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Trail Use Monitoring in Great Smoky Mountains National Park: Results from 1988, 1989, and 1990

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TRAIL USE MONITORING IN GREAT SMOKY MOUNTAINS NATIONAL PARK: RESULTS FROM 1988, 1989, AND 1990

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ABSTRACT

This report contains the results of three years of trail monitoring from 1988 to 1990. A major purpose of this study was to design a protocol for testing the feasibility of using various trail monitoring technologies under a variety of conditions on several different trails in Great Smoky Mountains National Park. These systems included electronic mat counters, electric-eye counters, and electric eye-triggered cameras.

Trails were selected based on estimated use levels, with both heavily used and lightly used trails being monitored. The trails selected during the three monitoring periods ranged from various short trails to the entire length of the Appalachian Trail through the park.

The reliability of the monitoring equipment proved to be good under most conditions. Average daily use was calculated for all trails and segments within each trail, as well as variances between months during the summer and fall seasons. The number of cars in trailhead parking lots was correlated with the number of hikers on various segments of the trails.

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STUDY PURPOSE

Introduction

The necessity of having up-to-date and accurate information on visitor use and distribution of a natural resource area is well known. Proper management of any resource must depend on an understanding and sensitivity to the resource itself and to the traits and behaviors of the users (Burde 1988). In the Great Smoky Mountains National Park (GRSM), information about overnight hikers has been collected since 1972 with data from the backcountry permit system and from studies on the use patterns by overnight hikers (Burde and Curran 1986; Burde and Renfro 1986). This data has been useful in assessing trends in backcountry use as well as providing information needed for determination of carrying capacity of individual sites. However, these studies have concentrated only on overnight hikers. Assessing trail use in general by all types of hikers (day and overnight) is an area which has received little systematic research in GRSM.

Purpose and goals

The primary purpose of this study was to design a protocol for assessing total hiker use on the trail system in GRSM. The goal of the first two summers (1988 and 1989) was to assess the feasibility and accuracy of various trail monitoring technologies to monitor the amount and type of trail use. The focus of the 1990 season was to apply the methodology devised in the previous two years to the Appalachian Trail (AT) segment that bisects GRSM.

Applications to management

A number of questions regarding the use of trails by persons other than those backpacking have direct bearing on management issues. Trail maintenance should take into account the amount of traffic each trail segment receives. Better estimates of the total amount of trail use, by segment, will allow trail maintainers to establish more reasonable maintenance schedules and priorities. Developing an understanding of trail use could also be helpful in properly allocating interpretive and management resources.

METHODS AND MATERIALS

Overview

Review of published accounts of various monitoring projects led to the selection of three different but compatible systems (Deland 1976; James and Schreder 1972; Leonard, et al. 1980). A remote sensing electric-eye counter was selected to work in conjunction with a camera system. The electric eye with the camera was used in the 1988 study, and the electric eye alone was used in 1989. Buried pressure-sensitive mat counters were chosen as the primary means to assess trail use on most trails. A bridge extension counter,
modeled after a counter used in the national parks in New Zealand, was constructed for use on one trail in the 1989 study. In monitoring the Appalachian Trail, only pressure-sensitive mat counters were utilized.

Direct observation by the researchers involved with the project was made to corroborate the functioning of the various types of counters for reliability. A reading was made from the counter, hikers were observed crossing the mat or electric eye and the number observed recorded, and then a second reading was taken from the counter in order to check the reliability of the equipment.

Trail segment selection

The selection of trail segments to be monitored was based on a number of factors. The first consideration was the expected amount of use by all types of hikers. The goal was to select trail segments that reflected a range of popularity from very popular to almost unknown. This would provide a test of the equipment under widely different traffic loads. A description of the trail segments selected for study follows. Detailed descriptions of each mat location for all three years are available from the authors on request.

In 1988 Alum Cave Bluff Trail, the Chimneys, Laurel Falls, and the Appalachian Trail (AT) segment from Newfound Gap to Charlies Bunion were selected for assessing use on heavily utilized trails. Albrights Grove, Cove Mountain and Sweat Heifer trails were selected as trails likely to be lightly used. Expected to represent a medium use pattern was the Ramsey Cascade Trail in the Greenbrier area.

In 1989 the Alum Cave Bluff trail and Boulevard trail were monitored again as part of monitoring the entire Mount Leconte trail system. In addition to these two trails, the system included Rainbow Falls trail, Bullhead trail, Trillium Gap trail, and the LeConte side of Brushy Mountain trail. To continue assessing use of the Greenbrier area of the park, Porters Creek trail, the Grapeyard trail, Old Settlers trail, and the Greenbrier side of Brushy Mountain trail were monitored. Use on another segment of the Appalachian Trail was assessed in 1989, that being the segment between Newfound Gap and Clingmans Dome. The trail to Andrews Bald was also monitored as it was thought to be a popular day hike from

Clingmans Dome. Indian Gap trail from the Newfound Gap road down to Chimneys was observed to assess the number of hikers going the "back way" to Chimneys. The newly built Oconoluftee River trail was monitored in June and July of 1989. The final trail monitored that year was the Lakeshore trail from Hazel Creek to Lakeview Road.

The 70-mile segment of the AT that lies within the GRSM was selected for study in 1990. Included as part of this effort were some of the trails that connect with the AT and provide access to it. For example, four trails in the Cosby and Big Creek sections that provide access to the AT were monitored. Some sites had already been installed during the previous study (1989) and were still in service. Counters at each of the endpoints of the AT in the park (Big Creek and Fontana) were installed. Subsequent locations reflected junctions of various trails that could be used for access to the AT or were landmark points along the AT frequently used by both backpackers and dayhikers such as Charlies Bunion, Silers Bald, and Spence Field. A total of 22 locations were selected.

Data collection

Data collection was accomplished by the Uplands Field Research Laboratory personnel assigned to the social science projects with the aid of volunteers working in the park, undergraduate psychology students from the University of Tennessee at Knoxville, and the "ridge runner," an employee of the Smoky Mountain Hiking Club whose primary duty was to patrol the GRSM segment of the AT throughout the summer of 1990. The assistance provided by these persons was most valuable in assuring adequate monitoring of the instruments and the timely collection of the data.

To facilitate data collection by a large team of individuals, the counter locations were carefully recorded on quadrant maps, and detailed descriptions of the physical characteristics of the locations were prepared. Of the two ways of pinpointing mat locations, the verbal descriptions seemed to work better. One could easily find the vicinity of a station from a detailed topographical map but still be totally unable to find the counter without very specific guidelines.

Sampling procedures

The sampling design of this study was constrained by the available personnel and the length of the season under study. Within those limitations the following considerations dictated the sampling design used during the first two seasons: (1) testing for differences in the average daily use of a trail by month over the summer, (2) testing of variance between segments within the same trail, and (3) testing for variance in average daily use of a trail by season. (In 1990, data collection was simplified, variance having been shown to be slight during the first two seasons.)

The first objective was accomplished by collecting as many counts as possible for all trail segments within a month. The second objective was met by the placement of trail counters at appropriate locations on all the trails. The third objective was attempted by monitoring trail use on selected trails year round. Data was gathered for comparison between summer (June, July, and August) and fall (September and October). Winter data collection was not feasible because as the ground freezes the mat counters cease to function.

The collection of data following this sampling design tested the main objective of the study; that is, how to best calibrate a trail as to the amount of use it receives. Data was collected using several types of trail monitoring equipment which are described in the next section.

DESCRIPTION OF EQUIPMENT

Electronic mat counters

Electronic mat counters used in this study were manufactured by Tapeswitch Corporation of America. Each vinyl electronic mat switch measured 17 by 23 in. The mats were sandwiched between two 24 by 24 inch pieces of 1/4-inch masonite and/or 1/2 inch plywood, sealed with duct tape, wrapped in heavy-duty plastic, and placed in a burlap bag before being buried in the trail. The masonite was required to protect the mats from sharp rocks and to distribute a hiker's weight evenly over it. The plastic was for waterproofing and the burlap provided a rough surface for the soil to cling to.

Each mat was connected to a small digital counter, manufactured by Redington counters (Model 7600-630), which has a built-in lithium battery. In order to waterproof the counters, each was sealed in a heavy clear plastic bag so that the numbers were visible through the plastic, sealed with duct tape, and buried in the ground next to the trail. When a hiker stepped on the buried mat, the switch was closed; when the hiker's foot was lifted from the mat, the switch was opened and the counter advanced one count. A detailed description of installation of mat counters is presented in Appendix A.

Electric eye counters

The electric eye counters used in this study were purchased from the Diamond Traffic Products division of Diamond Scale Construction, Oak Ridge, Oregon. According to the manufacturer's literature, it is "a portable, battery powered, instrument for counting traffic on forest trails. It was designed and developed at the Missoula Equipment Development Center,. USDA Forest Service, Missoula, Montana, and was manufactured according to the U.S. Department of Agriculture, Forest Service Interim Specification 7100-0050 and MEDC Drawing No. 456..."

The unit is designed to be bolted to the side of a tree, with a small reflector mounted on the opposite side of the trail being sampled. When a hiker passes through the electric eye beam, one count is recorded. The battery pack consisted of two 12-volt and one 6-volt lantern batteries stored in a plastic battery container originally designed for a car or boat battery. The battery box was encased in plastic and buried.

