MODELING DAY-HIKING IN THE TRANSITION TRAIL ZONE OF MOUNT RAINIER NATIONAL PARK

MARK E. VANDE KAMP

Technical Report NPS/PWR/UW/NRTR-2009—01
NPS 105/100443

October 2009

PROTECTED AREA SOCIAL RESEARCH UNIT
SCHOOL OF FOREST RESOURCES
BOX 352100
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-2100

The Protected Areas Social Research Unit is the applied social science program associated with the NPS Pacific Northwest Cooperative Ecosystem Studies Unit (NPS PNW CESU). This applied social science program has operated out of the University of Washington (UW) College of Forest Resources since 1970 when it was a part of the Cooperative Park Studies Unit (CPSU). With the establishment of the UW College of the Environment in 2009, the UW College of Forest Resources became the UW School of Forest Resources within the College of the Environment and PASRU is operating out of the UW School of Forest Resources.

The NPS (NPS PNW CESU) is located in the UW School of Forest Resources. The NPS PNW CESU is part of a larger partnership involving 7 federal agencies, 12 universities and the Alaska Department of Fish and Game. The PNW CESU was created in October of 2000 to provide research, technical assistance and education to enhance management of natural and cultural resources on public lands in the Pacific Northwest.

Copies are available from the following:

Technical Information Center
Denver Service Center
National Park Service
P. O. Box 25287
Denver, CO 80225-0287
303-969-2130

MODELING DAY-HIKING IN THE TRANSITION TRAIL ZONE OF MOUNT RAINIER NATIONAL PARK

MARK E. VANDE KAMP

Technical Report NPS/PWR/UW/NRTR-2009—01
NPS 105/100443

PROTECTED AREA SOCIAL RESEARCH UNIT
SCHOOL OF FOREST RESOURCES
BOX 352100
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-2100

October 2009

Produced in partial fulfillment of:

Task Agreement J9W88030023 by and between the National Park Service and the University of Washington written against the Pacific Northwest Cooperative Ecosystem Studies Unit Cooperative and Joint Venture Agreement CA9088A0008 entitled "Selecting Visitor Carrying Capacity Indicators and Proposing Potential Standards for Mount Rainier National Park."

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The success of this project depended in large part on the efforts of Robert Itami to develop a software package specifically designed to simulate the movements of recreational visitors. Without Bob and RBSim, this project would have been much more difficult.

1. INTRODUCTION

The University of Washington Protected Area Social Research Unit administered this project. It was proposed and funded by Mount Rainier National Park (MORA). The general purpose of the project was to simulate the movement of day hikers on a variety of trails in the Transition Trail Zone of Mount Rainier National Park. These computer simulations provide detailed estimates of visitor distribution in space and time that would be extremely difficult or impossible to collect directly. Such information is critical for effective planning of visitor management. More specifically, the information will be used in the Visitor Experience and Resource Protection (VERP) planning framework.

1.1 The Visitor Experience and Resource Protection (VERP) Framework

The VERP framework is a tool developed by the National Park Service to address user capacities and thus protect both park resources and visitor experience from impacts associated with visitor use. VERP was used in developing the Mount Rainier National Park General Management Plan, and the park has made a commitment to implement VERP throughout MORA. The VERP framework is an ongoing, iterative process of determining desired conditions (including desired cultural resource conditions, desired natural resource conditions, and desired visitor experiences), selecting and monitoring indicators and standards that reflect these desired conditions, and taking management action when the desired conditions are not being realized. VERP is a decision-making framework, but does not diminish management’s role in decision-making.

Information about visitor use is essential because VERP is, at its core, a means of managing the impacts associated with visitor use. It is difficult to imagine how decisions intended to limit the impact of visitation could be made in the absence of information describing current levels and patterns of visitor use.

1.1.1 The Transition Trail Zone in the VERP Framework and in This Document

MORA is a large park with diverse environments and recreation opportunities. Within the VERP framework, managers deal with such diversity by designating a variety of management zones for a given park. At MORA, the General Management Plan describes ten recreation zones. This document describes computer simulation of visitor use on several trails in only one of them – the Transition Trail Zone.

