold for the previous Very High visitation class range at the time of the study, so the modification had no effect on prior results.

Table 2. Visitation class ranges and averages for Very Low to Very High sample locations.

	Annual Visit Range		Average	Locations Sampled	
Class	**Lower**	**Upper**	**Annual Visits**[a]	**Primary**	**Secondary**
Very High	200,000	∞	296,774	2	0
High	75,000	199,999	118,797	10	9
Medium	25,000	74,999	50,031	12	27
Low	10,000	24,999	18,140	18	43
Very Low	1,000	9,999	7,615	3	43

[a] *Average annual class visits were calculated using data from the primary sample locations.*

For the 45 primary sample locations, the visitation class could be assigned directly after calculating the annual visitation estimate for each location. To classify the 144 secondary sample locations, an annual system-visitation estimate had to first be extrapolated from the 2 weeks (minimum) of data collected at each location. Because secondary samples were collected in sets of 15 over the course of many months, seasonal variations in visitation levels throughout the year had to be accounted for (Turner et al., 2013). To adjust for this variation, monthly weights were calculated using data from the 45 primary sample locations.

First, the total estimated number of visits were calculated for each month of the year for each primary sample location. Next, for each month of the year, the monthly total for each primary sample location was divided by the average monthly visitation of all locations to determine the proportional amount above or below the average. Once monthly proportions had been calculated for each month, the average proportion for each month was calculated to produce a monthly weight Figure 6.

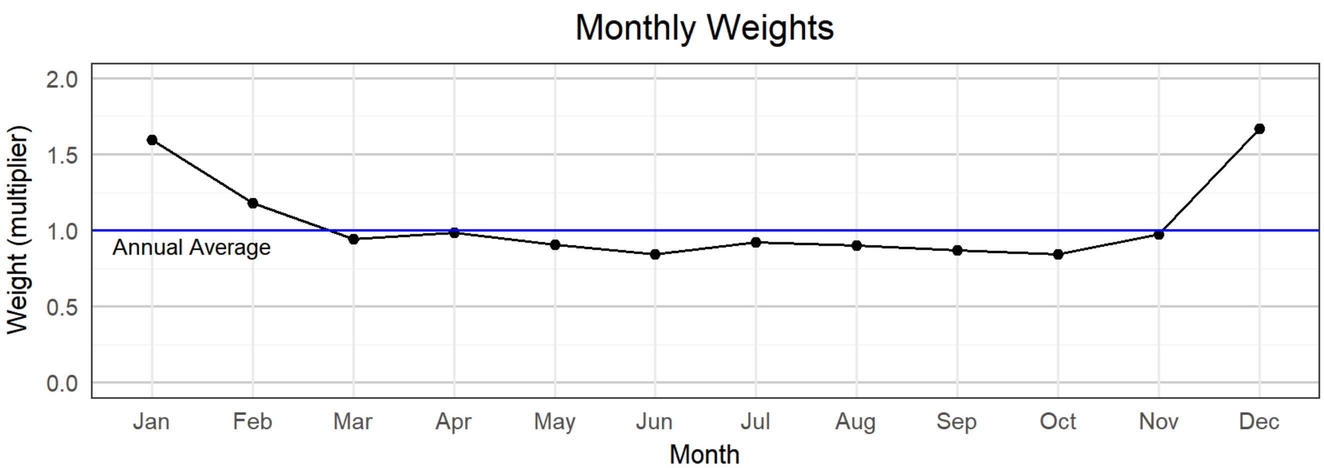


Figure 6. Monthly weights used for extrapolation of secondary sample locations.

Monthly weights were applied to the timestamped data from each secondary sample location (Equation 1) and then summed for each day in the sample period (Equation 2). Next, the daily average visitation for the installation period was calculated (Equation 3). Finally, the annual visitation was extrapolated by multiplying the daily average by 365 and applying an adjustment factor to reduce detections to visits (Equation 4). The resulting estimates were used to establish the visitation class of the secondary sample locations.

Monthly weighting calculations for visitation classification of secondary sample locations.

Terms

$c = \text{ weighted hourly count}$

$r = \text{raw (unweighted) hourly count}$

$w = \text{monthly weight}$

$d = \text{daily count}$

$n = \text{days in sample}$

$a = \text{adjustment factor}$

$v = \text{annual estimated visits}$

Equation 1 $$c = r * w$$

Equation 2 $$d = c_0 + c_1 + c_2 + \cdots + c_{23}$$

Equation 2 $$\bar{d} = \frac{d_1 + d_2 + d_3 + \cdots + d_n}{n}$$

Equation 4 $$v = \bar{d} * 365 * a$$

3 RESULTS

3.1 System-wide Visits

System-wide visitation metrics were calculated at several time scales including annual, seasonal, monthly, daily and hourly as well as by visitation class. Generally, results have been compiled as plots showing distributions as the proportional amount of annual visitation, with tables showing the absolute visitation numbers – including upper and lower estimates.

3.1.1 Annual Total Visits

The estimated number of annual total recreation visits to city-managed open space is 6.26 million, with a lower estimate of 5.51 million and an upper estimate of 7.01 million (Table 3)[9]. Counts from the primary sample locations (n = 45) accounted for approximately 44% of total estimated annual visits, roughly 2.73 million. Extrapolation of the average class visitation (Table 2) to secondary sample locations (n = 121) accounted for the remaining 56% of total estimated annual visits, about 3.53 million.

Visitation is not distributed proportionately relative to the number of locations in each visitation class. Out of the 167 sample locations included, 36% were measured at medium class or above (n = 60) but accounted for 77% of the total estimated visitation. The medium and high visitation classes each received around 2 million annual visits even though the number of High-class locations (n = 19) was roughly half (n = 39) the number of medium locations. These results indicate that the majority of visits to city-managed open space are concentrated to only a subset of the access locations. Considering that some areas – such as Chautauqua, Wonderland Lake and Sanitas – have more than one access location at a medium class or above, there is further evidence that visitation is concentrated to specific sub-regions of city-managed open space.

Estimates for individual primary sample locations are reported in Table 8 and a full breakout of visitation estimates by visitation class and sample type can be found in Table 11 in Appendix B: Annual Visitation by Sample Type.

Table 3. System-wide annual total recreation visits (with 95% confidence range) for each visitation class.

Class	Visits (95% CI)		Locations
Very High	593,548	(572,038 - 615,067)	2
High	2,257,145	(2,009,940 - 2,504,318)	19
Medium	1,951,206	(1,720,514 - 2,181,927)	39
Low	1,106,533	(908,849 - 1,304,349)	61
Very Low	350,275	(297,175 – 403,389)	46
Total	6,258,707	(5,508,516 - 7,009,050)	***167***

[9] Lower and upper estimates are based on the 95% Confidence Intervals of the calibration model coefficients for the primary sample locations.

3.1.2 Seasonal Visits

Visitation was relatively consistent for spring, summer, and fall[10], ranging between 26.6% and 28.5% (Table 4). Winter was the only markedly different season at 17.6% of annual visitation. The relative proportion of visitation within each trail visitation class was similarly consistent between seasons (Figure 7).

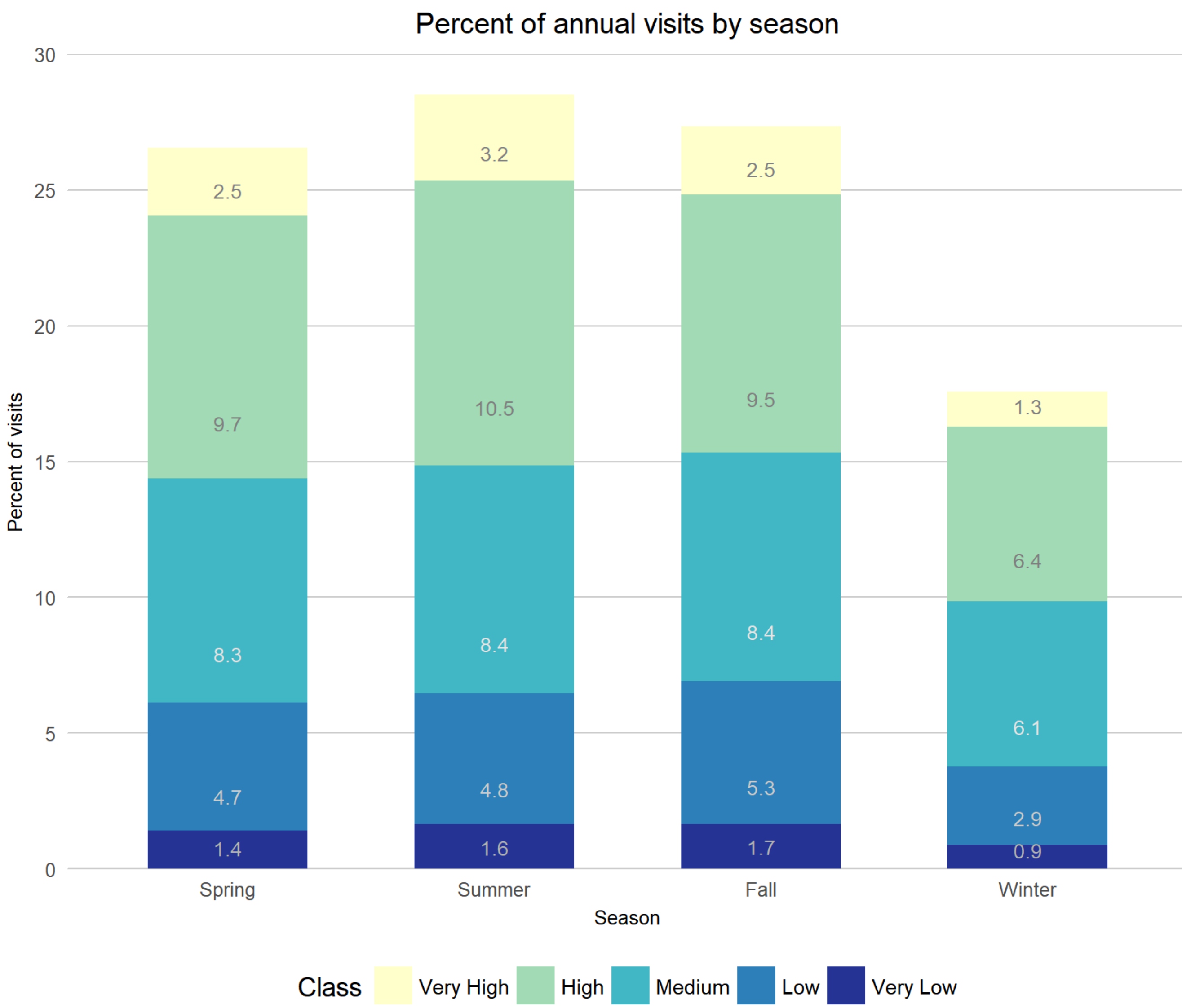


Figure 7. Distribution of system-wide seasonal visitation, represented as the proportion of overall annual visitation, with additional breakout by visitation class.

[10] For both the visitation estimate and survey components of the 2016-2017 visitation study, seasons were broadly categorized by months rather than specific date ranges. Spring: March-April-May, Summer: June-July-August, Fall: September-October-November and Winter: December-January-February.

Table 4. System-wide seasonal total visitation including upper and lower estimates by visitation class.