Electric eye in conjunction with a camera

In certain situations the electric eye unit was used to provide a relay signal to a camera in order to photograph the hikers as they were being counted. Use of the camera allowed for the collection of additional data about hikers using a particular trail, such as sex, approximate age, and type of equipment carried. Care was taken that the camera unit was placed only in public areas (close to trailheads) so that privacy would not be invaded. Additionally, the camera was back quite a distance from the trail and the pictures were deliberately blurred so that individual people could not be identified from the films. All films were destroyed after analysis.

The camera system consisted of the counter unit as described, along with a Minolta Super-8 movie camera mounted in a watertight enclosure that was bolted to the same tree used to mount the counter. The enclosure contained an electronic timer and relay switch. The switch triggered the camera to expose one frame each time the counter registered a count. The timer was used to mark 12-hour periods. Kodak Ektachrome 160 color film was used, providing approximately 3500 exposures per roll. The cameras and enclosures used in the study were purchased from Diamond Scale Construction, suppliers of the counter units. Films were viewed using a Elmo K-110SM Dual-8 projector.

Bridge counter

The bridge counter was constructed by the researchers based on plans of a similar type counter used in New Zealand to monitor trail traffic. The counter was located at the end of the second bridge on the Alum Cave trail. It was built from pine 2 by 4s to appear to be a continuation of the bridge. The counter was constructed with a movable, spring-loaded center section, which when stepped on activated a switch and counter. The same type of counter used with the mat switches was found to be the most reliable type of counter. Mechanical counters were first attempted, as was described in the New Zealand plans, but failed to work well here. The plans used in constructing the counter are shown in Appendix B.

Parking lot monitoring

Park management requested a method be developed to get an idea about how many people were on a given trail and how far back into the backcountry they were on that trail when a given parking lot was full or when there were a certain number of cars in that parking lot. In order to assess this, several methodologies of monitoring parking lots were tried. The simplest and most feasible method was to take an hourly count of the entire parking lot and overflow areas and calculate the number of people using the trail from that count using standard group size found in previous studies (Burde and Curran 1985; Peine and Renfro 1986). The specific analytical methods used for calculating the number of people on the trail based on the number of cars in a lot at any given time are described in the results section.

RESULTS

Reliability of mat counters

The placement and installation of the mats was critical in obtaining accurate counts. Critical variables affecting reliability included the width of the trail, the soil composition, the amount of drainage, and the slope of the location on the trail. Percent of agreement for mats on heavily and moderately used trails was calculated by dividing the number of counts on a mat by the number of people observed crossing the mat. The observation periods varied depending on how heavily used the trail was but averaged approximately one hour. The percentages of agreement are given in Table 1.

Further analysis was done on the reliability checks made on the Alum Cave trail in 1989 (refer to column 2 in Table 1). Eight to ten reliability observations were made at each counter location on this trail (with the exception of the top of Mount LeConte). Analysis of variance and Bonferroni post hoc tests revealed that the only statistically significant differences between reliabilities of the counters were between the Alum Cave trailhead mat and the two mats before and after the Bluffs ($F = 3.97$, $p. = .005$). However, even though statistically nonsignificant, counts made by both the electric eye and the bridge counter appeared significantly higher than the mat counter at the trailhead.

The mat counter consistently counted less hikers than did the electric eye or the bridge counter, which were similar in their counts. When it rained the mat location tended to get wet and people had a

Table 1. Percent of agreement between personal observation of hikers and counts for mat and electric eye counters - 1988 and 1989.

Location	Percent of Agreement*	N
1988		
Alum Cave Trail		
Alum Cave TH	.88	2
Alum Cave TH EE	.80	3
Arch Rock	.96	6
Before Bluffs	.90	4
After Bluffs	.91	3
Appalachian Trail		
Newfound Gap East	.78	1
AT EE	.90	3
Boulevard	.92	2
Jumpoff	1.00	1
Icewater Springs	.96	2
Charlies Bunion	.98	3
Chimneys		
Chimneys EE	.76	3
Chimneys TH	.89	3
Chimney Tops	.94	1
Albrights Grove		
Maddron Bald	.80	2
Albrights Grove	.36	2
Laurel Falls/Cove Mtn		
Laurel Falls EE	.57	3
Cove Mtn	.76	2
Greenbrier		
Ramsey Cascades TH	.61	3
Ramsey Trail	.87	5
Ramsey Cascades	.80	3

Location	Percent of Agreement	N
1989		
Alum Cave Trail		
Alum Cave TH	.69	10
Alum Cave TH EE	.96	6
Alum Cave Bridge	.98	9
Arch Rock	.85	8
Before Bluffs	.96	9
After Bluffs	.93	8
Appalachian Trail		
Newfound Gap East	.87	4
AT - Silers Bald	.92	3
Andrews Bald	.83	3
Greenbrier		
Old Settlers	1.00	3
Grapeyard	1.00	3
Roaring Fork		
Rainbow Falls TH	.96	3
Trillium Gap EE	.67	3

N = number of times observations were made; EE = electric eye locations (all other locations used mat counters; Bridge = "New Zealand style" bridge counter

*Percentages were calculated using by dividing the number of hikers counted by personal observation by the number of hikers detected by the mat and electric eye counters and multiplying by 100.

tendency to jump over it. Many children were missed by the mat counter because they chose to walk on the rocks beside the mat rather than in the trail. Additionally, some people walked side by side so that only one was counted. At the Alum Cave trailhead the electric eye and the bridge counter were found to be superior.

Arch Rock was a problem location all season in 1989, and the counts and reliabilities need to be interpreted with caution. The counts were consistently lower at Arch Rock than at the counter just before the Bluffs, which was not logically possible. Arch Rock tended to become muddy after heavy rain (which was frequent in 1989) and hikers would then tend to go around it. The reliability was not abnormally low because generally when reliability checks were made it was not raining.

The ideal condition for obtaining accurate counts was when the mat was buried on a slight grade in well-drained, loose, sandy, slightly rocky soil. Mats in the higher elevations tended to have higher reliabilities than in low elevations, probably due to humidity factors. Heavy rains in June and July of 1989 had deleterious effects on the counters attached to the mats. Several of them had to be replaced, resulting in the loss of data for many days.

Reliability of electric-eye counters

The main factor that effected the reliability of the electric-eye counters was the width of the trail. When a trail was wide, people tended to walk side by side through the electric eye beam, which counted then as only one person. Occasionally leaves blew through the beam which caused the counter to advance.

Assessment of hiker traffic on trail segments

In order to assess the amount of hiker traffic on the trail segments, an average traffic count per day for each mat counter and electric eye counter was calculated by dividing the number of hikers counted by the number of days between counter readings during a given period of time. The term "traffic" is used instead of "hikers" to reflect the fact that it was not possible using mat counters or electric eye counters without a camera to determine the percentage of hikers who were double-counted as they went up and then back down the trail. On most of the trails monitored it can be assumed that many hikers were double-counted. This is a limitation of using this type of equipment but the data still gave a good indication about how much traffic a trail received. Whether it is a single hiker counted twice or two separate hikers, the impact on the trail was the same.

Where percentages of agreement were either very low or reflected a large overcount, the averages were corrected by multiplying the average daily traffic by the reliability of the mat, yielding a more accurate figure for average number of hikers. For mats which had acceptable reliabilities (80 percent or better), the averages were not corrected. The overall average traffic per day for each trail and each mat or electric eye counter is illustrated in Tables 2 through 4. These figures give the overall amount of traffic per day at each counter location during the summer months. Further analysis examined differences in traffic between months and is presented in subsequent tables. Weekend versus weekday traffic data was not collected.

A series of graphs has been created for ease in comparing the use of various trails over the study period (Appendix C). For example, a graph

Table 2. Overall daily use patterns for selected trails - summer 1988

Location	Sample period	Hiker traffic per day
Alum Cave		
Trailhead EE	44 days	518.2
Trailhead mat	60 days	374.6
Arch Rock	60 days	277.8
Alum Cave	47 days	249.5
Mt. LeConte	48 days	141.8
Appalachian Trail to Charlies Bunion		
Newfound Gap East	61 days	552.4
.5 mi from TH	33 days	215.5
Icewater	53 days	90.3
Charlies Bunion	53 days	75.6
Sweat Heifer	31 days	7.8
Boulevard	59 days	58.5
Jumpoff	8 days	30.7
Chimneys		
Trailhead EE	46 days	706.5
.25 mi from TH	69 days	371.2
Chimney Tops	69 days	255.3
Ramsey Cascades		
Trailhead	39 days	179.2
1.5 mi from TH	59 days	97.6
Cascades	59 days	83.0
Albrights Grove		
Maddron Bald TH	82 days	15.8*
Start of Grove	82 days	13.3*
Laurel Falls/ Cove Mountain		
Trailhead	34 days	1486.7
.6 mi past Falls	46 days	32.1

EE = electric eyes (all other locations used mat counters); TH = trailhead

*Reflects one-way traffic as this trail is a loop trail.

Table 3. Overall daily use patterns for Mount LeConte trail system - summer 1989

Location	Sample period	Hiker traffic per day*
Boulevard Trail		
Newfound Gap East	74 days	576.7
Boulevard	78 days	35.4
Myrtle Point	68 days	28.9
Trillium Gap Trail		
Trailhead	67 days	1383.5
Past Grotto Falls	63 days	49.6
Top of LeConte	69 days	35.7
Rainbow Falls Trail		
Trailhead	79 days	265.8
Top of LeConte	76 days	26.8
Bullhead Trail**		
Trailhead	72 days	10.5
Top of LeConte	76 days	12.7
Alum Cave Trail		
Trailhead	80 days	383.2
Trailhead EE	38 days	518.5
Trailhead Bridge	56 days	501.9
Arch Rock***	63 days	311.8
Before Bluff	72 days	344.1
After Bluff	72 days	140.2
Top of LeConte	69 days	109.4

EE = electric-eye counter; Bridge = "New Zealand bridge counter"

* Seemingly extreme trailhead figures between Trillium Gap trailhead and all other Mount LeConte trailheads are accurate, due to Grotto Falls being located on the Trillium Gap trail.