The General Management Plan describes the Transition Trail Zone as an environment in which visitors can experience a sense of adventure and exploration. The number of people encountered would lead to many opportunities for social interaction, and opportunities for solitude would be uncommon. These descriptions of the desired conditions for the Transition Trail Zone allow higher levels of interaction with other visitors than in the other wilderness zones. Thus, commonly-used indicators of wilderness social conditions, such as the number of other parties encountered, are difficult to measure in this zone -- hiker recall of encounters is inconsistent when there are more than about seven encounters per day (Hall and Shelby 1996; Vande Kamp, Johnson, and Swanson 1998).

Computer simulation of visitor use can provide a variety of estimates describing the social conditions on trails. These estimates will be used to help managers select indicators and set standards that will protect the desired social and physical conditions in the Transition Trail Zone.

1.2 Computer Simulation Models of Visitor Use

VERP planning benefits when managers have access to a wide range of information describing visitor use. For example, summary statistics of the kind reported in the report titled *Visitor Use in the Management Zones of Mount Rainier National Park* (Vande Kamp 2009) are essential. In addition, computer simulation models based on descriptive information can provide more sophisticated estimates of visitation that can help managers gain insight into existing conditions and the relationships between visitation and various impacts on visitor experiences and physical resources.

Computer simulation models provide a range of information that can be of great use to managers. For example, a computer simulation can provide estimates of potential indicators that are difficult and/or expensive to measure directly. A simulation of day-hiker movement on the Wonderland Trail to Summerland can be used to estimate not only the number of encounters between hikers, but the longest times between encounters and the trail segments in which those periods of solitude are most likely to occur. Similarly, the simulation can be used to estimate the time intervals between hiking parties whose passages could disrupt the activity of birds nesting along a particular section of trail. Such estimates can help managers select indicators and set standards that will protect both visitor experiences and physical resources.

Computer simulations can provide both descriptive and predictive estimates of visitor use. Descriptive information is focused on existing levels and patterns of visitation. Such information can help managers answer questions such as, “How does visitation on Trail A compare to visitation on Trail B?” It can also identify “bottlenecks” or “choke points” where visitation is most dense and thus most likely to have impacts on experiences or physical resources. Finally, descriptive information can make routine monitoring feasible by estimating the relationship between an easy-to-collect measure (e.g., the number of vehicles in the parking area), and a difficult-to-collect measure (e.g., the longest amount of time between encounters with other parties while hiking in Summerland). Based on the modeled relationship, routine monitoring can focus on the easy-to-collect measure.

Predictive information is provided by simulation models when they are used to estimate visitation for possible future conditions (i.e., conditions different from those that were present when the source data for the models were collected). For example, a simulation could be used to estimate measures of visitation that might arise if: a) a change in management policy altered the types of hikers using a trail, b) use of some trails was constrained by construction or closure, or c) visitation rose to levels not yet experienced. Of course, the predictive information would be based on a variety of assumptions that might or might not hold true in that hypothetical future, but the same limitation applies to any predictive technique.

1.2.1 Stochastic, Itinerary-Based Simulation Using the RBSim Computer Program

Computer simulation has become a routinely-used tool in many industries and applications. A full review of the many types of simulation models and their uses is beyond the scope of this document. However, it is important to discuss some of the basic characteristics of the simulation models used here so that readers gain some understanding of the strengths and weaknesses of the approach used.

Attempts to model the distribution of park visitors can employ a range of techniques. At Mount Rainier, one attempt used a relatively simple mathematical model to estimate use in Paradise Meadow (Vande Kamp and Zwiebel 2004). That model, like many other simple models, was deterministic, that is, it contained no random factors and always produced the same outputs if given the same inputs. In contrast, the simulation models reported in this document are stochastic, that is, they include random factors that create variability in the model outputs from one run to the next. Stochastic models have a number of advantages. For example, they not only provide descriptions of visitor use, but also estimate the variability that might be expected in those descriptions. Because there is variability in their outputs, stochastic models must also be run multiple times, and their outputs must be aggregated as averages or other summary statistics. This document will report the number of model runs used to estimate the reported descriptions of visitor use.