Season	Class	Visits (95% CI)	
Spring	Very High	157,044	(151,346 - 162,744)
	High	573,086	(509,614 - 636,550)
	Medium	584,332	(515,201 - 653,471)
	Low	246,540	(202,961 - 290,146)
	Very Low	97,200	(83,901 - 110,476)
	Total	*1,658,202*	*(1,463,023 - 1,853,386)*
Summer	Very High	198,816	(191,614 - 206,021)
	High	654,703	(586,840 - 722,560)
	Medium	525,215	(463,829 - 586,610)
	Low	302,316	(248,020 - 356,666)
	Very Low	102,979	(86,506 - 119,485)
	Total	*1,784,029*	*(1,576,808 - 1,991,342)*
Fall	Very High	156,772	(151,118 - 162,429)
	High	595,167	(530,025 - 660,300)
	Medium	526,911	(464,507 - 589,322)
	Low	328,876	(268,843 - 388,942)
	Very Low	103,839	(87,119 - 120,579)
	Total	*1,711,566*	*(1,501,612 - 1,921,571)*
Winter	Very High	80,916	(77,961 - 83,873)
	High	402,351	(355,149 - 449,543)
	Medium	381,148	(335,524 - 426,781)
	Low	180,456	(149,230 - 211,712)
	Very Low	55,789	(47,873 - 63,683)
	Total	*1,100,659*	*(965,736 - 1,235,592)*

3.1.3 Monthly Visits

Similar to seasonal visitation, the distribution of monthly visitation was also relatively consistent across spring, summer, and fall, with March through November ranging between 8.4% and 10.1% of total annual visitation (Figure 8). The winter months of December, January, and February each account for between 5% and 7.1% of total annual visitation. June and October are the busiest months of the year with 10.1% and 9.6% of total annual visitation, respectively. In terms of absolute visitation, city-managed open space receives over a half million visits each month between March and November (Table 5).

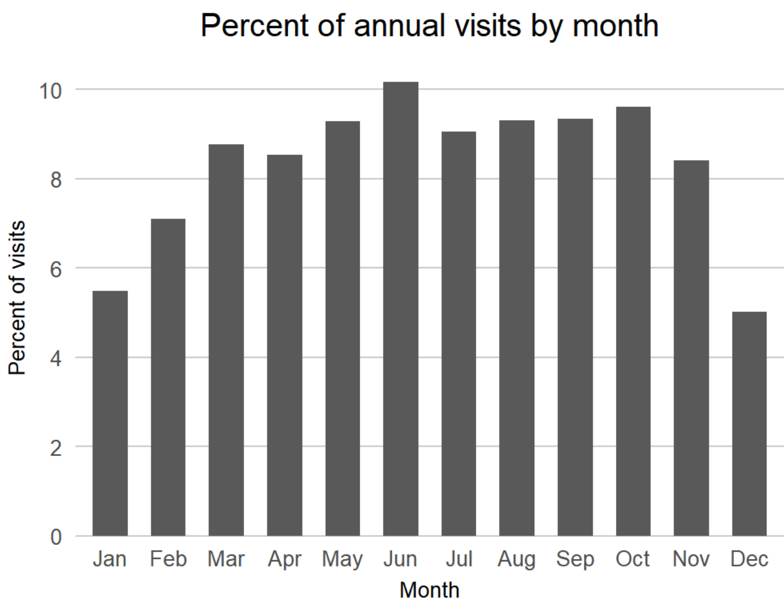


Figure 8. Distribution of system-wide monthly visitation, represented as the proportion of overall annual visitation.

Table 5. System-wide monthly total visitation, including upper and lower estimates by visitation class.

Month	Visits (95% CI)	
Jan	342,916	(301,521 - 384,315)
Feb	444,104	(389,339 - 498,873)
Mar	548,685	(482,157 - 615,215)
Apr	533,290	(468,796 - 597,787)
May	580,476	(513,407 - 647,551)
Jun	635,979	(563,137 - 708,852)
Jul	565,980	(499,787 - 632,207)
Aug	582,070	(513,885 - 650,284)
Sep	583,985	(513,619 - 654,375)
Oct	601,293	(527,379 - 675,225)
Nov	526,288	(460,614 - 591,971)
Dec	313,640	(274,876 - 352,404)

Aggregating all locations together at the monthly level, while indicative of overall visitation, does not offer any insight into how visitation levels fluctuate monthly among individual locations. To examine monthly visitation class level dynamics, the estimated number of monthly visits for each individual counter, symbolized by visitation class, was plotted (Figure 9). As the plot demonstrates, there were very few instances when the monthly visitation at a location in one visitation class exceeded the monthly visitation of a location in the visitation class above it. This indicates relative homogeneity of fluctuations in overall visitation between visitation classes on a monthly level. Stated another way, most locations tend to increase or decrease collectively at the monthly level, regardless of visitation class.

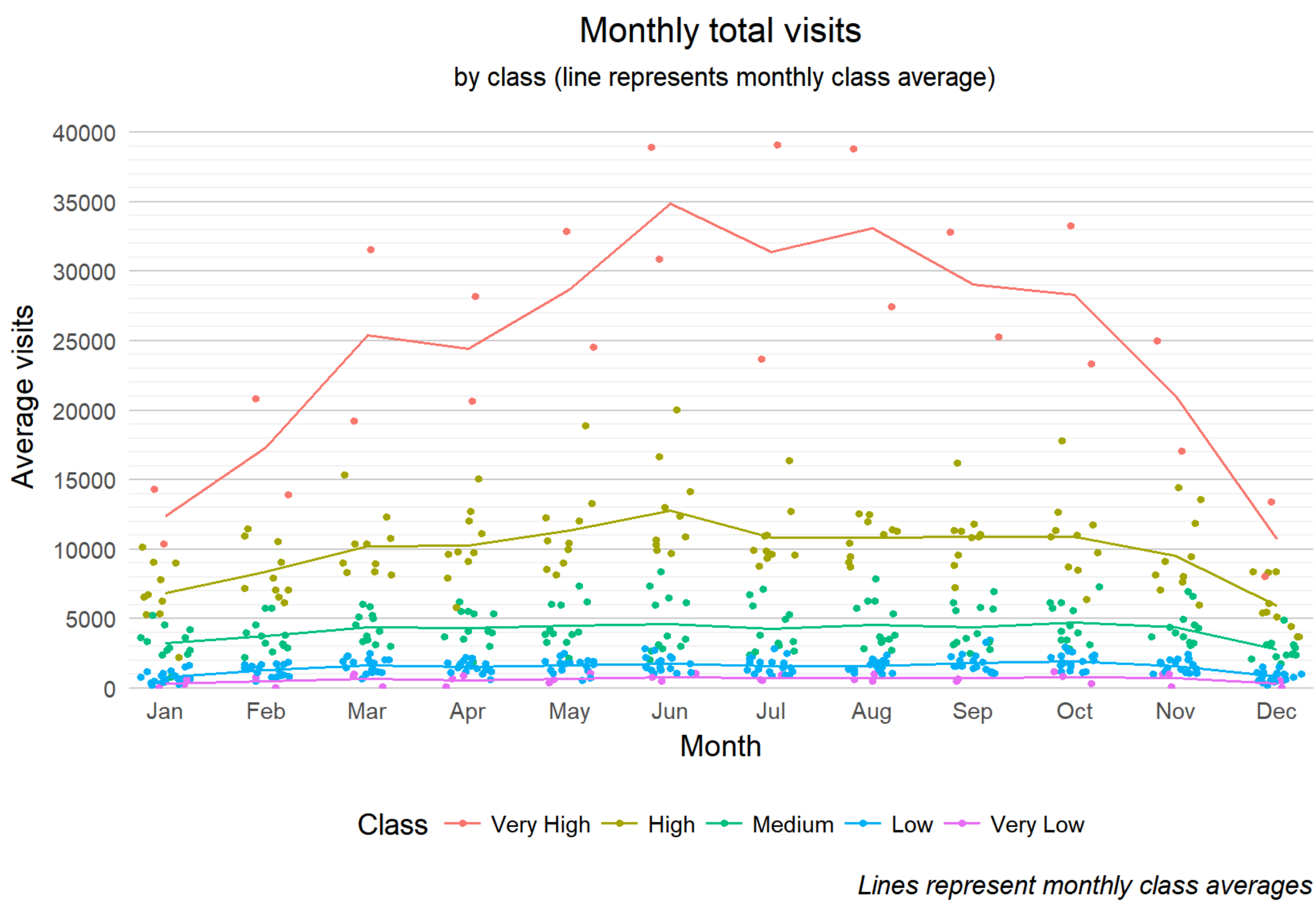


Figure 9. Distribution of monthly total visits for all 45 primary sample locations, symbolized by visitation class.

3.1.4 Daily Visits

At the daily level, weekdays (Monday – Friday) each received approximately 12% of annual visitation, with weekend days receiving approximately 20% each. Sunday received marginally more visitation at 20.6% than Saturday, 19.0%.

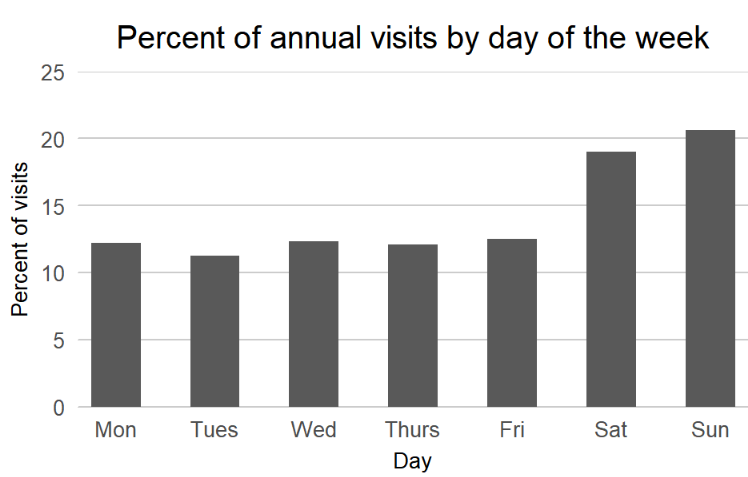


Figure 10. Distribution of system-wide daily visitation, represented as the proportion of overall annual visitation.

Table 6. System-wide daily total visits, including upper and lower estimates

Day	Visits (95% CI)	
Mon	762,459	(672,657 - 852,291)
Tues	704,597	(621,642 - 787,574)
Wed	771,367	(679,726 - 863,037)
Thurs	755,570	(666,170 - 844,992)
Fri	783,337	(690,817 - 875,890)
Sat	1,190,340	(1,045,242 - 1,335,457)
Sun	1,291,034	(1,132,264 - 1,449,817)

3.1.5 Hourly Visits

Nearly all visitation to city-managed open space occurs between the daytime hours of 6 a.m. to 9 p.m., with all remaining hours accounting for only 1.2% of total annual visitation. Visitation increases slightly faster during morning hours, peaking around 11 am, and gradually decreasing throughout the afternoon and evening (
Figure 11).

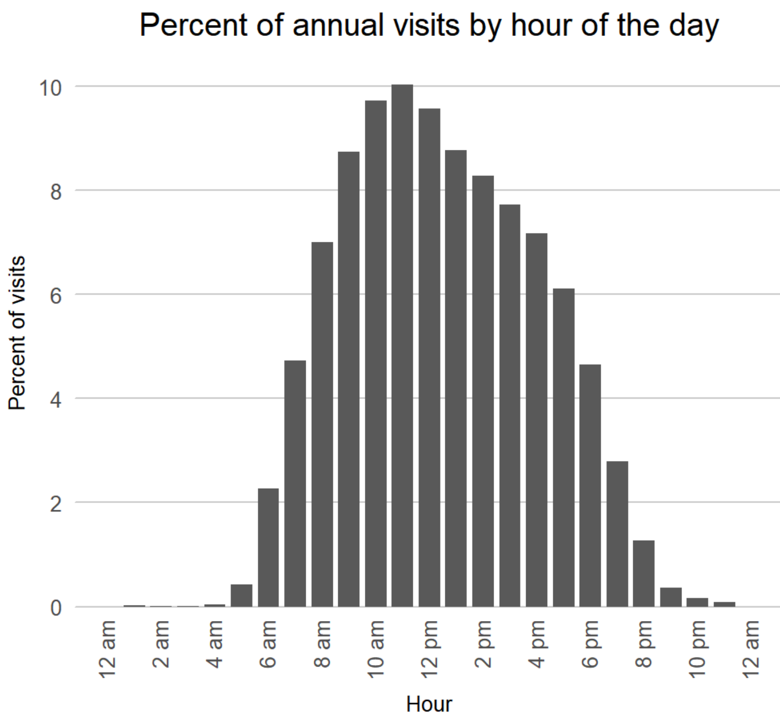


Figure 11. Distribution of hourly visitation at the system-wide level, represented as the percentage of total visitation that occurred during each hour of the day.