** Top of LeConte count higher than trailhead because of hikers "wandering" around top.

***Discrepancy between Arch Rock and Before Bluff averages due to frequent failure of the Arch Rock counter.

Table 4. Overall daily use patterns on selected trails - summer 1989

Location	Sample period	Hiker traffic per day
Lakeshore Trail		
Hazel Creek	45 days	3.4
Campsite 76	92 days	1.3
Tunnel trail	70 days	14.5
Lakeshore TH	70 days	6.5
Appalachian Trail Newfound Gap to Clingmans Dome		
Newfound Gap East	74 days	576.7
Newfound Gap West	70 days	50.2
Indian Gap AT	33 days	5.4
Indian Gap Chimneys	31 days	16.7
Mount Collins	64 days	5.6
To Silers Bald	64 days	64.1
Andrews Bald	85 days	60.3
Greenbrier		
Old Settlers	36 days	5.7
Grapeyard	36 days	2.4
Brushy Mountain	29 days	2.7
Porters Creek	29 days	9.2
Oconaluftee River Trail		
Trailhead	29 days	40.7

TH = trailhead; AT = Appalachian Trail

depicts use along the Appalachian Trail from one end to the other, which allows for quick comparison of use at various locations along its length. The graphs can also be used to compare use of trails of similar nature or in close proximity.

Specific counter results from 1988

In order to determine whether the number of hikers that used a given trail differed between months and between the summer and fall seasons, the average traffic per day for each month of data collection was calculated and is presented in Table 5. This data reveals that there were no extreme differences in number of hikers between the summer months. However, there were large differences in the number of people who used the trails in September versus October.

The October counts more closely reflect the use levels found in the summer. On some trails, particularly those with good views, the number of hikers in October surpassed the summer averages. Of particular interest was the AT to Charlies Bunion, where large increases were noted at Icewater, Charlies Bunion, and the Jumpoff, all areas which offer spectacular views. Additionally, the Chimneys trail had a substantial increase in the number of hikers in October.

There was a discrepancy between the counts on the mat counter located on the Alum Cave trail at the trailhead and the electric eye counter located just a few yards past the mat. The average daily traffic counted by the electric eye was considerably higher, at 518.2, than the count on the trailhead mat, at 374.6. Because there were several days where heavy rains made the mat location muddy, the average number counted could have been lowered due to hikers avoiding the muddy spot.

Table 5. Average daily traffic by month for selected trails - 1988

Location	June	July	August	Sept	October
Alum Cave					
Trailhead EE	518.2	514.3	—	—	—
Trailhead	374.6	381.1	455.9	181.3	265.6
Arch Rock	—	277.8	318.2	136.4	288.5
Alum Cave	—	249.5	295.7	156.3	281.0
Mount LeConte	—	141.8	143.6	90.3	165.6
Appalachian Trail to Charlies Bunion					
Trailhead	552.4	554.8	583.8	230.4	489.2
.5 mi from TH	215.5	221.5	—	—	—
Icewater	—	90.3	99.0	66.5	135.3
Charlies Bunion	—	75.6	83.1	61.7	123.5
Sweat Heifer	—	7.8	—	—	—
Boulevard	—	58.5	46.7	36.0	72.6
Jumpoff	—	—	30.7	—	—
Chimneys					
Trailhead	—	706.5	692.9	345.0	832.8
.25 mi from TH	—	371.2	334.5	176.9	337.7
Chimney Tops (projected)*	—	255.3	264.3	123.3	232.2
Ramsey Cascades					
Trailhead	—	176.2	187.2	66.6	125.2
1.5 mi from TH	—	97.8	87.1	41.0	59.8
Cascades	—	84.4	85.0	34.3	46.4
Albright Grove					
Maddron Bald TH	—	—	15.8	13.5	19.4
Albright Grove	—	—	13.3	9.8	14.7
Laurel Falls/ Cove Mountain					
Trailhead	—	—	1486.7	920.2	1345.5
.6 miles past Laurel Falls	—	24.4	24.0	—	—

EE = electric-eye counter; TH = trailhead

*Numbers reflect projected figures based on percent of hikers who go to the top (68.8%) from the .25 mile point on the trail (summer percentage).

Specific counter results from 1989

As was done in 1988, average daily traffic at each counter location was calculated for each month. In examining the figures given in Table 6, it is obvious that while July and August counts were relatively stable, the counts for the month of June were for the most part either missing or considerably lower. Because of the abnormally high amount of rainfall in June, data was hard to collect and equipment had a high malfunction rate. When the weather improved in July, the counters worked much more reliably.

Consistent with 1988 results, the number of hikers fell in September and increased again in October on most trails. The one exception to this seems to be the Lakeshore trail counters at the Tunnel. Use was light but relatively constant for the summer months and then increased in both September and October. Some trails were not monitored into the fall, namely some of the Greenbrier trails and AT trails. Oconaluftee River trail was only monitored in June and July. Other locations had a high rate of malfunctioning equipment so fall data is missing.

Comparison of common trails 1988 and 1989

There were several counter locations that were monitored both in 1988 and 1989, primarily on the Alum Cave trail. Analysis of variance was used to test for significant differences at these locations between years. The results are depicted in Table 7. While there were significant differences between location and month, as would be expected, there were no statistically significant differences in the number of hikers at these locations between 1988 and 1989.

Table 6. Average daily traffic by month on selected trails - 1989.

Location	June	July	August	Sept	October
Boulevard Trail					
Newfound Gap East	448.4	608.3	673.6	297.4	547.7
Boulevard TH	—	35.5	35.2	31.4	—
Myrtle Point	—	30.0	27.8	25.8	—
Trillium Gap Trail					
Trailhead	—	1259.6	718.3	—	—
Grotto Falls	—	49.0	50.2	24.5	45.9
Top of LeConte	—	23.9	47.5	—	—
Rainbow Falls Trail					
Trailhead	213.3	246.0	338.0	159.4	262.0
Top of LeConte	—	25.1	28.4	—	—
Bullhead Trail					
Trailhead	—	8.0	13.0	10.2	—
Top of LeConte	—	10.6	14.8	—	—
Alum Cave Trail					
Trailhead	263.6	407.7	358.6	171.7	324.0
Trailhead EE	—	552.3	485.6	241.4	—
Trailhead Bridge	—	593.7	410.1	237.4	647.1
Arch Rock *	—	284.8	264.0	—	—
Before Bluff	—	303.4	384.8	—	—
After Bluff	—	137.9	142.4	116.7	237.6
Top of LeConte	—	121.6	97.1	—	—
Lakeshore Trail					
Hazel Creek	3.4	—	—	—	—
Campsite 76	1.1	1.6	1.3	—	—
Tunnel trail	13.0	14.0	16.5	19.0	27.0
Lakeshore TH	5.5	6.4	7.6	5.5	11.1

Table 6. (cont.)

Location	June	July	August	Sept**	October**
Appalachian Trail Newfound Gap to Clingmans Dome					
Newfound Gap East	448.4	608.3	673.6	297.4	547.7
Newfound Gap West	29.5	61.0	60.0	21.9	44.7
Indian Gap Chimneys	—	—	16.7	7.7	—
Mount Collins	—	5.3	5.9	2.8	5.0
To Silers Bald	—	52.3	75.8	31.8	91.2
Andrews Bald	55.3	61.4	64.1	—	80.3
Greenbrier Trails					
Old Settlers	—	5.7	—	—	—
Grapeyard	—	2.4	—	—	—
Brushy Mountain	—	—	2.7	1.2	4.9
Porters Creek	—	—	1.2	6.0	14.9
Oconoluftee River Trail					
Trailhead	41.2	40.2	—	—	—

TH = trailhead; EE = electric-eye counter

* Low counts at Arch Rock due to frequent failure of this counter.

**Several September and October counts are missing because of equipment failure, vandalism, or removal.

Table 7. Average daily traffic on common trails - 1988 versus 1989.*

	June	July	August	September	October
Newfound Gap East					
1988	552.4	554.8	583.8	230.4	489.2
1989	448.4	608.3	673.6	297.4	547.7
Boulevard Trailhead					
1988	—	58.5	46.7	36.0	72.6
1989	—	35.5	35.2	31.4	—
Alum Cave Trailhead Mat					
1988	374.6	381.1	455.9	181.3	265.6
1989	263.6	407.7	358.6	171.7	324.0
Alum Cave Trailhead Electric Eye					
1988	518.2	514.3	—	—	—
1989	—	552.3	485.6	241.4	—
Arch Rock					
1988	—	277.8	318.2	136.4	288.5
1989	—	284.8	264.0	—	—
Before Alum Cave Bluffs					
1988	—	249.5	295.7	156.3	281.0
1989	—	303.4	384.8	—	—
After Alum Cave Bluffs					
1988	—	141.8	143.6	90.3	165.6
1989	—	137.9	142.4	116.7	237.6

*These differences were statistically significant by location ($F = 47.25$, $p. = .001$) and by month ($F = 11.16$, $p = .001$), which was expected. There were no statistically significant differences between 1988 and 1989 ($F = 1.48$, $p = .226$).