Among stochastic models, there are two very different approaches to building simulations– these might be labeled the itinerary-based approach, and the agent-based approach. The simulation models reported in this document are itinerary-based. In itinerary-based models, each hiking party is assigned a set itinerary as it enters the simulation. That itinerary will be carried out no matter what conditions are present in the model. In an agent-based approach, each hiking party is assigned a set of decision rules to follow. The party's itinerary is not determined until it moves through the simulation and "decides" how to proceed at a number of points along the way. Each approach has different strengths and weaknesses. Itinerary-based approaches tend to be easier to construct, to be well suited to describing conditions that currently exist, and to be poorly suited to predicting visitor use in situations where structural changes might be made to the trails or other facilities in the simulation. In contrast, agent-based approaches are more difficult to construct (determining decision rules that reproduce existing use patterns can be a complex process), but they can be used to predict visitor use in situations with major changes to the trails or other facilities. Given the priorities of this project, itinerary-based models were thought to be the superior option.

Many computer programs are available for building simulation models. They range from very general programs suitable for simulations of many situations, to very specific programs designed to simulate specific situations such as manufacturing processes or vehicle traffic. They also range in cost, from free programs available for download to as much as $50,000 (Vande Kamp 2003). There have been relatively few attempts to create simulation models of recreational visitor movements. After an attempt to build a simulation of wilderness recreation in the 1970s (van Wagtendonk and Cole 2005), there was a hiatus before more recent simulation modeling efforts (see Cole 2005). Two computer programs have been used in the majority of recent efforts to build simulation models of recreational visitor use: 1) Extend, developed by Imagine That, Inc., is a general purpose software package suitable for use in business, industry, and government applications, and 2) RBSim, developed by GeoDimensions Pty Ltd., a special-purpose simulator designed for use in modeling recreational visitor use on linear networks such as trails or roads. RBSim was selected for use in this project largely because its focus on recreational systems made it easier to use, and because it made extensive use of GIS data in both the input and output of the simulations it produced.

One aspect of RBSim that also made it attractive was the intent of GeoDimensions Pty Ltd. to develop the program with a user-friendly interface such that working with the program would require relatively little training. This aspect of the program has not been developed in the manner envisioned at the time of its adoption for this project.

In summary, the computer simulation models reported in this document are stochastic, itinerary-based, and developed using the RBSim simulator program.

1.3 The Structure of this Document

This document describes computer simulation of day-hiking on three different trails in the Transition Trail Zone of Mount Rainier National Park. These trails include: 1) the Wonderland Trail to Summerland, 2) the Comet Falls Trail, and 3) the Spray Park Trail. Each trail simulation will be reported in a separate chapter below.

Each chapter will follow the same format, with different sections describing the basic information that forms the foundation of each simulation, the characteristics of the simulation, and the use estimates provided by the simulation. The sections are described, in order, below.

1.3.1 Description of Visitor Use

Two closely-related forms of descriptive information are necessary to simulate day-hiking on trails. The first type of information describes the number of visitors entering the trail and the times when they enter. The second type of information describes where visitors hiked and when they passed specific points along the trails. These two types of information were generally provided by the two methods of data collection reported in the report titled *Visitor Use in the Management Zones of Mount Rainier National Park* (Vande Kamp 2009). The first, and simplest, method involves the use of electronic trail counters to collect counts of hikers, as well as information about the times when they passed the counter. The second method, called the waypoint survey, was developed specifically to collect itinerary information. Waypoint surveys provide detailed information about the movement of hiking parties on trails, as well as information about the amount of time they spend in specific areas. The simulation models described in this document are built based on the descriptive information collected by trail counters and waypoint surveys, and presented in the *Visitor Use...* report.

1.3.2 Entry Distributions

The data collected using electronic trail counters are routinely presented in the form of frequency distributions showing the number of hiker passages during specified time periods (usually one-hour intervals). Trail counters record hikers passing in both directions, but simulation models require frequency distributions describing the number of hikers *entering* the trail. This section of each chapter will describe the entry distribution of visitors to the trail being simulated, as well as the methods and data used to estimate that distribution.