Table 7. System-wide hourly total visitation for each hour of the day, including lower and upper estimates.

Hour	Visits (95% CI)	
0	3,099	(2,755 - 3,445)
1	1,504	(1,355 - 1,654)
2	992	(889 - 1,095)
3	983	(875 - 1,092)
4	2,774	(2,443 - 3,108)
5	26,727	(23,649 - 29,822)
6	141,706	(125,065 - 158,366)
7	295,526	(260,518 - 330,538)
8	438,645	(386,610 - 490,680)
9	547,016	(480,779 - 613,255)
10	608,410	(534,464 - 682,353)
11	627,609	(551,343 - 703,872)
12	598,781	(526,843 - 670,726)
13	548,814	(482,950 - 614,691)
14	518,361	(456,198 - 580,535)
15	483,740	(425,835 - 541,657)
16	448,621	(395,261 - 501,992)
17	382,234	(336,593 - 427,884)
18	291,324	(256,431 - 326,233)
19	174,676	(153,729 - 195,633)
20	79,757	(70,663 - 88,863)
21	22,309	(19,887 - 24,739)
22	9,699	(8,620 - 10,783)
23	5,400	(4,762 - 6,040)

Seasonality and the day of the week affected the hourly visitation pattern, including when the peak-visitation time occurred and whether there were one or two spikes in daily visitation. Weekend visitation tended to have a single peak-visitation hour, occurring at 10 a.m. and 11 a.m. during the spring, summer and fall, and around 1 p.m. during the winter. Weekday visitation during the spring, summer and fall tended to peak twice: in the morning between 9 a.m. and 12 p.m. and again between 5 p.m. and 8 p.m. Changes to hourly patterns over the seasons is likely due to a combination of work schedules, length of day, and attempts to avoid mid-day heat during summer months.

Winter weekday visitation, however, tended to have a single peak between 12 p.m. and 2 p.m., likely a result of fewer daylight hours and early afternoon typically being the warmest time of the day.

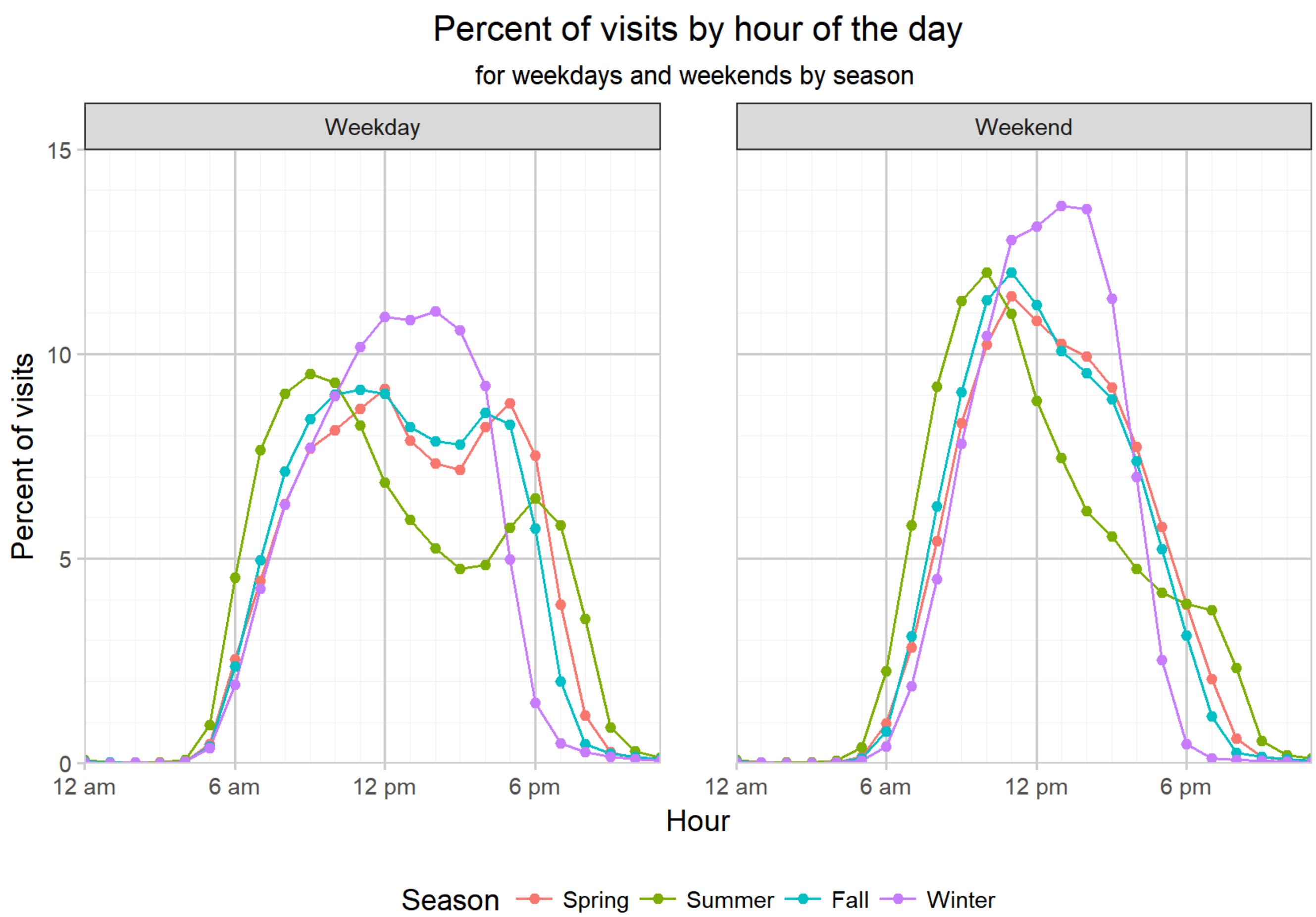


Figure 12. Distributions of system-wide hourly visitation for weekends and weekdays, represented at the proportion of annual visits that occurred within each hour by weekday and season.

Figure 13 shows the highest resolution of visitation patterns examined for this report, with average hourly visitation distributions broken out by day of the week, season, and visitation class. Hourly visitation patterns across all classes are generally consistent with system-wide seasonal (Figure 7), daily (Figure 10), and weekend/weekday (Figure 12) distributions. Within each visitation class, weekend visitation is generally 60 to 70 greater than weekday visitation. Weekday visitation in spring, summer and fall is typically bimodal, with visitation peaking in the morning and later afternoon, for all visitation classes except for Very Low. The greater variation in visitation patterns revealed in the Very Low visitation class is probably due to a combination of factors, including the low sample size (*n=3*) for the study and lower popularity – leading to greater variation in visitation over time at these locations. A final distribution pattern of note revealed in Figure 13 is that the peak weekend visitation in each visitation class is roughly equal to the peak weekday visitation in the visitation class above it. This means that the average weekend visitation at a Medium visitation class trailhead would generally be expected to be similar to weekday visitation at a High visitation class trailhead.

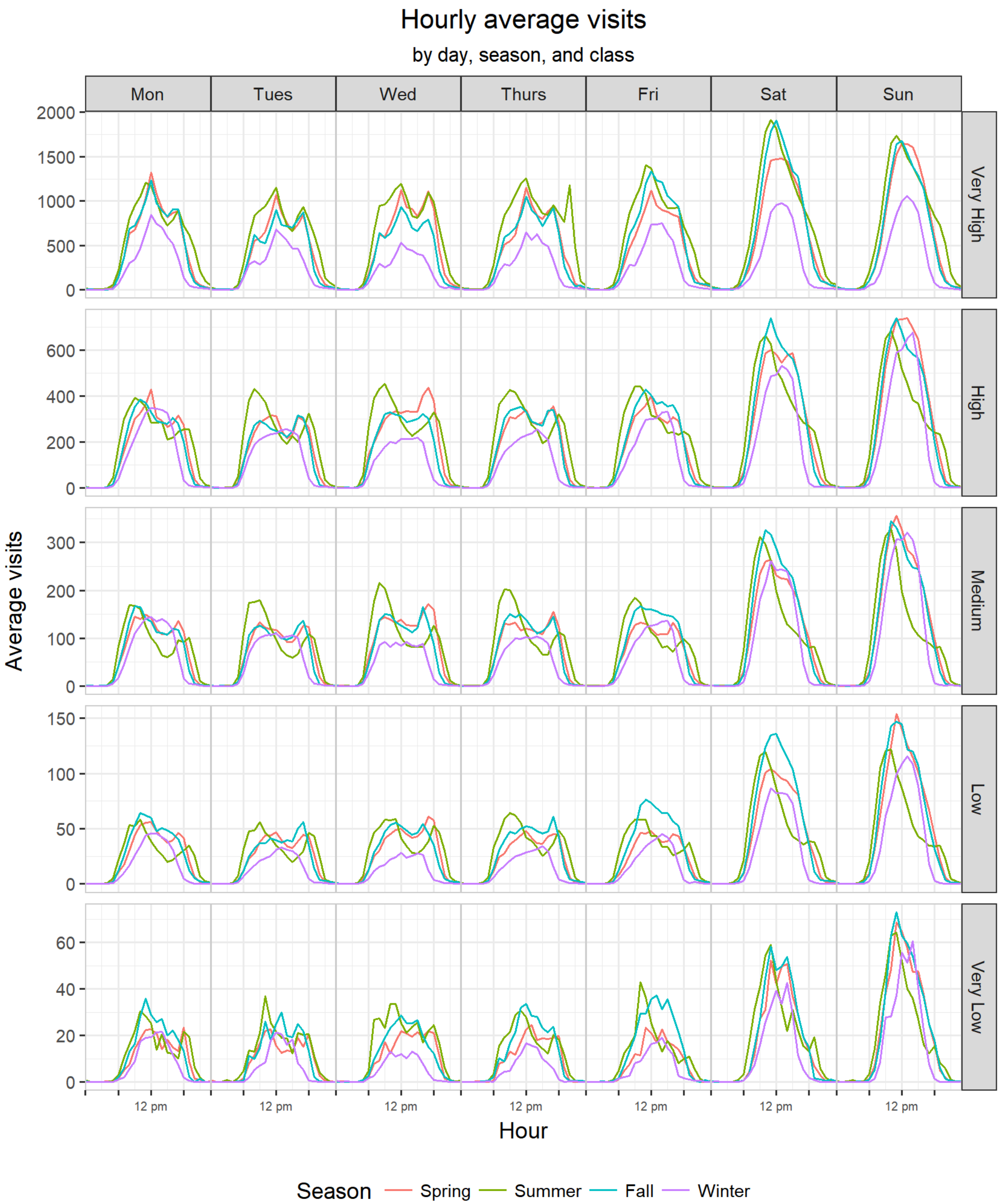


Figure 13. Distribution of system-wide hourly visits by day of the week, season, and visitation class, represented as the average number of hourly visits

3.2 Annual Visits for Select Sample locations

Annual visitation was calculated individually for the 45 primary sample locations (Table 8). The Chautauqua Trail was the busiest sample location during this study, with around 350,000 annual visits. The second busiest sample location was Boulder Creek at Arapahoe and Foothills, which is a Greenway trail located along Boulder Creek in the interior of this city. The department manages several Greenway trails throughout the city (including the Bobolink Multi-Use Trail). While these locations may not fit the typical characterization of many OSMP managed trails, their proximity to valuable natural resources – such as riparian areas – makes it important to understand visitation at these locations. Other areas that received high levels of visitation include Sanitas, Wonderland Lake, South Mesa, Marshall Mesa, and Bobolink/South Boulder Creek Community Center. These areas typically have multiple locations where people can access the area and thus multiple locations would need to be aggregated to account for total area visitation. Not all locations in a given area were necessarily selected as primary sample locations so adding together locations listed in Table 8 may not provide a complete estimate of area visitation levels.