Andrews Bald - a special case trail

There was a single opportunity to determine the number of overnight hikers versus dayhikers on one trail in 1989. This was the Andrews Bald trail accessed from the Clingmans Dome parking lot. Andrews Bald is a popular short day hike, publicized in the short day hikes brochure available to visitors to GRSM, but is also used by backpackers hiking the Appalachian Trail. The closing of Clingmans Dome Road for adelgid spraying gave the opportunity to determine just how many people hiked to Andrews Bald as a day hike because when Clingmans Dome Road was closed, there was no access to the trailhead other than to overnight hikers. The results are presented in Table 8, and are quite are dramatic. The average number of hikers per day fell at both Silers Bald (on the AT) and at Andrews Bald, where the average dropped from 75.2 per day to 6.0 per day. From this data it is apparent that the Andrews Bald trail was used primarily by day hikers.

Specific counter results from 1990;

The Appalachian Trail

The protocol established through the previous seasons for use of the pressure-sensitive mat counters was put into effect at the beginning of the summer season and installation of the equipment was essentially complete within three weeks. Data collection for the entire trail segment began during the last week in June. Results are displayed in Table 9.

The use patterns on the AT were consistent with patterns one would find on a trail used by both dayhikers and backpackers. It can be assumed that those sections of the trail that were not accessible from a major road or were located several miles from a trailhead were utilized almost exclusively by the overnight-hikers. Sections of the trail accessed from

Table 8. Per day traffic with Clingmans Dome Road open and closed - July 1989

Location	Road open	Road closed
Indian Gap*	3.5	9.3
Mt. Collins	6.6	1.3
Silers Bald	58.8	32.5
Andrews Bald	75.2	6.0

*Access to this trail was open when the road was closed. The road was blocked at Collins Gap.

Table 9. Average hiker traffic per day on the AT; summer 1990

Location	Sample period	Hiker traffic
Big Creek	78 days	28.8
Davenport Gap	88 days	17.3
Chestnut Branch	66 days	22.3
Davenport Shelter	21 days	31.3
Low Gap	78 days	12.0
Inadu Knob	74 days	10.8
Richland Mt	82 days	9.3
Charlies Bunion	82 days	132.4
.5 miles before Newfound Gap*	33 days	215.5
Newfound Gap East	29 days	570.7
Newfound Gap West*	70 days	50.2
Indian Gap*	33 days	5.4
Collins Gap*	64 days	6.5
Clingmans Dome	85 days	69.2
Silers Bald	81 days	25.2
Sams Gap	48 days	11.9
Thunderhead	32 days	12.8
East Spence Field	73 days	19.6
West Spence Field	30 days	10.7
Mollies Ridge	30 days	17.4
Doe Knob	40 days	19.4
Birch Spring Gap	40 days	16.3
Fontana	68 days	14.1

* Data for these locations were collected in 1988 and 1989 but included complete the Appalachian Trail profile. Numbers given for all other locations are 1990 data.

a road or located a short distance from a trailhead were used by both dayhikers and backpackers and counts tended to be higher than the more remote areas.

The number of backpackers traversing the AT during summer months was reasonably constant at around 10 per day at any given location along the trail. One segment of the trail that did not fit this pattern was between Newfound Gap and Clingmans Dome where traffic was consistently very light, around 5 persons per day. Apparently this segment was avoided by all but the most ardent through-hikers. This trend appeared in 1989 and was confirmed by the 1990 data.

The most heavily used segments of the AT were those that served as access to both backpackers and dayhikers. These segments were from Newfound Gap to Charlies Bunion, from Clingmans Dome to Silers Bald and the segment that traverses Spence Field. Among these segments there was a large variation with the Charlies Bunion segment receiving more than twice as much use as any other.

Data was collected from some counters along the AT in the fall, primarily the month of October. Table 10 displays the fall results compared with the counts obtained in the summer months. As can be seen in examining this table, the amount of hiker traffic fell during the fall along the AT with the exception of Spence Field which was a popular dayhike destination as well as an overnight location. Because of the outstanding views from Spence Field of the fall foliage in Cades Cove, an increase in use during October is not surprising. However, the decrease in hikers at Charlies Bunion is surprising as it also offers spectacular views. No explanation can be made for the decrease in hikers to the Bunion in 1990 except for possible counter malfunction.

Table 10. Average hiker traffic per day on the Appalachian Trail - fall versus summer 1990.

Location	Summer	Fall
Big Creek	28.8	7.1
Davenport Gap	17.3	8.7
Chestnut Branch	22.3	11.7
Davenport Shelter	31.3	—
Low Gap	12.0	—
Inadu Knob	10.8	—
Richland Mt	9.3	5.7
Charlies Bunion	132.4	83.5
Newfound Gap East*	570.7	547.7
Newfound Gap West*	50.2	44.7
Collins Gap*	6.5	5.0
Clingmans Dome	69.2	—
Silers Bald	25.2	21.7
Sams Gap	11.9	—
Thunderhead	12.8	—
East Spence Field	19.6	24.6
West Spence Field	10.7	—
Mollies Ridge	17.4	—
Doe Knob	19.4	—
Birch Spring Gap	16.3	—
Fontana	14.1	12.0

*Data for these locations were collected in 1989 but are included here to complete the Appalachian Trail profile. Numbers given for all other locations are 1990 data. Fall data were unavailable for several locations due to equipment failure or removal prior to fall collection.

Camera in conjunction with electric-eye counter

In 1988 a super-8mm camera was used with the electric-eye counter near the trailhead for trail segments on the AT to Charlies Bunion, Alum Cave, and the Chimneys. Because of the tremendous number of individual photographs taken (over 17,000) on Alum Cave and Chimneys in a short period of time, every fifth frame was examined, rather than every frame. The number of adults, children, males, females, and type of equipment carried on every fifth frame was noted. To get an estimate of the actual number of people passing the camera, these figures were multiplied by five.

On the AT, traffic was light enough that it was possible to view every frame and record the information. When the camera unit was used on the AT, it was found that the average hiker traffic per day was 165.5 from the film taken by the camera and was 171.9 from the electric eye during the period of time that the camera was operating. These figures are for traffic counts, not for individual hikers.

The correspondence count between the electric eye and camera at the Chimneys was 619.8 average hikers per day by the electric eye and 575.0 by the camera (estimated). For Alum Cave, estimates were 590.8 hikers per day for the electric eye and 626.9 for the camera (estimated). Because these figures represent estimates based on sampling every fifth frame in the film for Chimneys and Alum Cave, the numbers will not agree completely.

The analysis of the photographs is presented in Table 11. When the film was examined, the number of adult males, adult females, male children, and female children was recorded. The number of backpacks and daypacks was also recorded. Note that there are several instances in

Table 11. Analysis of photographs from electric-eye triggered camera.

Appalachian Trail - 14 day period

Category	N	Percent	Average per day
Adult male	1048	41.6	74.9
Adult female	746	29.7	53.3
Adult undetermined	386	15.3	27.6
Child male	134	5.3	9.6
Child female	96	3.8	6.9
Child undetermined	105	4.8	7.5
Framepacks	125	5.8	--
Daypacks	452	20.7	--
No equipment	1603	73.5	--

***Alum Cave Trail - 7 day period**

Category	N	Percent	Average per day
Adult male	2065	41.2	295.0
Adult female	1870	37.3	267.1
Adult undetermined	75	1.5	10.7
Child male	610	12.2	87.1
Child female	370	7.4	52.9
Child undetermined	25	0.5	3.6
Framepacks	10	0.2	--
Daypacks	300	7.5	--
No equipment	3700	92.5	--

***Chimneys Trail - 4 day period**

Category	N	Percent	Average per day
Adult male	1045	45.4	261.3
Adult female	870	37.8	217.5
Adult undetermined	75	3.3	18.6
Child male	175	7.6	43.8
Child female	120	5.2	30.0
Child undetermined	15	0.7	3.8
Framepacks	0	0.0	--
Daypacks	65	3.3	--
No equipment	1925	96.7	--

*Numbers of hikers and percentages are estimates based on viewing every fifth frame and multiplying the numbers obtained by 5 for Alum Cave and Chimneys. No statistical analyses were performed.

which it was not possible to determine the sex of the hiker, especially on the AT, due to the photographs being slightly blurred to ensure individual hikers could not be identified and the distance the camera unit was placed from the trail.

The camera can be used to gather limited demographic information and reveal types of equipment carried on the trail, making it a useful technology. It is also useful for determining the direction of hiker traffic on a trail. A major disadvantage of using the camera is the time required to view the enormous numbers of photographs collected on a heavily used trail. It should be noted that the purpose of using the camera in this study was to determine the effectiveness of the unit for trail monitoring. It was not intended that valid data specifically about hikers on these trails be collected. The data presented only illustrates what type of information can be gathered using the camera and is not meant to give a valid representation of the types of hikers that used any given trail.

Parking lot calculations

At busy trailhead parking lots one can assume (based on summer observations both in 1988 and 1989) that the lots will be full to overflowing constantly during the hours of 10:00 a.m. to 4:00 p.m., with frequent turnover of vehicles at heavily used trailheads. Trail use, based on vehicles in the parking lot, can be assessed by taking a count of the vehicles both in the lot and parked alongside the road and multiplying that number by 3.3, which has been found to be the average number of visitors per vehicle at GRSM, both in the literature, (Burde and Curran 1985; Peine and Renfro 1986), and by personal observation in both years. Then percentages of that number can be calculated for given segments of the trail based on the results of the mat counts. When this is done, from the number of vehicles in the parking lot at a given time, one will have a good idea of how many people are on the trail and how far back they travel. An example of this method, using Alum Cave trail and Chimneys trail, is given in Table 12. **Note:** this is an example of the method that can be used; it is not actual data.