1.3.3 Pauses/Stops

Most day-hiking trips feature stops during which hikers might eat lunch, rest, or simply observe the scenery. These stops can significantly alter the relationships between visitation and its impacts on physical resources and the quality of visitor experiences. This section of each chapter will describe the pauses and stops that will be built into the simulation, as well as the methods and data used to estimate those stops.

1.3.4 Assumptions and Simplifications

Computer simulations are models of visitor movement and distribution. As such, they are simplifications of reality. Simplification is a strength because it makes if feasible to build the simulation and use it to estimate important measures of visitation. Nonetheless, it is important to describe the various assumptions and simplifications used in the construction of the model because some of them may invalidate certain types of use estimates. For example, different parties of visitors may actually stop at a variety of sites in a general location such as Comet Falls or Summerland. However, without information about the specific location of those sites and likelihood of their use, the simulation may have all parties stop at a single location. Such a simplification would be unlikely to affect the number of encounters between parties while hiking, but would dramatically affect the likelihood and duration of encounters between stationary parties. This section of each chapter will describe assumptions and simplifications, and discuss some of their implications.

1.3.5 Validation

The ideal method of validating estimates of visitation based on simulation models is to collect data that are fully independent of the data used in developing the model and compare those independent observations to the model predictions. Studies designed specifically to collect validation data have not been conducted for any of the models reported in this document. However, some independent data are available for the trails (e.g., total hiking times recorded in all the waypoint surveys and the counts recorded by the upper trail counter on the Wonderland Trail to Summerland). Thus some assessment of simulation validity can be made for all the trails. This section of each chapter will describe the methods used to assess simulation validity, the results of those assessments, and any alteration of the simulation made to address shortcomings identified by the validity assessment.

1.3.6 Simulation Results

This document is not intended to report all the potentially useful estimates of visitor use that might be generated using the simulation models. Instead, a limited set of estimates closely related to discussions of social indicators and standards (see the report titled *Visitor-Experience Indicators and Standards for the Wilderness Zones of Mount Rainier National Park* [Vande Kamp 2009]) will be presented. Such estimates include measures describing encounters between parties. Additional estimates of visitor use might be generated in the future. The computer files and RBSim computer program that make up each simulation will be archived and transferred to Mount Rainier along with this document.

2. SIMULATING THE WONDERLAND TRAIL TO SUMMERLAND

The Wonderland Trail to Summerland is a popular day-hiking destination in the White River/Sunrise area of MORA. The park website states, “This is one of Mount Rainier's most crowded trails, hosting several hundred hikers per day on a nice summer weekend.” As part of the Wonderland Trail, it is used by both day-hikers and backpackers who wish to hike all or part of the Wonderland Trail loop. Day hikers access the trail from a trailhead near the bridge over Fryingpan Creek on the Sunrise Road. Parking capacity at the trailhead is 27 vehicles but can overflow along roadway shoulders (BRW 1994). Because the trail is heavily used, the park website and other information ask that visitors hike only on the constructed trails and rest on nearby rocks.

The trail ascends gradually through mature forest for several miles before entering the open but brushy upper valley of Fryingpan Creek where hikers find good views of Mount Rainier. Shortly after crossing the creek at a small cascade, the trail climbs steeply for another .5 mile before reaching the open subalpine meadows of Summerland, approximately 4.25 miles from the trailhead.

Any simulation is a limited representation of reality. One of the primary limitations of the simulation model describing the Wonderland Trail to Summerland (and also of the models representing other transition trails) is the fact that it measures encounters between parties that are hiking, and does not count encounters that occur while one or both parties are stopped at a destination. The discussion below describes some reasons for accepting this limitation, but the issue is highlighted here so that readers are aware that the simulation model is focused on (and limited to) hiking encounters.