Table 8. Annual total visits for the 45 primary sample locations.

ID	Site Name	Class	Visits (95% CI)	
170	Chautauqua Trail	Very High	349,050	(332,940 - 365,154)
354	Boulder Creek at Arapahoe and Foothills	Very High	244,498	(239,098 - 249,913)
169	Bluebell Road	High	175,064	(161,664 - 188,460)
61	Sanitas Valley Trail	High	132,758	(103,573 - 161,944)
66	Wonderland Trail Poplar Ave	High	130,251	(115,733 - 144,761)
139	South Mesa Trailhead	High	121,639	(104,020 - 139,265)
60	Mount Sanitas Trail	High	117,800	(106,390 - 129,206)
70	Wonderland Utica East	High	114,880	(109,725 - 120,038)
118	South Boulder Creek Community Center	High	104,828	(94,779 - 114,869)
608	Bobolink Natural-Surface Trail	High	103,297	(92,295 - 114,294)
356	Marshall Mesa	High	99,556	(92,632 - 106,478)
54	Settlers Trailhead West	High	87,898	(77,052 - 98,747)
74	Fourmile Trailhead	Medium	69,515	(63,225 - 75,807)
117	Bobolink Multi-Use Trail	Medium	68,801	(59,000 - 78,603)
63	Sanitas Valley View	Medium	66,767	(60,153 - 73,378)
174	Gregory Canyon	Medium	63,057	(58,554 - 67,560)
123	South Boulder Creek Marshall	Medium	61,290	(56,040 - 66,556)
113	Dry Creek Trailhead	Medium	44,918	(35,926 - 53,905)
82	BVR Trailhead South	Medium	44,156	(36,620 - 51,695)
86	Eagle Trailhead	Medium	42,958	(37,031 - 48,883)
155	North Fork Shanahan	Medium	37,902	(32,414 - 43,388)
104	East Boulder Trail - Valmont	Medium	35,948	(32,922 - 38,974)
83	BVR Trailhead North	Medium	32,946	(30,204 - 35,688)
137	Flatirons Vista Trailhead	Medium	32,113	(27,300 - 36,925)
138	Doudy Draw Trailhead	Low	23,628	(20,700 - 26,553)
140	Fowler East	Low	23,583	(17,859 - 29,304)
607	Prairie Vista Trail	Low	21,742	(17,764 - 25,722)
609	Cowdry Draw West	Low	21,431	(16,931 - 25,939)
81	Eagle Trail West	Low	21,290	(19,442 - 23,134)
107	Sawhill Entrance West	Low	20,901	(17,664 - 24,130)
194	Ute Trail	Low	20,600	(16,812 - 24,383)
136	Greenbelt Plateau Trailhead	Low	20,574	(16,771 - 24,383)
244	Lion's Lair Spur	Low	18,852	(18,067 - 19,643)
147	South Boulder Creek Trail Broadway	Low	18,731	(17,360 - 20,107)
79	Foothills Trail Near US 36	Low	17,812	(10,468 - 25,144)
154	Greenbriar Undesignated	Low	16,418	(12,366 - 20,494)
191	Gregory Canyon Spur	Low	16,167	(13,784 - 18,550)
602	High Plains West	Low	14,474	(10,371 - 18,585)
88	Cottontail Trail South	Low	13,027	(9,076 - 16,982)
606	Hardscrabble Connector	Low	12,870	(12,186 - 13,558)
68	Foothills Trail Locust Pl	Low	12,279	(10,613 - 13,951)
103	East Boulder Trail White Rocks	Low	12,139	(9,951 - 14,328)
84	Lefthand Trailhead	Very Low	9,905	(7,931 - 11,885)
252	Joder Interim East	Very Low	9,505	(8,283 - 10,717)
201	Boy Scout Trail	Very Low	3,434	(3,167 - 3,706)

3.3 Annual Visitation Change: Repeated Primary Locations

Of the 45 primary sample locations selected for the current study, 33 represented direct repeats of locations included in the 2005-2005 study (Table 9). Comparison of the visitation levels between the two studies indicates that changes in visitation levels have not occurred evenly across all locations.

Table 9. Comparison of 2005 and 2017 annual total visits for the 33 direct repeat primary sample locations.

		2005		2017			
ID	**Site Name (2017)**	**Visits**	**Class**	**Visits**	**Class**	**Difference**	**Percent**
170	Chautauqua Trail	111,479	High	349,050	Very High	237,571	213
169	Bluebell Road	92,987	High	175,064	High	82,077	88
118	South Boulder Creek - Community Center	59,657	Medium	104,828	High	45,171	76
139	South Mesa Trailhead	79,088	High	121,639	High	42,551	54
66	Wonderland Trail - Poplar Ave	95,383	High	130,251	High	34,868	37
70	Wonderland Utica - Utica East	81,293	High	114,880	High	33,587	41
356	Marshall Mesa	66,975	Medium	99,556	High	32,581	49
54	Settlers Trailhead - West	60,124	Medium	87,898	High	27,774	46
117	Bobolink Trailhead	148,810	High	172,098	High	23,288	16
61	Sanitas Valley Trail	110,659	High	132,758	High	22,099	20
60	Mount Sanitas Trail	96,205	High	117,800	High	21,595	22
174	Gregory Canyon	48,107	Medium	63,057	Medium	14,950	31
194	Ute Trail	8,668	Very Low	20,600	Low	11,932	138
137	Flatirons Vista Trailhead	23,674	Low	32,113	Medium	8,439	36
123	South Boulder Creek - Marshall	55,031	Medium	61,290	Medium	6,259	11
107	Sawhill Entrance West	15,022	Low	20,901	Low	5,879	39
86	Eagle Trailhead	37,704	Medium	42,958	Medium	5,254	14
63	Sanitas Valley View	62,611	Medium	66,767	Medium	4,156	7
155	North Fork Shanahan	33,970	Medium	37,902	Medium	3,932	12
88	Cottontail Trail South	10,740	Low	13,027	Low	2,287	21
74	Fourmile Trailhead	67,956	Medium	69,515	Medium	1,559	2
201	Boy Scout Trail	2,628	Very Low	3,434	Very Low	806	31
79	Foothills Trail - Near US 36	17,822	Low	17,812	Low	(10)	0
84	Lefthand Trailhead	10,243	Low	9,905	Very Low	(338)	-3
136	Greenbelt Plateau Trailhead	21,851	Low	20,574	Low	(1,277)	-6
68	Foothills Trail - Locust Place	14,386	Low	12,279	Low	(2,107)	-15
147	South Boulder Creek – Broadway	22,222	Low	18,731	Low	(3,491)	-16
83	Boulder Valley Ranch – South	51,859	Medium	44,156	Medium	(7,703)	-15
138	Doudy Draw Trailhead	31,776	Medium	23,628	Low	(8,148)	-26
104	East Boulder Trail Valmont[a]	45,029	Medium	35,948	Medium	(9,081)	-20
103	East Boulder Trail White Rocks[a]	24,598	Low	12,139	Low	(12,459)	-51
81	Eagle Trail West[b]	39,524	Medium	21,290	Low	(18,234)	-46
113	Dry Creek Trailhead[c]	113,932	High	44,918	Medium	(69,014)	-61
	Net Change	***1,762,013***		***2,298,766***		***536,753***	***30***

[a] *The bridge at Boulder Creek was closed during the study, requiring visitors to do out-and-back rather than through trips, which likely reduced use throughout the entire East Boulder – White Rocks trail corridor.*

[b] *The location of the trail counter at this location in 2004-2005 (in the swing of the pedestrian gate) likely registered extra detections from the gate, potentially inflating the visitation estimate.*

[c] *The location of the trail counter in 2004-2005 between gate and trash cans likely included some double counts from people returning to trash cans to dispose of dog waste bags. Much of the creek has also been fenced off since 2005 for New Zealand mud snail control.*

3.4 Annual Visits for Interior Locations

To estimate the number of recreation visits to select interior trails, including annual visitation to several popular destination areas, staff placed trail counters at 16 interior locations. While the primary objectives of this study were to understand how many visits city-managed open space received, staff were also interested in understanding how visitation is sustained further into the system. Notably, interior destinations within the proximity of the Chautauqua access area generally received elevated levels of visitation, including the Upper Chautauqua trail, 1st/2nd Flatirons trail, and the Royal Arch trail (Table 10). Understanding how visitation at these interior locations correlates with visitation at the various entry locations surrounding them will be explored further in future analyses.

Table 10. Annual total visits for the 16 interior located locations, including upper and lower estimates.

ID	Site Name	Class	Visits (95% CI)	
707	Chautauqua - Upper	Very High	219,257	(207,961 - 230,557)
706	1st/2nd Flatiron Trail	High	131,009	(128,563 - 133,455)
700	Royal Arch	High	105,245	(102,968 - 107,521)
709	Kohler Mesa	Medium	60,018	(57,024 - 63,008)
711	East Ridge Trail	Medium	57,734	(51,724 - 63,746)
705	Flatirons Loop	Medium	55,523	(53,024 - 58,019)
710	Mallory Cave Trail	Medium	43,095	(39,795 - 46,395)
701	Green Mountain - West	Medium	37,271	(33,029 - 41,505)
702	Saddle Rock	Medium	36,325	(35,265 - 37,385)
712	Mesa - Shadow Canyon	Low	15,764	(13,954 - 17,568)
604	Shanahan UT	Low	12,656	(11,999 - 13,317)
703	Bear Peak	Low	10,428	(9,318 - 11,544)
713	Hogback Ridge Summit	Low	10,282	(6,693 - 13,874)
708	Hogback Ridge	Very Low	9,657	(4,868 - 14,454)
704	South Boulder Peak	Very Low	9,075	(8,370 - 9,785)
614	Gunbarrel East UT	Very Low	8,903	(8,309 - 9,503)

3.5 Annual Dog Visits

Using visitor party composition data from the visitor survey, staff estimate the ratio of dog visits at 28.7% of person visits (VanderWoude & Kellogg, 2018) for a total of 1.79 (95% CI, 1.58 – 2.00) million annual dog visits. The question structure on the visitor survey does not allow specific attribution of the number of dogs to individual people but rather to the visitor party. Thus, it is only possible to calculate dog visits as a ratio of person visits and 28.7% should not be interpreted as the proportion of specific people that visit with dogs. For a breakdown of the distribution of the number of dogs per visitor party relative to the size of the visitor party, see Appendix D in the 2016-2017 Visitor Survey Report (VanderWoude & Kellogg, 2018).

4 DISCUSSION

4.1 Visitation Levels and Patterns

The goal of this study was to develop a quantitative understanding of system-wide recreation visits to city-managed open space to support the department and the public in making informed decisions relating to visitation. Using the methods outlined in this report, staff were able to fully meet this goal, and the department and public now have an updated quantitative dataset to help guide future management and planning efforts. By conducting this study, staff have gained a greater understanding of many aspects of visitation to city-managed open space that are worth discussing. Following is a brief discussion on some of the highlights from this report.