Personal observations of parking lots were made but it was not possible for a single researcher to collect enough data for the purpose of statistical analysis or computations of vehicle turnover rate due to the rapid flow of traffic at parking lots such as Alum Cave or Laurel Falls. Also, it was not possible to watch all hikers coming and going from their cars or determine the amount of time a car was in the lot, as the cars are not only parked in the designated spaces but along the roadside as well. If this type of data was to be collected, a team of volunteers would be needed which, for this segment of the study, were not available. However, the method proposed is a workable and valuable method for determining an estimate of the number of people who are on a trail at a given point in time.

DISCUSSION

One of the main objectives of this study was to assess the reliability of various types of trail monitoring equipment under a number of different trail conditions. The data collected from both 1988 and 1989 provide an initial analysis of the feasibility of using specific types of monitoring equipment on different types of trail conditions in GRSM. The experiences of 1990 confirm and expand this knowledge. This information

Table 12. Method for calculating number hikers based on parking lot counts*

Alum Cave Trail

Given the number of cars in parking lot = 49
Estimate average number of people on the trail: (49) (3.3) = 161.7
From previously determined percentages of hikers per location derive table:

Location	Percent at location	Estimated number of hikers
Trailhead	100.0	161.7
Arch Rock	55.5	89.7
Alum Cave	49.8	80.5
Beyond Alum Cave	28.3	45.7

Estimate number of hikers staying near trailhead: 161.7 - 89.7 = 72

Chimneys Trail

Given the number of cars in parking lot = 27
Estimate average number of people on the trail: (27) (3.3) = 89.1
From previously determined percentages of hikers per location derive table:

Location	Percent at location	Estimated number of hikers
Trailhead	100.0	89.1
.25 mi from TH	52.5	46.7
Chimney Tops	36.1	32.4

Estimate number of hikers staying near trailhead: 89.1 - 46.7 = 42.4

*This is an illustration of the method to be used in calculating the number of hikers on a trail at a given period of time based on the number of cars in a parking lot. The number of cars given in the example is the maximum number which can park in the lined spaces in the parking lot.

Use 3.3 for average number of persons per vehicle (Burde and Curran 1985; Peine and Renfro 1989).

can be used to develop the protocol for a long-term monitoring program of trail use in the park.

Mat counters

The mat counters have proven to be a reliable and inexpensive way to monitor traffic under most trail conditions. Trails which have a width too wide for a single mat counter can be monitored with mats placed side by side, as was done on the Chimneys trail. Mat counters can be used reliably with a wide variety of trail conditions and soil compositions. It was found that the most reliable results are obtained when mats are buried in slightly rocky soil which has a high sand or loam content and the trail has a slight slope. However, mats which were buried in soil that was predominantly clay had good reliability as long as they were buried under less than 2 inches of soil. As long as the location does not get overly soggy for long periods of time, mats will work in just about any type of soil. Mats should not be placed in areas where it is likely to become muddy, as hikers will tend to go around the mat. The critical variable is how much water stands on the trail during heavy rain. As was found in June of 1989, no counter worked during periods of endless rain.

It was also found that mats used on horse trails were just as reliable as those used on hiker-only trails. Horses tended to step on the mats with only one hoof and their weight had no deleterious effects on the mats when they were properly installed.

Electric-eye counters and camera system

Electric-eye counters were used primarily on trails either too wide or too rocky for mat counters to be used. Placement of the electric-eye counters is critical because of the tendency for people to walk side by side on wide trails. If the electric eye can be placed in a relatively narrow section of the trail where a natural barrier exists or can be placed at the end of a bridge, reliabilities are much improved. Electric-eye counters are reliable if placed accurately but are considerably more expensive than mat counters and require much more upkeep.

The use of a camera with an electric eye is useful only in limited circumstances. The only time it is recommended when it may be necessary to know what type of people are using a trail or in what direction they are travelling. The camera is expensive, extremely time consuming, and generally not necessary for assessing the use of a trail.

Bridge counter

The bridge extension counter, modeled after the New Zealand counter, was found to be a reliable and effective method for monitoring trail use. Its use is limited to trails that have appropriate foot bridges and must be used close to a trailhead because of the weight of the counter. However, there are numerous trails in GRSM which would lend themselves to the use of this type of counter. Advantages of the bridge-type counter in long-term monitoring are its permanence, reliability, and ease of maintenance. Its only disadvantage is that it tends to be detected by hikers more easily than mat counters since it has a movable section.

Monitoring period

For mat counters, electric-eye counters and bridge counters, it is possible to accurately assess the number of hikers that use a trail in the summer by installing the counter for a one-month period of time during any month of the summer season. As was found in both 1988 and 1989, monthly variation between June, July, and August is minimal except in the case of extreme weather situations. Any one-month period of time during the summer months should give a representative number of summer hikers for a given trail. However, the months of September and October must be monitored separately, as the variation in use for these two months is much greater than in the summer months. Spring and winter months were not monitored in this study and perhaps should be considered for monitoring in the future.

Parking lot counts

Counting cars in parking lots is useful after a trail has been calibrated using the trail monitoring equipment. Once the use of a trail is known, parking lot counts can be used to predict how many people are on a trail at any given time and their distribution on the trail. Parking lot counts are recommended as an adequate method for long-term monitoring of a trail which has already been calibrated but not as substitute for the use of trail monitoring equipment in the initial calibration of a trail. It is also recommended that a method for calibrating a parking lot for frequency of car turnover rate be developed.

While the parking lot counts are useful for moderately to heavily used trails, this method could not be used on lightly used trails such as Albrights Grove or some of the Greenbrier trails, as the parking lot would have to be checked more frequently than feasible just to catch a single car there. Additionally, some of the trails monitored, such as the Boulevard and Bullhead, have their trailheads at intersections with other trails. These types of trails could only be monitored with counters. The use of parking lots for access to creeks during summer months can also be a limiting factor in the utility of parking lot counts unless creek access counts are of interest.

RECOMMENDATIONS FOR FURTHER STUDY

The effort of the past three seasons has resulted in a growing body of baseline data for trail traffic on a number of trails and trail segments within GRSM. The data collected to date have been useful in illustrating the various levels of use on these trails. The question of whether to extend these studies in the form of long-term monitoring must balance the utility of such monitoring versus the costs involved.

Equipment costs

The expense involved in doing this kind of trail monitoring was not great. Equipment costs ran about $1,500 per year. The equipment used in the great majority of instances over the last three years was the combination of a buried pressure-sensitive mat connected to a self-contained counter. The total cost per station is approximately $65 at 1990 prices.

There were incidental costs for consumable items such as duct tape, plastic, particle board, plywood, and burlap sacks needed to protect the equipment and to help bind the soil to the buried mats. These costs were low enough as to be essentially incidental.

Replacement of the battery-powered counters (at about $35 each) constituted the largest outlay for equipment. These units worked reliably enough but were susceptible to excessive soil moisture. The best efforts at waterproofing were often defeated by long rainy spells. To be safe, a project should allow two counters per station over the course of a summer season.

Personnel costs

The greatest cost in undertaking further trail monitoring will be in terms of the person-hours needed to install, monitor, and retrieve the equipment. Subsequent costs in processing the data collected would depend on the level of analysis desired.

The installation of mat counters is not overly difficult as long as certain factors are carefully controlled. The equipment does weigh enough that carrying more than two complete stations for any distance becomes quite a chore. In order to speed installation of a large number of mats, a cooperative effort by three or more persons is helpful.

Monitoring the equipment through the season involves collection of data and repair as needed. These are non-technical chores that are challenging primarily in finding the buried equipment. It can be difficult to spot a location that was installed by someone other than oneself. The hiking and driving time to and from the sites is the greatest expense of person-hours in this activity.

Retrieving the equipment is, naturally, similar to installation with the exception that packing out the equipment is less strenuous due to leaving behind the biodegradable burlap and particle board. Leaving these elements buried at the site helps prevent the creation of a depression in the trail and eliminates packing out the usually rotted materials. In rainy weather the burlap seldom lasted more than a couple of months. The fiber board did not degrade that quickly, but it did deteriorate in a few months.

Summarizing, a monitoring project involving no more than 25 sites can easily be handled by a single individual who has access to help from two or three others for perhaps two weeks at both the beginning and ending of the project. No specialized knowledge is required of that person nor are there any physical demands that one capable of hiking 8 to 10 miles a day could not manage. The analysis of data requires some knowledge of statistics and computer techniques but this analysis of data need not be the responsibility of the same individual who installs the equipment and collects the data.

Whether or not a trail assessment could be run by a volunteer would depend entirely on the competence of the individual. It is doubtful, however, that a volunteer would be available for the length of time required to adequately sample an entire summer and fall. It would probably be necessary to have a National Park Service employee oversee the project. The task would required very little time, however, for someone who could take advantage of volunteers to do the "legwork".