2.1 Description of Visitor Use: Wonderland Trail to Summerland

Studies of visitor use of the Wonderland Trail to Summerland include counts collected using electronic trail counters and itinerary information collected using waypoint surveys. The results of these studies are reported in the report titled *Visitor Use in the Management Zones of Mount Rainier National Park* (Vande Kamp 2009). These results describe use during the summer hiking season (i.e., after the trail is largely free of snow – usually July through early September). Thus, summary statistics such as averages apply only to the summer hiking season. This seasonal limitation applies both to the studies of visitor use and the simulation model developed based on those studies.

For the purposes of modeling, the descriptive information of primary interest concerns the absolute number of hikers to be modeled, and the times at which they begin their hikes (i.e., the entry distribution). This section focuses on the absolute number of visitors using the trail and the distribution of entry times is discussed in the next section.

Trail counters record hiker passages. Thus, day-hikers to Summerland will be counted twice. In addition, the model simulates the movements of hiking parties rather than individual hikers. Because of these factors, the trail counter results must be translated into counts of hiking parties. The method used to translate counts of hiker passages to counts of hiking parties is quite simple. Passages are first divided by 2, based on the assumption that each hiker passed the counter twice, and then divided by 2.6, the average party size recorded by the 2004 and 2005 waypoint surveys.

One potential problem with this method of estimating the number of hiking parties is that it mixes information from the waypoint survey, which includes only day-hikers, with the trail counter data, which include both day-hikers and backpackers. Given that the simulation should model interactions between all parties, not just day-hikers, and because there is little information available to support estimates of the number of backpackers or the times at which they hike this section of trail, the simulation includes a simplifying assumption that all use of the trail can be estimated by modeling backpackers in the same manner as day-hikers. This simplifying assumption incorporates three secondary assumptions: 1) the proportion of backpackers hiking the trail in each direction is approximately equal, 2) the party size of backpackers is not sufficiently different from 2.6 that it will invalidate the simulation results, and 3) the times that backpackers travel the trail are not sufficiently different from day-hikers that they will invalidate the simulation results. Given the likelihood that the number of backpackers is relatively small in relation to the number of day-hikers, these assumptions are thought to be appropriate.

The following use estimates are derived from the trail counts of hiker passages. Average use of the trail on weekdays is estimated to be 17 parties (90 hikers). On weekends, average use is estimated to be 36 parties (188 hikers). Busy days are commonly represented by selecting the level of use on the day that was busier than 95 percent of all the observed days. Use on this 95th percentile day, averaged from the 2004 and 2005 observations, is estimated to be 52 parties (271 hikers).

The prevalence of off-trail hiking among day-hikers can have important implications for the estimation of encounters between parties based on simulation models. It is much simpler to estimate the encounters between parties using a linear trail system than encounters when parties are moving at random across the landscape. The 2005 waypoint survey found that only 23 of 220 hiking parties (10.5 percent) reported leaving the official trails in Summerland. Based on these findings, the simulation model incorporates a simplifying assumption that all hiking parties remain on the official trail, and no attempt is made to incorporate off-trail routes into the simulated itineraries. The precise effect of this assumption on the estimates of encounters between parties is unknown. However, examination of the off-trail routes indicated in the survey, and anecdotal observation in Summerland suggest that much of the off-trail hiking consists of short excursions to find secluded resting or eating spots, with a return to the official trail via the same route. Such activity is unlikely to have a significant effect on the number of encounters that parties will have while hiking the official trail.

2.2 Entry Distribution: Wonderland Trail to Summerland

The second type of descriptive information essential for building simulation models is the frequency distribution of hikers entering the trail across the time of day. The fact that trail counters do not differentiate between hikers moving in different directions on the trail also complicates the estimation of these entry distributions. For example, the figure below shows the hourly distribution of hiker passages recorded on weekdays and weekends by the electronic trail counter located near the trailhead. Note that there are morning and afternoon peaks corresponding to the times when many visitors begin and end (respectively) their hikes. However, without additional information about rates of visitor entry, the overlap between the entry and exit distributions makes it impossible to determine the hourly distribution of only those visitors who are beginning their hikes.