Based on data collected between June 1, 2016 and May 31, 2017[11], staff estimate annual visitation to be 6.26 (95% CI, 5.51 – 7.01) million visits, up from an estimated 4.68 (95% CI, 4.38 – 5.00) million visits based on data collected during the same months in 2004 and 2005. This represents an overall increase of 34% growth over a 12-year period. If the rate of increase is assumed to be constant between these two visitation studies – which cannot be confirmed or rejected based on available data – then visitation to city-managed open space has been increasing at 2.4% annually.

The validation that visitation has increased generally meets the perceptions and expectations of staff and likely the public as well. While the fact that overall visitation has increased may not come as a surprise to many, there are several additional results that are of interest.

Perhaps the most significant finding is that monthly visitation levels on city-managed open space do not exhibit the strong seasonality observed at other public lands, such as those of the National Park Service (Ziesler & Singh, 2018), where visitation gradually increased in spring to a peak in summer and then tapers off again to winter. In fact, monthly visitation to city-managed open space exhibits a bimodal distribution with June being the busiest month, accounting for about 10% of total annual visitation (~ 636,000 visits) and October the second busiest month at 9.6% (~ 601,000 visits). Visitation to city-managed open space is lowest in the winter (314,000 to 444,000 monthly visits) but spring, summer and fall months all received visitation levels around 500,000 monthly visits.

The lack of a strong seasonal pattern indicates that city-managed open space remains popular for passive recreational throughout most of the year. This pattern is not wholly unexpected given the significant local and regional visitation base but there are some potential management implications worth noting. First, while many public land management agencies (including OSMP) utilize seasonal staff to support increased resource demands during a distinct peak visitation period (i.e. summer), sustained levels of visitation from March to November mean that the "off-season" is, at a minimum, much shorter on city-managed open space than comparative agencies. Management activities – such as infrastructure maintenance, visitor services, and resource protection that require active staff engagement – may require near-continuous support throughout the year on city-managed open space.

Another significant finding is that visitation across days of the week is virtually identical to the 2004-2005 study (Vaske et al., 2009). Each weekday receives approximately 12% of total annual visitation, with 19% on Saturday and Sunday the highest at 21%. Hourly patterns also appear to be consistent across days of the week. Weekend visitation tends to have a single peak-visitation hour, occurring at 10 a.m. and 11 a.m. during the spring, summer

[11] Due to several delayed equipment installations, some locations continued to receive data collection beyond the one-year mark (May 31, 2017) to ensure a minimum of 365 days of continuous data collection.

and fall, and around 1 p.m. during the winter. Weekday visitation during the spring, summer and fall tends to peak twice: in the morning between 9 a.m. and 12 p.m. and again between 5 p.m. and 8 p.m. The daily and hourly patterns suggest that while there have been significant increases in overall visitation levels, some visitation dynamics on city-managed open space appear to be more consistent. When developing long-range visitation management strategies, focusing on visitation dynamics that are more stable, such as the daily and hourly patterns of visitation, may deliver more reliable outcomes for planning and management efforts.

Hourly and daily visitation patterns at the system-wide level are relatively consistent with the patterns previously identified in 2004-2005, suggesting that while the level of visitation has increased, it has increased similarly across all days of the week and hours of the day. Around 40% of visitation still occurs on weekends, with the remaining 60% equally distributed across weekdays. Nearly all visitation (98.8%) occurs between 6 a.m. and 9 p.m., indicating that nighttime use remains low. When compared to nighttime use as estimated during the 2004-2005 study (1.4%), which used the more narrow time period of 11 p.m. to 6 a.m., the overall percent nighttime use has decreased.

An examination of annual visitation for primary sample locations indicates that Chautauqua, Sanitas, Wonderland Lake, South Mesa, Bobolink, and Marshall Mesa areas are some of the highest visitation areas on city-managed open space. These findings are generally in line with staff expectations and likely public perceptions as well. While there are many aspects of site-specific visitation dynamics that are beyond the scope of this report, the initial results suggest that the majority of visitation is concentrated to certain areas of the system.

Of the 33 primary locations included in both the 2004-2005 and 2016-2017 (present) study, 6 went up a visitation class. Based on data from both the primary and secondary locations, city-managed open space now has 20 access locations at or above the High visitation class. Not all locations grew proportionally to the system-wide average of 34%. Chautauqua, in particular, was far above the system-wide average at 213% increase, growing from an estimated 111,479 visits in 2004-2004 to 349,050 (Table 9). Other locations – such as Mount Sanitas (22%), Gregory Canyon Trail (31%) and Wonderland Trail – Poplar Avenue (37%) – appear to have increased more closely to the system-wide average. Some locations – including Sanitas Valley View (7%), Fourmile Trailhead (2%) and Foothill Trail - US 36 (0%) – have seen minimal or no significant change since the last study. Thus, not all areas of the system have experienced changes in visitation to the same degree or in the same direction. The fact a location has changed should not be interpreted as a direct indication of management focus. When considering visitor experience and resource management objectives of an area, changes in visitation levels are only one variable of a much larger equation that must be evaluated when determining management actions for that area.

Hourly and daily patterns at the system-wide annual level appear to be relatively consistent with the 2004-2005 estimates, suggesting that in general, visitation levels have increased similarly across days of the week and hours of the day. About 40% of visitation occurs on the weekend with the remaining 60% equally distributed across days of the week. Nearly all visitation (98.8%) occurs between 6 a.m. and 9 p.m. Using the nighttime period of 11 p.m. to 6 a.m., as defined during the 2004-2005 study, visitation as on overall percentage has decreased from 1.4% to 0.65% between the previous estimate and this one.

Finally, one of the secondary objectives of this study was to gather a “first look” at visitation levels beyond entry locations. This was accomplished by installing trail counters at interior locations, including trails and destinations accessible from the Chautauqua area trailheads. Estimates from these trail counters indicate that the 1st/2nd Flatiron and Royal Arch trails both receive over 100,000 visits annually (Table 10). Bear Peak (10,428) and South

Boulder Peak (9,075) both received slightly lower visitation than expected by staff. Findings from the visitor survey show that the median trip length is around 60 minutes, which suggests that mountain peak destinations, such as Bear Peak and South Boulder peak, are too far for many people to reach given the length of time they spend on the trails during a given visit. At this time, the high-level results from these interior locations generally indicate that developing a better understanding of visitation patterns beyond the trailhead will be an important component of any visitation management strategies. The relative visitation that any area of city-managed open space receives will be a combination of both the input (level of visitation at entry locations) and subsequent dispersion of visitation (travel patterns).

4.2 Next Steps and Opportunities

The visitation estimates presented in this report detail one of the two core components of the 2016-2017 Visitation Study conducted by the OSMP's Human Dimensions Program. The other component consisted of an on-site visitor survey that collected input from visitors on the types of recreational activities they were engaging in, experiences they had, and other key metrics designed to understand various dimensions of visitors to city-managed open space. Staff have plans to conduct a paired analysis of both the estimate and survey datasets. Through this paired analysis, staff will begin exploring the data for potential relationships between levels of visitation and visitor characteristics including activity type, length of visitation, demographics, number of unique visitors, and various dimensions of visitor experiences.

The development, implementation, and analysis of this study has been a multi-year endeavor and, given the various enhancements made to the 2004-2005 study methods, is the largest visitation related data collection effort that the department has undertaken to date. The data collected from this study will support a wide variety of current and future departmental efforts, including but not limited to the development of strategies for OSMP's Master Plan. Conducting a system-wide data collection effort of this magnitude was undertaken, in large part, due to the long interval since the 2004-2005 study and a need to collect data across a wide range of visitation variables. However, data collection at this scale does have limitations. Primarily, infrequent large data collection efforts require substantial time resources to collect and analyze the data necessitating long time lags between updates to visitation conditions on city-managed open space. While implementing and analyzing the data from this visitation study, staff have identified opportunities to greatly enhance the collection and provision of visitation data.

Preliminary analysis of trail counter data from the primary and secondary sample locations indicate that system-wide visitation levels can be estimated with a high degree of accuracy at the monthly and annual level, using a small network of strategically located trail counters. Staff is currently working on the development of a system-wide visitation model that will be used to select locations for the long-term installation of a network of trail counters. A continuous visitation estimate program will not only provide higher-frequency visitation data for trend analysis but will also allow site-specific studies to be evaluated in context with inter-annual fluctuations in system-wide visitation levels.

All of the visitation data examined for this report were collected using automated trail counters, which have been established as an industry standard for collecting visitation data for pedestrian visitation on public lands. This type of equipment continues to provide a highly cost-effective and accurate solution for collecting visitation data, but it does have its limitations. Most notably, visitation levels can only be collected at a single, static, point and thus estimating visitation over a broad geographic area requires a large network of trail counters. The ubiquity of smartphones with location-based apps and services are emerging that can potentially provide higher-resolution information about visitation dynamics on city-managed open space. While it is unlikely that mobile technologies will fully replace the need for field-based measurements in the near future, staff are continuing to explore opportunities to expand or enhance the precision and coverage current estimates.

4.3 SUMMARY

The visitation estimates presented in this report indicate that visitation to city-managed open space is dynamic. Overall system-wide visitation has increased 34% from 4.68 million to 6.26 million annual visits in the last 12 years, but not all locations on city-managed open space have seen the same level of growth. Some locations have seen growth significantly above than the system average of 33% while others have seen no growth or even a slight decrease. Patterns of visitation are similarly dynamic, with visitation distribution across days of the week remaining virtually unchanged since 2004-2005 despite the 33% increase in visitation. Seasonal distributions indicate that visitation remains relatively high from March through November, with peak visitation during June and October. Hourly patterns further reveal that weekdays at many locations tend to have a bimodal distribution, with visitation peaking in the (between 9 a.m. and noon) and again in the late afternoon (between 4 p.m. and 6 p.m.) while weekend visitation tends to be unimodal with a single peak around noon.

The goal of this study was to develop a quantitative dataset from which the department and the public can evaluate and discuss visitation levels so that the Boulder community can continue the legacy stewarding open space for the conservation of natural resources and the provision of high-quality recreation experiences. The findings from this report may confirm some perceptions (e.g. visitation has increased) and challenge others (e.g. visitation has not increased significantly everywhere), but it will hopefully provide a common baseline from which to frame future decisions related to management of city-managed open space. As with many studies, it is possible that many new questions will arise from the results presented in this report. The process of data collection, analysis, and interpretation is an iterative process, and the department and staff are committed to continually improving the quality, value, and utility of these data so that we can support the community in making informed, data-driven decisions about the future of city-managed open space.

5 REFERENCES

Anderson, D. H., Lime, D. W., & Wang, T. L. (1998). *Maintaining the quality of park resources and visitor experiences* (p. 149). Department of Forest Resources University of Minnesota. Retrieved from http://www.wilderness.net/toolboxes/documents/vum/vum_nps_tactics_handbook.pdf

City of Boulder. (2005). *Visitor Master Plan*. City of Boulder: Open Space and Mountain Parks.