At the levels of study referred to above, the costs of continuing a long-term trail monitoring scheme are not great. Equipment costs could be covered by a budget of about $1000 per data collection season unless the more expensive electric eyes and cameras were used. Labor expenditures of 40 hours per week for 12 to 20 weeks for one person, with the addition of one or two others for about two weeks at the beginning and end of the term of study, would be sufficient to manage the project. The actual dollar expenses incurred for labor would, of course, be dependent upon the level of payment to those individuals. Volunteers working under minimal direction of a National Park Service supervisor should be adequate for the task.

Potential protocols for long-term monitoring in GRSM

With the data from three seasons already collected, it seems appropriate to recommend extension of this effort over time and in new locations. Most of the trails serving the Tennessee side of the park along Highways 441 and 73 have been studied, along with the entire length of the AT within the park. It would be entirely possible, at the level of intensity referred to above, to complete base-line data collection for the entire park within three to four years. To ensure the most effective use of personnel, contiguous areas should be targeted, cutting down on driving and hiking time.

The best situation from a scientific standpoint would be to continue at an intense level of study until a systematic park-wide effort is complete. At that point, assessment of changes in hiker behavior could be examined. Follow-up studies could be conducted more easily and could take advantage of selective sampling of both trails and trail segments, allowing for much greater geographic coverage than is appropriate in gathering baseline data. In such a situation, mat counters at trailheads would collect sufficient data to evaluate potential changes in traffic patterns. Such evaluations could be attempted at intervals of 2, 5, or 10 years, or whatever time seemed sufficient to provide the information desired.

At a minimal level, some sense of hiker traffic on the trail segments already studied could be achieved through monitoring the use of parking lots at trailheads. Such a procedure could be translated into approximations of how many people are using those trails and where the heaviest concentrations of persons along those trails might be found. A parking lot census taken during any period of good weather in the summer season (with the possible exception of the days during the 4th of July holiday) should yield reasonably accurate approximations of hiker traffic. Sampling would need to cover the hours of 10:00 a.m. through 4:00 p.m. to provide confidence that the majority of hikers have been accounted for.

Conclusion

It is hoped the case has been made that continuation of the trail study is an effort that will efficiently yield valuable information. We face an era of rapid change that will see the environment altered, budgets shrink, and visitor populations grow. Knowing where park visitors are going and what they are doing will be increasingly important to effective management of both the natural and human resources of the park. Having objective data upon which to make decisions regarding allocations of increasingly scarce resources will ensure that those decisions will be easier to make and will reflect the true needs of the system.

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APPENDIX A:

MAT COUNTER INSTALLATION INSTRUCTIONS

MAT COUNTER INSTALLATION INSTRUCTIONS

1. The general construction of a mat counter is sandwich-like. The mat is set between a layer of 1/2-inch plywood (bottom), and 1/8-inch masonite (top). The edges of this sandwich are then sealed with duct tape. It is important to be sure that when the duct tape is applied it does not pinch the mat into a permanent "on" condition.

   This unit is then wrapped in heavy duty plastic and all seams taped with duct tape. The plastic serves as some protection against the elements. The whole thing then goes into a burlap sack (an old coffee or potato sack may be used). The burlap sack helps to hold the soil in place around the mat unit, and to hold the mat unit securely in place in the soil.

2. If the plywood is bowed it should be placed bow up in the sandwich construction. This will assure that the mat is supported from below, therefore allowing it to count, rather than just flex, when stepped on.

3. Mats should be placed about 2 to 3 inches deep in the trail. This is a good compromise between the necessity of soil coverage and the danger of too much weight being placed on the mat, rendering it inoperable.

4. The hole for the mat should be well cut so that the unit sits on flat surface and is not just hanging in the hole by its sides. This will ensure that the mat will not just flex when stepped on. It is best to make the hole just a bit bigger than the unit, and be sure the bottom corners are squared to avoid this hanging effect.

5. Disturb the trail as little as possible during installation, smoothing it over by hand when you are finished to make the location least visible. Leaf litter or loose gravel sprinkled over the location helps to hide the impact you have made.

6. Choose a narrow spot in the trail where people will not be walking side by side or walking around the mat.

7. Do not place the mat near a convenient rest stop. This will cause extra counts of resting traffic from those who may be lunching on a comfortable rock or log or viewing scenery.

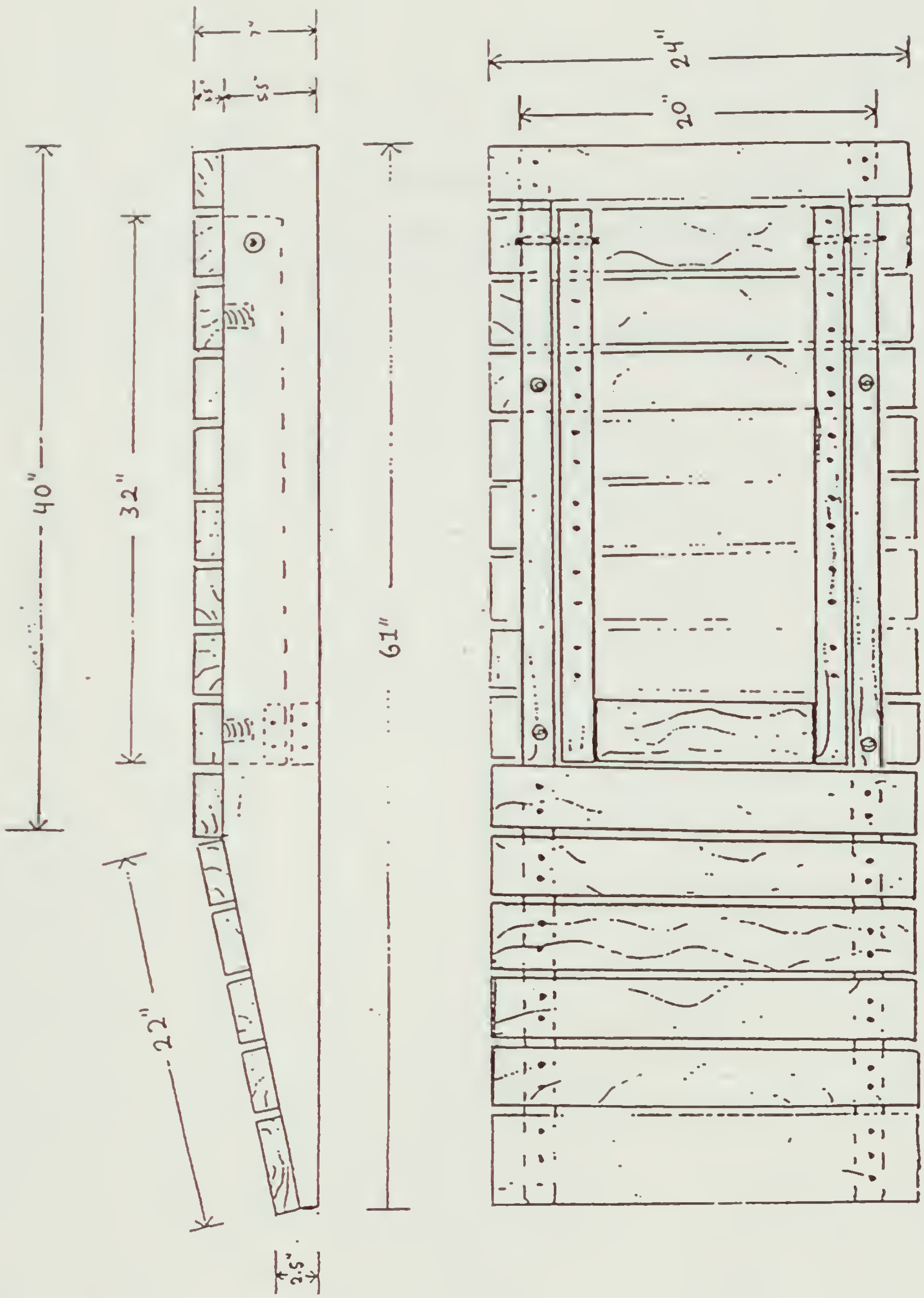
8. Choose a soil with good drainage. People will not usually walk through a puddle. A slight slope in the trail is also helpful, since water that does not run off may remain in the soil, making it heavier and therefore increasing the likelihood of weighting the mat to a permanent "on" position.

9. Wrap the counter in a waterproof container (a ziploc bag well covered with duct tape is a simple, inexpensive container).

10. The counter should be placed high and dry (up and off the trail). Placing the counter up off the trail insures that it won't be stepped on and that water running down the trail will not threaten the integrity of the counter's operation.