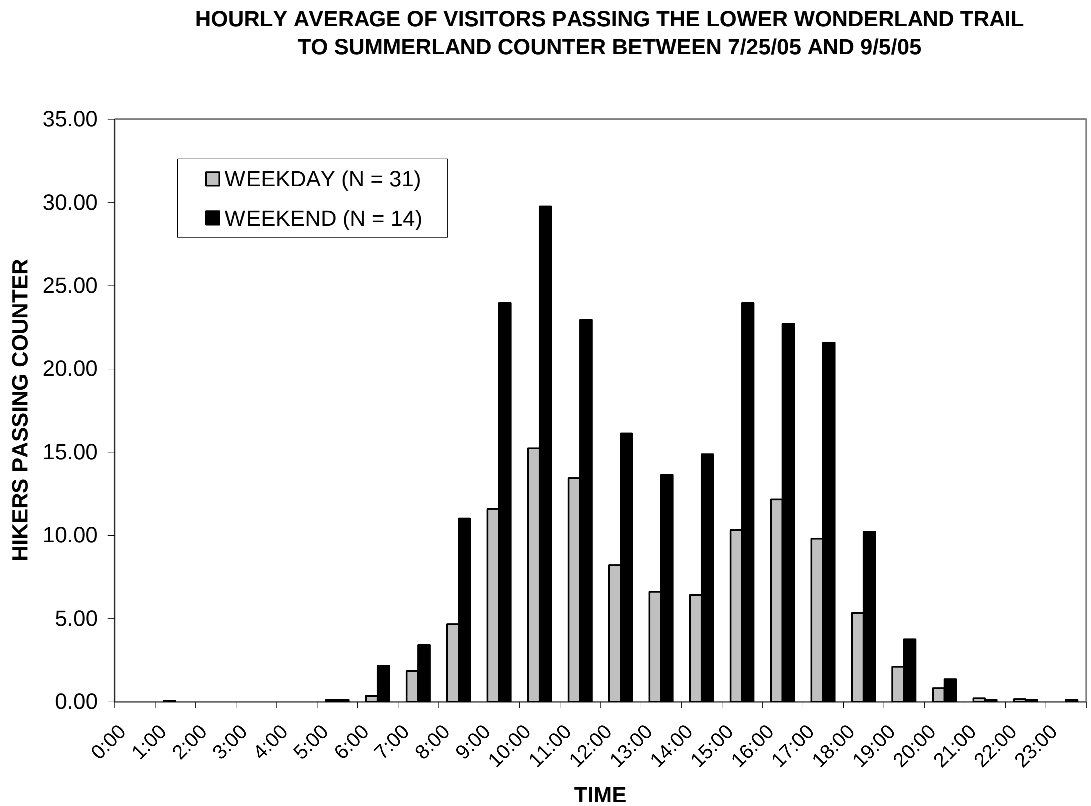

Figure 1. Hourly weekend and weekday distributions of visitors passing the lower trail counter (near the trailhead) on the Wonderland Trail to Summerland in 2005.

The waypoint surveys provide an additional source of information to be used in combination with the trail counter data to estimate entry distributions. Because the waypoint surveys were given only to hikers beginning their hikes, and included the time of contact, entry distributions are available for the hours when the surveys were conducted. Extrapolating to earlier hours based on the trail counter data, a full distribution can be estimated.

The figure below shows the hourly distribution of hiking parties that were contacted during the 2004 and 2005 waypoint surveys. The distribution represents only weekend days because: a) hiking patterns differed on weekends and weekdays, and b) the primary purpose for constructing the current simulation model is to investigate conditions during peak use. Because surveys were conducted between 8:00 and 4:00, this distribution can not serve as the full entry distribution for the simulation. Thus, we must also consider the possibility of hikers entering before and after the observed period.