City of Boulder. (2017). *Open Space and Mountain Parks: 2016 Resident Survey* (Resident Survey). Boulder, Colorado: City of Boulder Open Space and Mountain Parks Department. Retrieved from https://www-static.bouldercolorado.gov/docs/2016-osmp-resident-survey-report-1-201705310956.pdf?_ga=2.27533180.1739444255.1527614884-1827189851.1494444851

Colorado Department of Local Affairs. (2018). County Population Growth [State]. Retrieved May 30, 2018, from https://gis.dola.colorado.gov/apps/demographic_dashboard/

D'Antonio, A., Monz, C., Larson, N., & Rohman, A. (2016). An application of recreation resource assessment techniques to inform management action in an urban-proximate natural area. *Journal of Outdoor Recreation and Tourism*, *14*, 12–21. https://doi.org/10.1016/j.jort.2016.04.002

Giolitto, M. (2012). *City of Boulder Open Space and Mountain Parks: 2010-2011 Visitor Survey Report ver. 1.0* (Visitory Survey Report). Boulder, Colorado: City of Boulder Open Space and Mountain Parks Department. Retrieved from https://www-static.bouldercolorado.gov/docs/2010-11-visitor-survey-report-1-201304101153.pdf?_ga=2.98768606.1739444255.1527614884-1827189851.1494444851

Nickerson, N. (2016). What We Know about Crowding and Visitor Experiences. *Institute for Tourism and Recreation Research Publications*. Retrieved from http://scholarworks.umt.edu/itrr_pubs/340

Pettebone, D., Newman, P., & Lawson, S. R. (2010). Estimating visitor use at attraction sites and trailheads in Yosemite National Park using automated visitor counters. *Landscape and Urban Planning*, *97*(4), 229–238. https://doi.org/10.1016/j.landurbplan.2010.06.006

R Development Core Team. (2017). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org

Turner, S., Lasley, P., & Pourteau, C. (2013). *Monitoring Trail Use: Case Study Applications at San Antonio Missions National Historical Park and Guadalupe Mountains National Park* (Final Technical No. TTI 401090-1) (pp. 1–104). San Antonio Missions National Historical Park & Guadalupe Mountains National Park: National Park Service.

VanderWoude, D., & Anacker, B. (2016). *Chautauqua Study Area Visitation Monitoring Report* (Visitation Study) (p. 32). City of Boulder Open Space and Mountain Parks. Retrieved from https://www-static.bouldercolorado.gov/docs/2015-osmp-chautauqua-visitation-study-1-201604181200.pdf?_ga=2.152872825.1720145308.1508895999-1827189851.1494444851

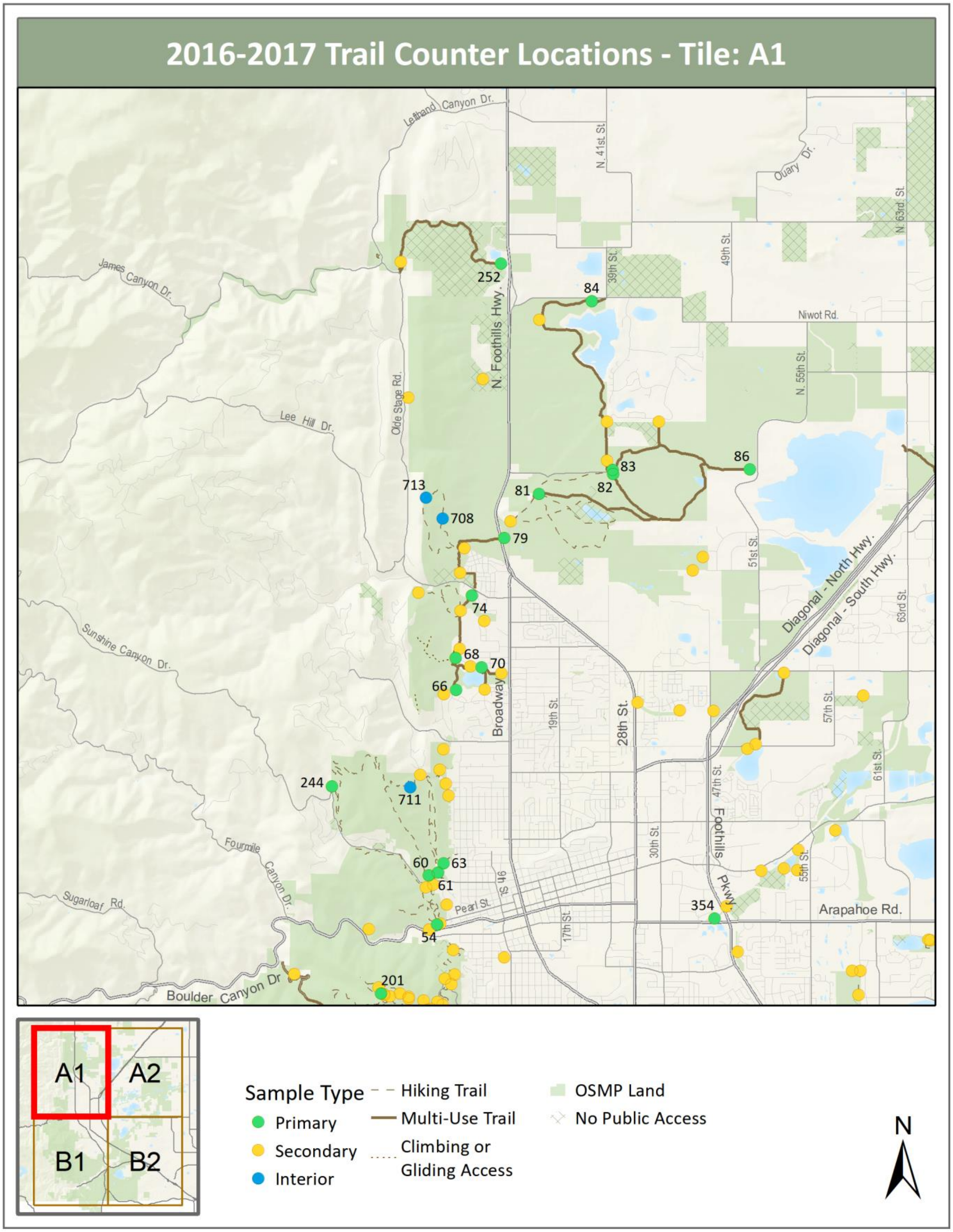
VanderWoude, D., & Kellogg, A. (2018). *2016-2017 Visitor Survey Report* (Monitoring Report). Boulder, CO: The City of Boulder Open Space and Mountain Parks Department.

Vaske, J. J. (2008). *Survey research and analysis: Applications in parks, recreation and human dimensions*. Venture Publ.

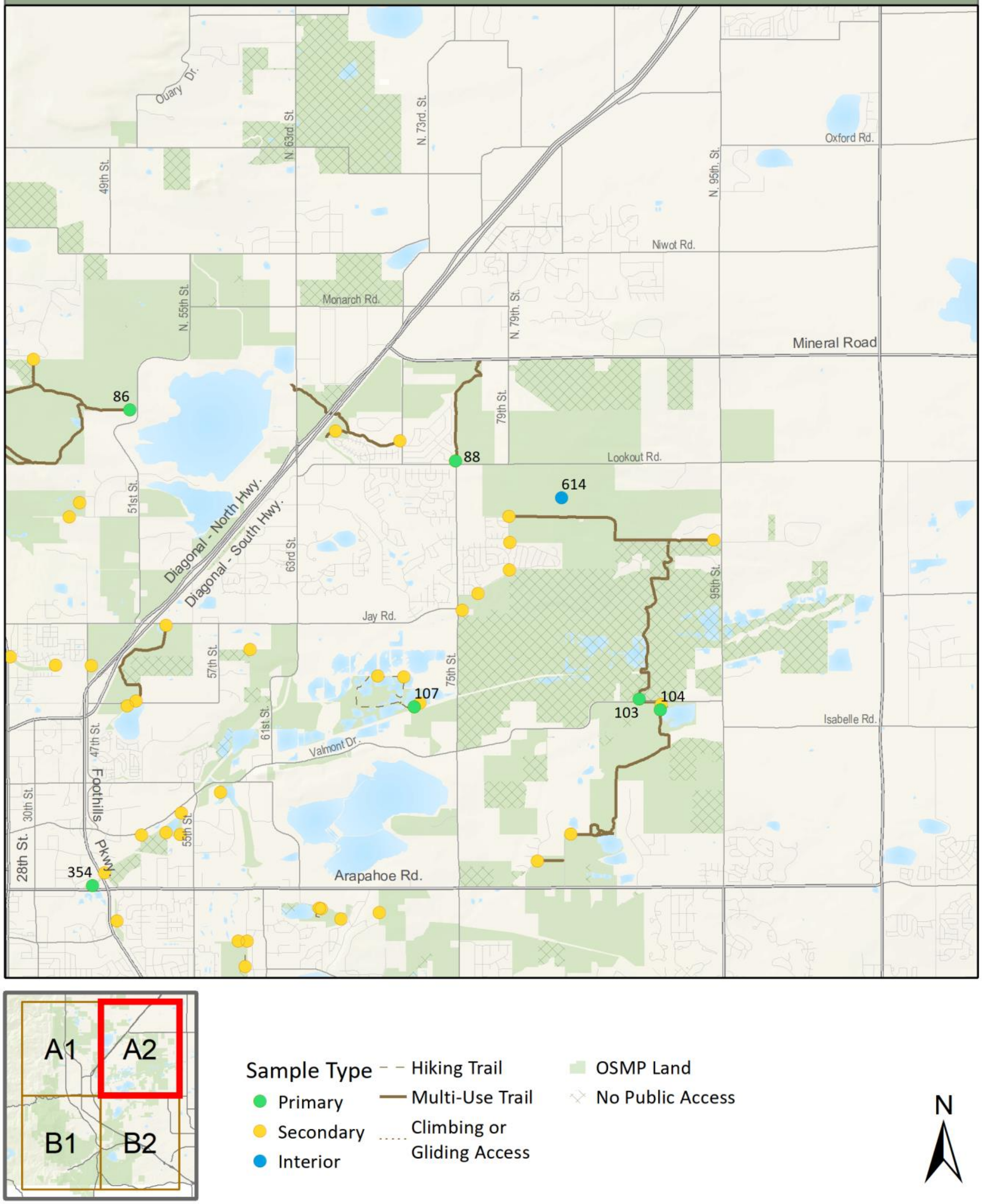
Vaske, J. J., Donnelly, M. P., & Shelby, L. B. (2009). *Estimating visitation to Boulder Open Space and Mountain Parks* (HDNRU No. 80). Fort Collins, CO: Colorado State University. Retrieved from https://www-static.bouldercolorado.gov/docs/2004-5-visitation-study-report-1-201304101202.pdf?_ga=2.30022399.139543516.1523977794-1827189851.1494444851