APPENDIX B:

PLANS FOR CONSTRUCTION OF BRIDGE COUNTERS



40"
32"
22"
61"
24"
20"
7"
5.5"
3.5"

APPENDIX C:

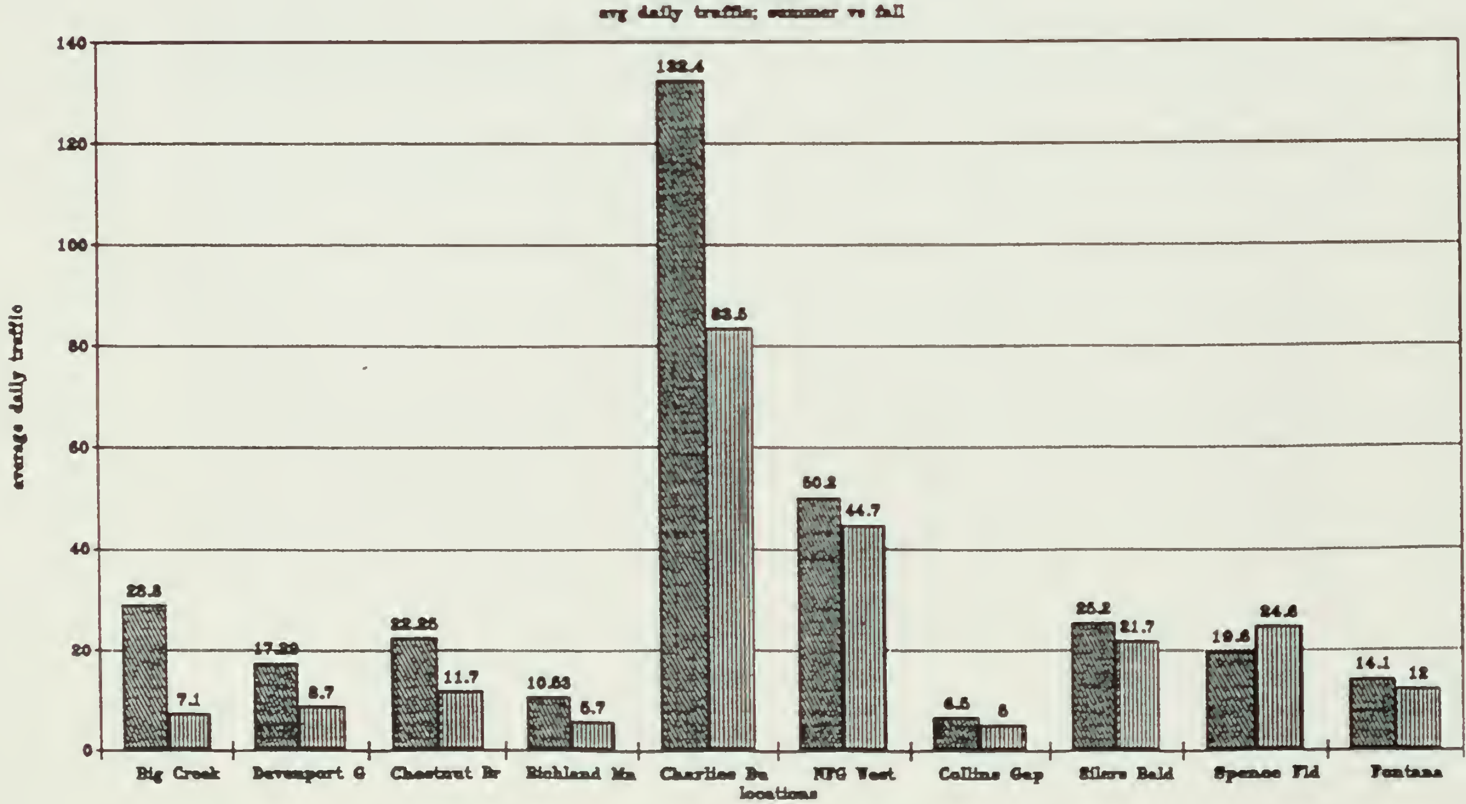
GRAPHS OF HIKER TRAFFIC ON SELECTED TRAILS