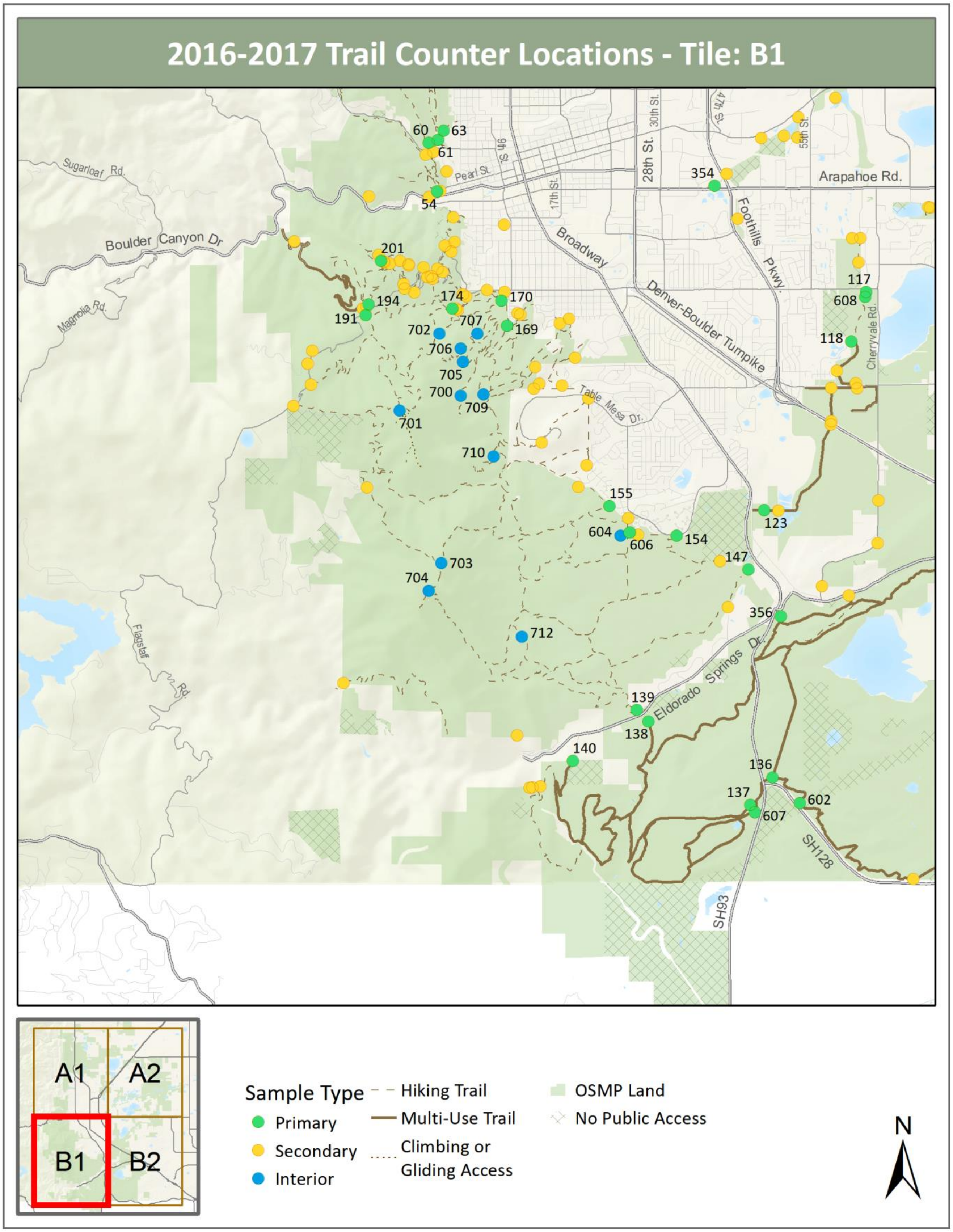
Ziesler, P. S., & Singh, P. (2018). *Statistical Abstract: 2017* (Statistical Abstract No. NPS/NRSS/EQD/NRDS—2018/1156) (p. 114). Fort Collins, Colorado: National Park Service.

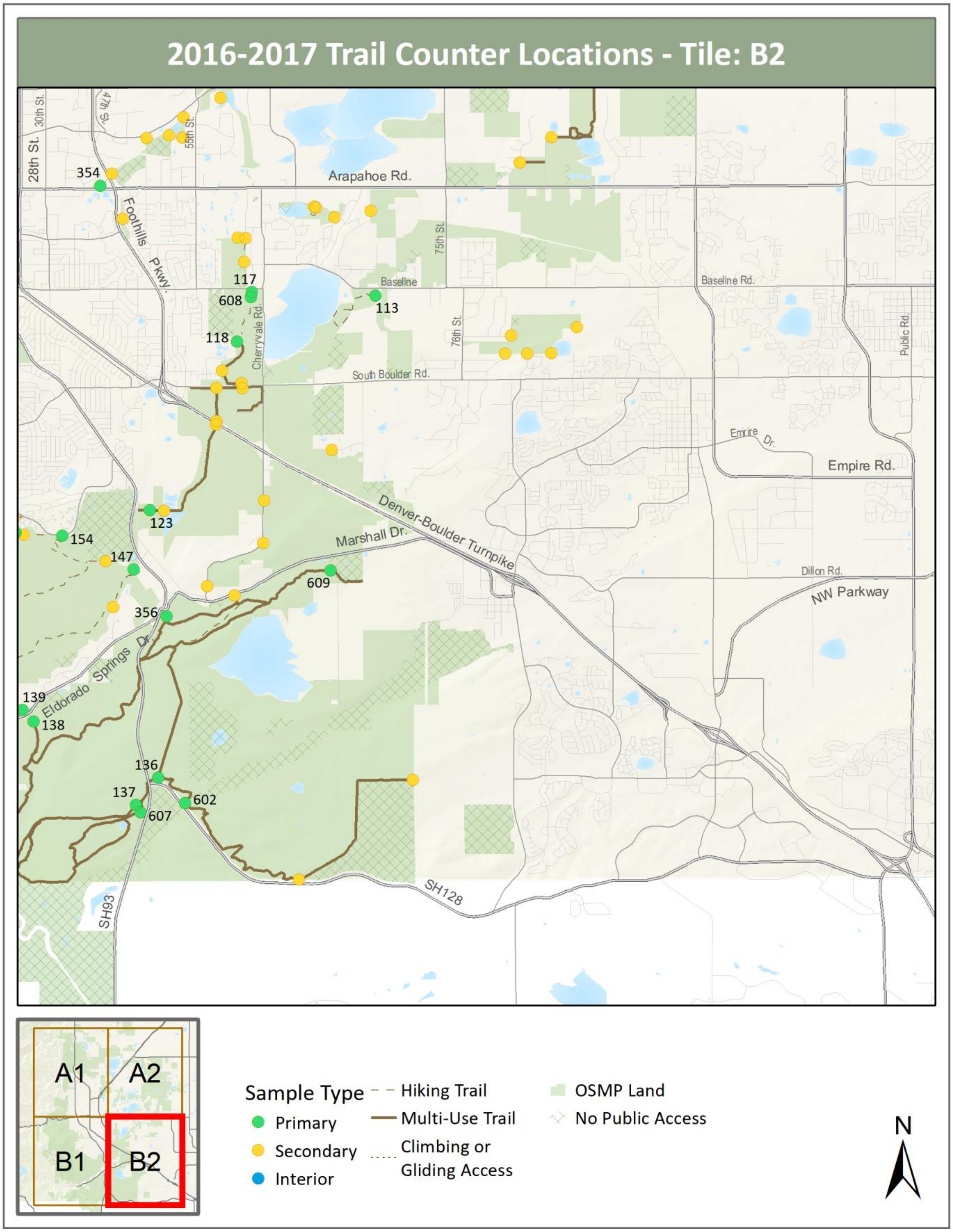
APPENDIX A: SAMPLE LOCATION MAPS



2016-2017 Trail Counter Locations - Tile: A2




2016-2017 Trail Counter Locations - Tile: B1
Sugarloaf Rd.
Boulder Canyon Dr
Magnolia Rd.
Pearl St.
9th St.
17th St.
28th St.
30th St.
47th St.
55th St.
Arapahoe Rd.
Broadway
Foothills Pkwy.
Denver-Boulder Turnpike
Cherryvale Rd.
Table Mesa Dr.
Flagstaff Rd.
Eldorado Springs Dr.
SH93
SH128
60
63
61
54
354
201
194
191
174
170
707
702
169
706
705
700
709
701
710
117
608
118
155
604
606
154
123
147
703
704
356
712
139
138
140
136
137
607
602
A1
A2
B1
B2
Sample Type
Primary
Secondary
Interior
Hiking Trail
Multi-Use Trail
Climbing or Gliding Access
OSMP Land
No Public Access
N



2016-2017 Trail Counter Locations - Tile: B2
Arapahoe Rd.
Foothills Pkwy.
28th St.
30th St.
47th St.
55th St.
75th St.
76th St.
Cherryvale Rd.
Baseline
Baseline Rd.
South Boulder Rd.
Public Rd.
Emrire Dr.
Empire Rd.
Denver-Boulder Turnpike
Marshall Dr.
Dillon Rd.
NW Parkway
Eldorado Springs Dr.
SH93
SH128
354
117
608
113
118
123
154
147
609
356
139
138
136
137
607
602
A1
A2
B1
B2
Sample Type
Primary
Secondary
Interior
Hiking Trail
Multi-Use Trail
Climbing or Gliding Access
OSMP Land
No Public Access
N

APPENDIX B: ANNUAL VISITATION BY SAMPLE TYPE

Table 11. System-wide annual total recreation visits by sample location type for each visitation class (with 95% confidence range).

		Primary		Secondary		All Locations	
Class	**Average**	**Locations**	**Visits**	**Locations**	**Visits**	**Visits Locations (95% CI)**	
Very High	296,774	2	593,548	-	-	593,548	(572,038 - 615,067)
High	118,797	10	1,187,971	9	1,069,174	2,257,145	(2,009,940 - 2,504,318)
Medium	50,031	12	600,371	27	1,350,835	1,951,206	(1,720,514 - 2,181,927)
Low	18,140	18	326,518	43	780,015	1,106,533	(908,849 - 1,304,349)
Very Low	7,615	3	22,844	43	327,431	350,275	(297,175 - 403,389)
Total		***45***	***2,731,252***	***122***	***3,527,455***	6,258,707	(5,508,516 - 7,009,050)

APPENDIX C: DATA CLEANING SUMMARY

Table 12. Missing and invalid data replacement percentages for the 45 primary sample locations and 16 interior sample locations.

		Valid		Outlier		Missing		Replaced	
ID	Site Name	Records	Percent	Records	Percent	Records	Percent	Records	Percent
706	1st/2nd Flatiron Trail	8098	92.4	149	1.7	513	5.9	662	7.6
703	Bear Peak	8314	94.9	121	1.4	325	3.7	446	5.1
169	Bluebell Road	8647	98.7	66	0.8	47	0.5	113	1.3
117	Bobolink Multi-Use Trail	8682	99.1	17	0.2	61	0.7	78	0.9
608	Bobolink Natural-Surface Trail	8368	95.5	252	2.9	140	1.6	392	4.5
354	Boulder Creek and Arapahoe	8760	100.0	0	0.0	0	0.0	0	0.0
201	Boy Scout Trail	8281	94.5	250	2.9	229	2.6	479	5.5
83	BVR Trailhead North	8524	97.3	53	0.6	183	2.1	236	2.7
82	BVR Trailhead South	8483	96.8	13	0.1	264	3.0	277	3.2
707	Chautauqua - Upper	8105	92.5	115	1.3	540	6.2	655	7.5
170	Chautauqua Trail	8615	98.3	100	1.1	45	0.5	145	1.7
88	Cottontail Trail South	8707	99.4	7	0.1	46	0.5	53	0.6
609	Cowdry Draw West	8649	98.7	64	0.7	47	0.5	111	1.3
138	Doudy Draw Trailhead	8649	98.7	63	0.7	48	0.5	111	1.3
113	Dry Creek Trailhead	8703	99.3	7	0.1	50	0.6	57	0.7
81	Eagle Trail West	8540	97.5	7	0.1	213	2.4	220	2.5
86	Eagle Trailhead	8616	98.4	7	0.1	137	1.6	144	1.6
104	East Boulder Trail Valmont	8267	94.4	16	0.2	477	5.4	493	5.6
103	East Boulder Trail White Rocks	8700	99.3	12	0.1	48	0.5	60	0.7
711	East Ridge Trail	8258	94.3	30	0.3	472	5.4	502	5.7
705	Flatirons Loop	8650	98.7	110	1.3	0	0.0	110	1.3
137	Flatirons Vista Trailhead	7781	88.8	66	0.8	913	10.4	979	11.2
68	Foothills Trail Locust Pl	8509	97.1	14	0.2	237	2.7	251	2.9
79	Foothills Trail Near US 36	8523	97.3	40	0.5	197	2.2	237	2.7
74	Fourmile Trailhead	8526	97.3	16	0.2	218	2.5	234	2.7
140	Fowler East	8600	98.2	89	1.0	71	0.8	160	1.8
701	Green Mountain - West	8284	94.6	66	0.8	410	4.7	476	5.4
136	Greenbelt Plateau Trailhead	8445	96.4	74	0.8	241	2.8	315	3.6
154	Greenbriar Undesignated	8422	96.1	32	0.4	306	3.5	338	3.9
174	Gregory Canyon	8665	98.9	47	0.5	48	0.5	95	1.1
191	Gregory Canyon Spur	8605	98.2	24	0.3	131	1.5	155	1.8
614	Gunbarrel East UT	8708	99.4	3	0.0	49	0.6	52	0.6
606	Hardscrabble Connector	8659	98.8	5	0.1	96	1.1	101	1.2
602	High Plains West	8399	95.9	126	1.4	235	2.7	361	4.1
708	Hogback Ridge	8659	98.8	54	0.6	47	0.5	101	1.2
713	Hogback Ridge Summit	8670	99.0	39	0.4	51	0.6	90	1.0
252	Joder Interim East	8498	97.0	17	0.2	245	2.8	262	3.0

ID	Site Name	Valid		Outlier		Missing		Replaced	
		Records	Percent	Records	Percent	Records	Percent	Records	Percent
709	Kohler Mesa	7631	87.1	39	0.4	1090	12.4	1129	12.9
84	Lefthand Trailhead	8586	98.0	54	0.6	120	1.4	174	2.0
244	Lion's Lair Spur	8701	99.3	15	0.2	44	0.5	59	0.7
710	Mallory Cave Trail	7693	87.8	65	0.7	1002	11.4	1067	12.2
356	Marshall Mesa	8378	95.6	115	1.3	267	3.0	382	4.4
712	Mesa - Shadow Canyon	8247	94.1	50	0.6	463	5.3	513	5.9
60	Mount Sanitas Trail	8087	92.3	31	0.4	642	7.3	673	7.7
155	North Fork Shanahan	8429	96.2	35	0.4	296	3.4	331	3.8
607	Prairie Vista Trail	8459	96.6	64	0.7	237	2.7	301	3.4
700	Royal Arch	8277	94.5	97	1.1	386	4.4	483	5.5
702	Saddle Rock	8052	91.9	46	0.5	662	7.6	708	8.1
61	Sanitas Valley Trail	8602	98.2	18	0.2	140	1.6	158	1.8
63	Sanitas Valley View	8401	95.9	55	0.6	304	3.5	359	4.1
107	Sawhill Entrance West	8682	99.1	9	0.1	69	0.8	78	0.9
54	Settlers Trailhead West	8572	97.9	48	0.5	140	1.6	188	2.1
604	Shanahan UT	8064	92.1	10	0.1	686	7.8	696	7.9
118	South Boulder Creek Community Center	8699	99.3	11	0.1	50	0.6	61	0.7
123	South Boulder Creek Marshall	8529	97.4	16	0.2	215	2.5	231	2.6
147	South Boulder Creek Trail Broadway	8532	97.4	15	0.2	213	2.4	228	2.6
704	South Boulder Peak	8017	91.5	392	4.5	351	4.0	743	8.5
139	South Mesa Trailhead	8488	96.9	37	0.4	235	2.7	272	3.1
194	Ute Trail	8669	99.0	45	0.5	46	0.5	91	1.0
66	Wonderland Trail Poplar Ave	8518	97.2	47	0.5	195	2.2	242	2.8
70	Wonderland Utica East	8465	96.6	8	0.1	287	3.3	295	3.4

APPENDIX D: CALIBRATION RESULTS

Table 13. Results from linear regression calibration models for all Primary and Interior trail counter sample locations including upper and lower 95% confidence intervals for the correction factor (coefficient).

Note: Some locations may have more than one set of model results as new calibrations were conducted if there was a significant modification to the trail counter installation.

ID	Site Name	Sample Type	R^2	Coefficient (95% CI)		SE	P
706	1st/2nd Flatiron Trail	Interior	1.00	1.05	(1.03 - 1.07)	0.01	<.001
703	Bear Peak	Interior	0.97	0.88	(0.79 - 0.97)	0.04	<.001
169	Bluebell Road	Annual	0.99	1.46	(1.35 - 1.57)	0.05	<.001
117	Bobolink Multi-Use Trail	Annual	0.97	1.25	(1.07 - 1.42)	0.08	<.001
608	Bobolink Natural-Surface Trail	Annual	0.98	1.36	(1.22 - 1.51)	0.06	<.001
354	Boulder Creek at Arapahoe	Annual	1.00	1.10	(1.08 - 1.13)	0.01	<.001
83	Boulder Valley Ranch Trailhead - North	Annual	0.99	1.11	(1.02 - 1.20)	0.04	<.001
82	Boulder Valley Ranch Trailhead - South	Annual	0.92	1.18	(0.98 - 1.39)	0.09	<.001
201	Boy Scout Trail	Annual	0.99	1.02	(0.94 - 1.10)	0.03	<.001
707	Chautauqua - Upper	Interior	1.00	1.34	(1.27 - 1.41)	0.03	<.001
170	Chautauqua Trail	Annual	0.99	1.49	(1.42 - 1.55)	0.03	<.001
88	Cottontail Trail South	Annual	0.84	1.13	(0.79 - 1.47)	0.15	<.001
609	Cowdry Draw West	Annual	0.92	1.66	(1.31 - 2.01)	0.16	<.001
138	Doudy Draw Trailhead	Annual	0.97	1.33	(1.17 - 1.50)	0.07	<.001
113	Dry Creek Trailhead	Annual	0.93	0.84	(0.67 – 1.00)	0.08	<.001
81	Eagle Trail West	Annual	0.98	1.07	(0.97 - 1.16)	0.04	<.001
86	Eagle Trailhead	Annual	0.97	1.33	(1.14 - 1.51)	0.08	<.001
104	East Boulder Trail Valmont	Annual	0.97	1.13	(1.04 - 1.23)	0.05	<.001
103	East Boulder Trail White Rocks	Annual	0.93	1.13	(0.92 - 1.33)	0.09	<.001
711	East Ridge Trail	Interior	0.97	1.11	(0.99 - 1.22)	0.05	<.001
705	Flatirons Loop	Interior	1.00	1.02	(0.97 - 1.06)	0.02	<.001
137	Flatirons Vista Trailhead	Annual	0.95	1.33	(1.13 - 1.53)	0.09	<.001
68	Foothills Trail Locust Pl	Annual	0.96	1.07	(0.92 - 1.21)	0.07	<.001
79	Foothills Trail Near US 36	Annual	0.72	1.38	(0.81 - 1.95)	0.26	<.001
74	Fourmile Trailhead	Annual	0.98	1.23	(1.12 - 1.34)	0.05	<.001
140	Fowler East	Annual	0.87	1.51	(1.14 - 1.87)	0.17	<.001
701	Green Mountain - West	Interior	0.98	1.11	(0.98 - 1.24)	0.05	<.001
136	Greenbelt Plateau Trailhead	Annual	0.91	1.20	(0.98 - 1.43)	0.10	<.001
154	Greenbriar Undesignated	Annual	0.88	1.11	(0.84 - 1.38)	0.12	<.001
174	Gregory Canyon	Annual	0.99	1.09	(1.01 - 1.16)	0.04	<.001
191	Gregory Canyon Spur	Annual	0.97	1.00	(0.85 - 1.15)	0.06	<.001
614	Gunbarrel East UT	Interior	0.98	1.04	(0.97 - 1.11)	0.03	<.001
606	Hardscrabble Connector	Annual	1.00	1.17	(1.11 - 1.23)	0.03	<.001
602	High Plains West	Annual	0.89	1.80	(1.29 - 2.31)	0.22	<.001
708	Hogback Ridge	Interior	0.73	1.89	(0.95 - 2.83)	0.41	<.01

ID	Site Name	Sample Type	R^2	Coefficient (95% CI)		SE	P
713	Hogback Ridge Summit	Interior	0.92	1.31	(0.86 - 1.77)	0.18	<.001
252	Joder Interim East	Annual	0.96	1.14	(0.99 - 1.28)	0.07	<.001
709	Kohler Mesa	Interior	1.00	1.13	(1.08 - 1.19)	0.02	<.001
84	Lefthand Trailhead	Annual	0.90	0.72	(0.56 - 0.88)	0.07	<.001
84	Lefthand Trailhead	Annual	0.96	1.01	(0.84 - 1.17)	0.07	<.001
244	Lion's Lair Spur	Annual	1.00	1.11	(1.06 - 1.15)	0.02	<.001
710	Mallory Cave Trail	Interior	0.99	1.05	(0.97 - 1.13)	0.03	<.001
356	Marshall Mesa	Annual	0.99	1.02	(0.95 - 1.10)	0.03	<.001
712	Mesa - Shadow Canyon	Interior	0.98	1.25	(1.11 - 1.40)	0.06	<.001
60	Mount Sanitas Trail	Annual	0.97	1.13	(1.02 - 1.24)	0.05	<.001
155	North Fork Shanahan	Annual	0.95	1.07	(0.91 - 1.22)	0.07	<.001
607	Prairie Vista Trail	Annual	0.95	1.32	(1.08 - 1.57)	0.11	<.001
700	Royal Arch	Interior	1.00	1.02	(1.00 - 1.04)	0.01	<.001
702	Saddle Rock	Interior	1.00	1.01	(0.98 - 1.04)	0.01	<.001
61	Sanitas Valley Trail	Annual	0.97	1.47	(1.20 - 1.74)	0.11	<.001
61	Sanitas Valley Trail	Annual	0.89	1.83	(1.40 - 2.27)	0.20	<.001
63	Sanitas Valley View	Annual	0.98	1.27	(1.15 - 1.40)	0.06	<.001
107	Sawhill Entrance West	Annual	0.96	1.38	(1.16 - 1.59)	0.09	<.001
54	Settlers Trailhead West	Annual	0.96	1.69	(1.48 - 1.89)	0.10	<.001
604	Shanahan UT	Interior	1.00	1.09	(1.03 - 1.14)	0.02	<.001
118	South Boulder Creek - Community Center	Annual	0.99	1.47	(1.33 - 1.61)	0.06	<.001
123	South Boulder Creek - Marshall	Annual	0.99	1.38	(1.27 - 1.50)	0.05	<.001
147	South Boulder Creek - Trail Broadway	Annual	0.98	1.19	(1.11 - 1.28)	0.04	<.001
704	South Boulder Peak	Interior	0.98	1.06	(0.98 - 1.14)	0.04	<.001
139	South Mesa Trailhead	Annual	0.97	1.64	(1.41 - 1.88)	0.10	<.001
194	Ute Trail	Annual	0.95	1.18	(0.96 - 1.39)	0.09	<.001
66	Wonderland Trail Poplar Ave	Annual	0.97	1.00	(0.88 - 1.11)	0.05	<.001
70	Wonderland Utica East	Annual	1.00	1.42	(1.36 - 1.49)	0.03	<.001

NOVEMBER 2018 REPORT CORRECTIONS

The version of the 2016-2017 Visitation Estimate Report (issued November 2018) includes revisions to the original estimates published in the first version of the report (August 2018). During additional data analysis, an error in the analysis syntax used for calculating weighted estimates for the secondary samples was discovered. This error resulted in some locations being misclassified into the incorrect visitation class. Correcting and rerunning the analysis syntax resulted in the following changes from the original report:

- Inclusion of one additional location that met the minimum threshold of 1,000 annual visits (Very Low volume class), bringing the total number of primary and secondary locations from 166 to 167.
- A change in the distribution of the number of locations within each volume class.
- An overall system-wide increase of around 10,000 annual estimated visits, brining the grand total from 6.25 to 6.26 million annual visits.
- Minor changes to seasonal, monthly, daily and hourly total visits.

Overall, the changes to total estimated visits was relatively minor (around 1/10th of one percent). The overall distribution of seasonal, monthly, daily, and hourly use patterns remain virtually identical to previously published figures. Finally, since this error only affected secondary locations, which are used to extrapolate system-wide visitation, the figures published for individual primary sample locations were not impacted.