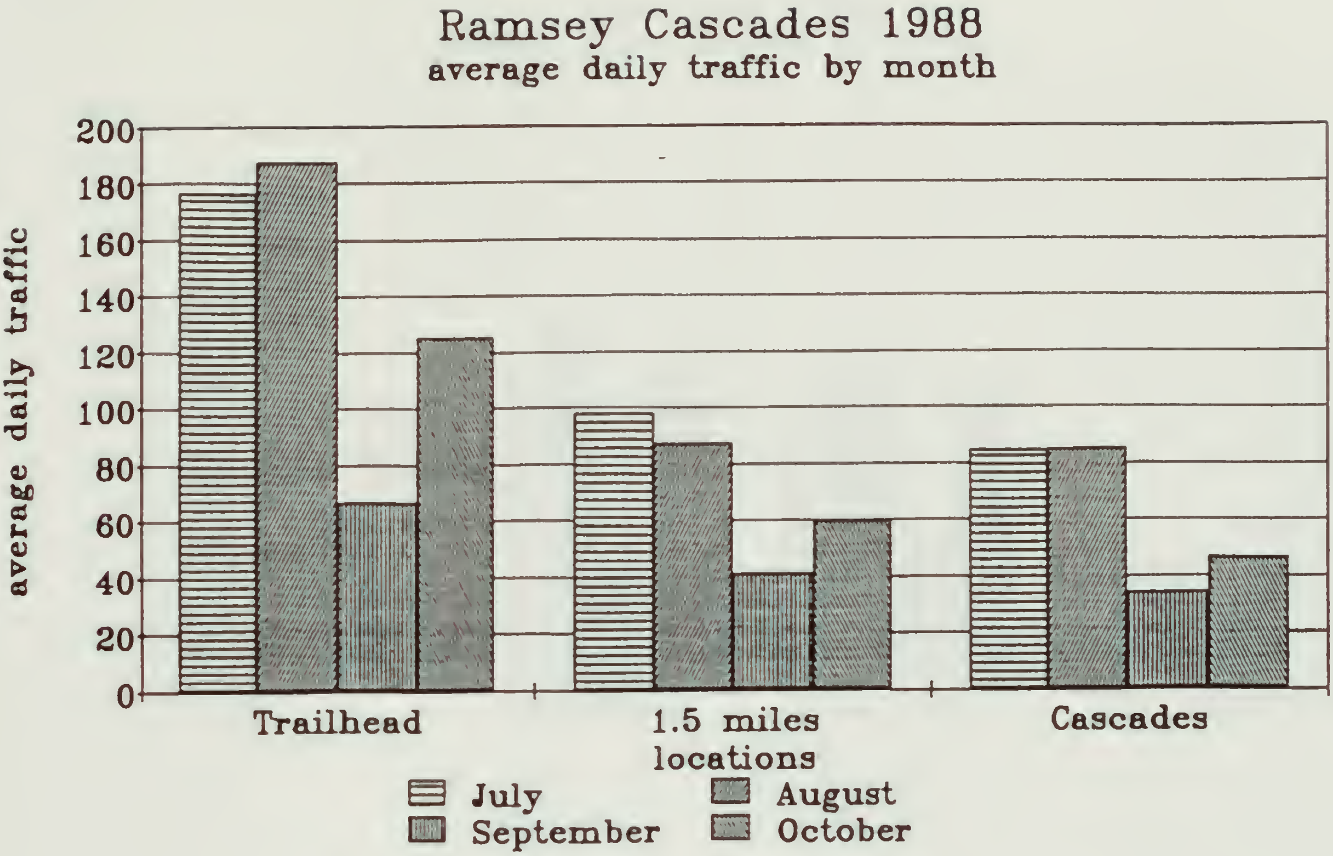
AT to Charlies Bunion 1988

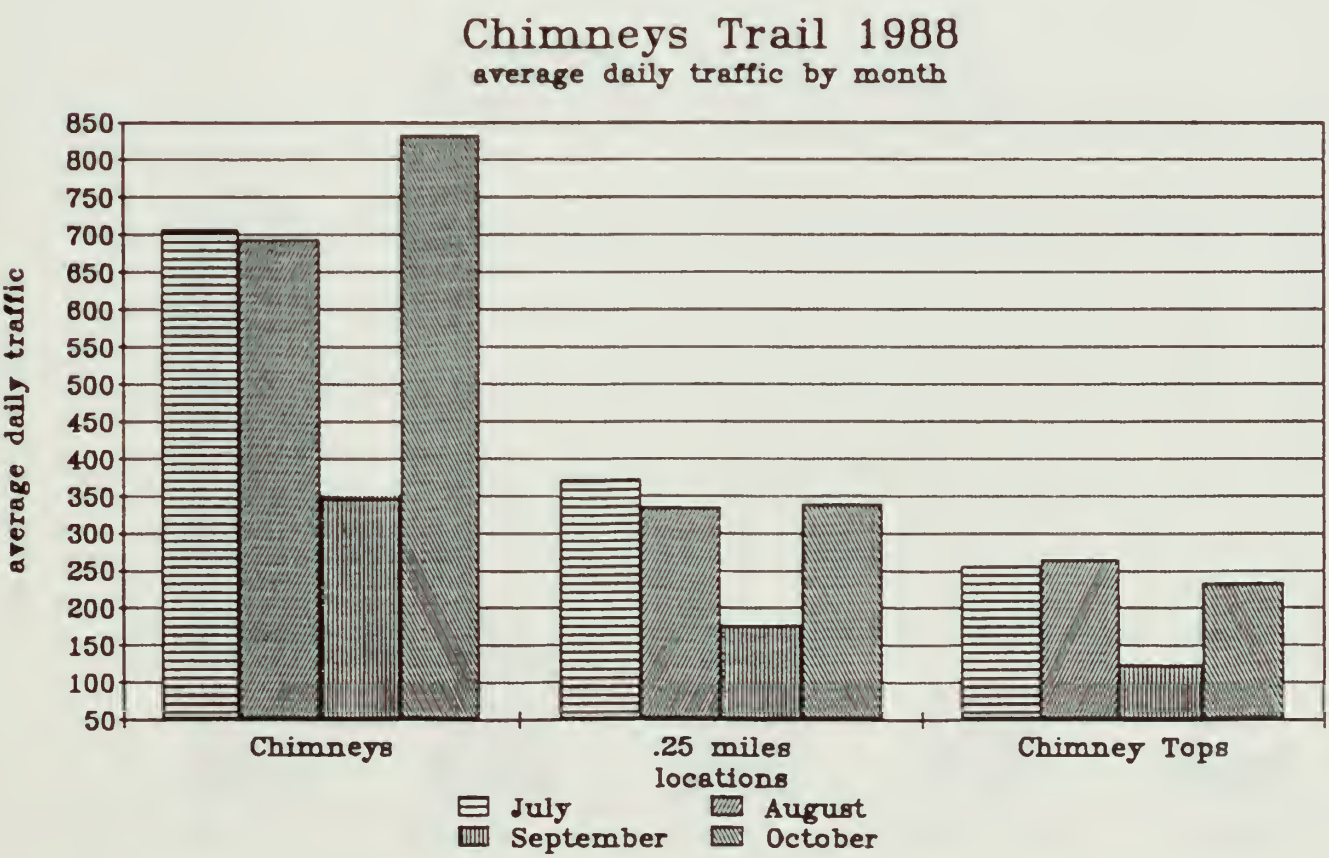
average daily traffic by month

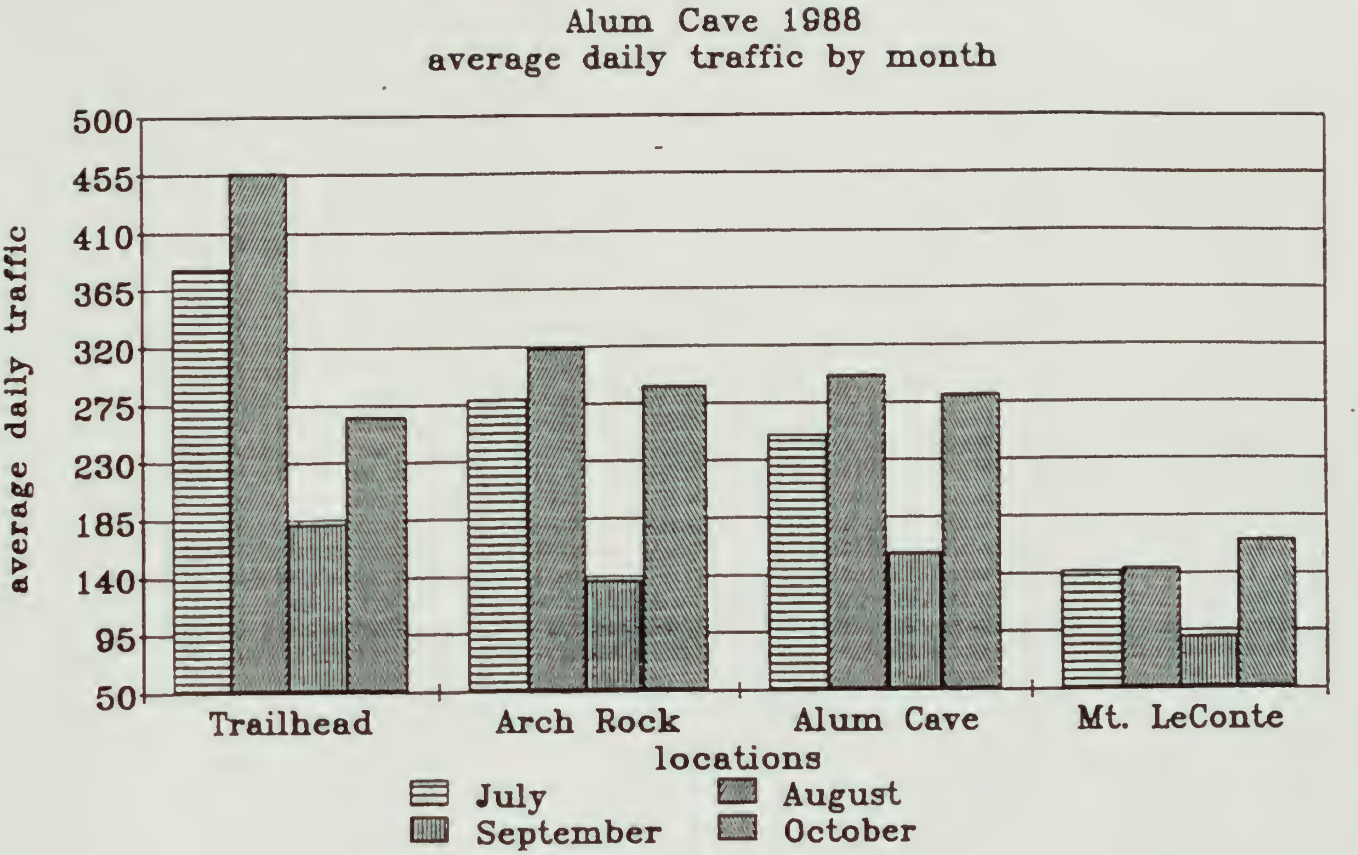
AT 1990

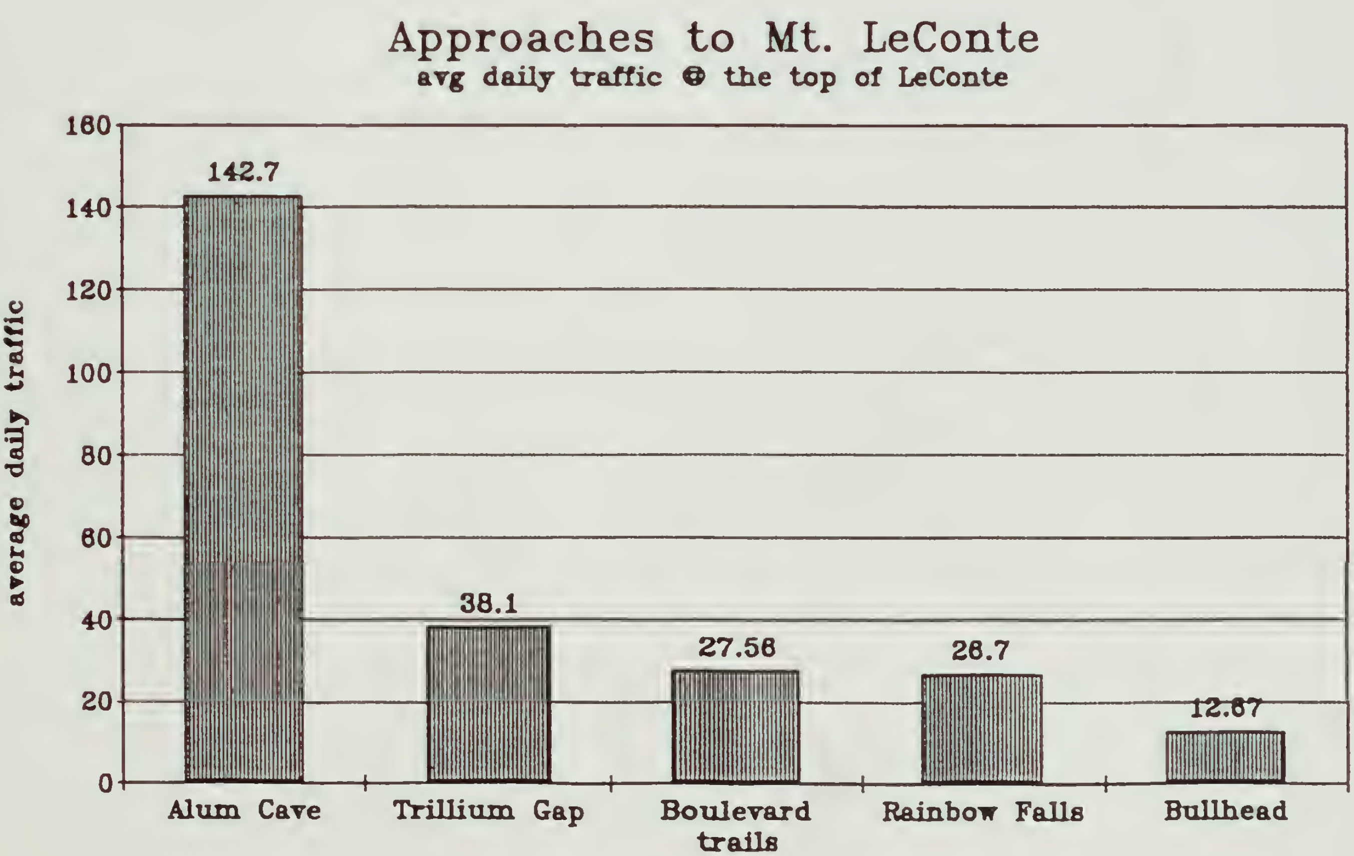
avg daily traffic; summer vs fall




Ramsey Cascades 1988
average daily traffic by month
average daily traffic
200
180
160
140
120
100
80
60
40
20
0
Trailhead
1.5 miles
Cascades
locations
July
August
September
October


Chimneys Trail 1988
average daily traffic by month
average daily traffic
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
Chimneys
.25 miles
Chimney Tops
locations
July
August
September
October


Alum Cave 1988
average daily traffic by month
500
455
410
365
320
275
230
185
140
95
50
average daily traffic
Trailhead
Arch Rock
Alum Cave
Mt. LeConte
locations
July
August
September
October


Approaches to Mt. LeConte
avg daily traffic @ the top of LeConte
160
140
120
100
80
60
40
20
0
average daily traffic
142.7
38.1
27.56
26.7
12.67
Alum Cave
Trillium Gap
Boulevard trails
Rainbow Falls
Bullhead

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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