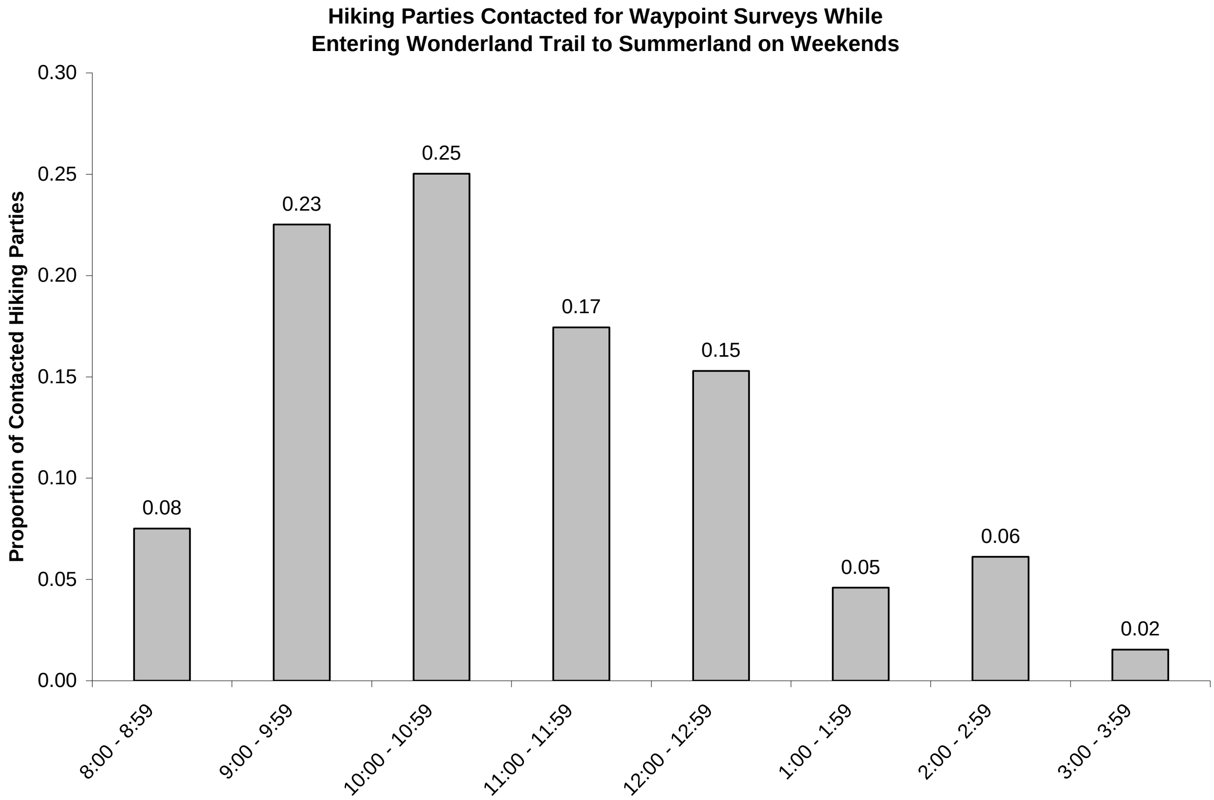

Figure 2. Hourly proportion of parties contacted for waypoint surveys on the Wonderland Trail to Summerland in 2004 and 2005.

Use before 8:00 is estimated based on the trail counter data. If we assume that all counts prior to 8:00 record hikers entering the trail, then we can estimate entries between 7:00 and 8:00 to be 31 percent of the entries between 8:00 and 9:00. Likewise, entries between 6:00 and 7:00 can be estimated as 20 percent of the entries between 8:00 and 9:00. Based on the extremely low number of passages recorded by the trail counter prior to 6:00, a simplifying assumption is made that no hikers enter prior to that time.

The proportion of hiking parties contacted for the waypoint surveys between 3:00 and 4:00 was very low, and was thought unlikely to increase in later hours based on the lack of novel hiking destinations in the first few miles of the trail (note that the majority of trail users hike the full distance to Summerland). Thus, a simplifying assumption is made that no hiking parties enter the trail after 4:00.

The figure below shows the entry distribution used in constructing the simulation model of visitor use on the Wonderland Trail to Summerland. The distribution is represented in terms of the proportion of visitors entering during each hour because the simulation might be run with different total numbers of hiking parties entering. The distribution of hiker passages recorded by the trail counter during the same hours in 2005 is included in the figure for comparison purposes.

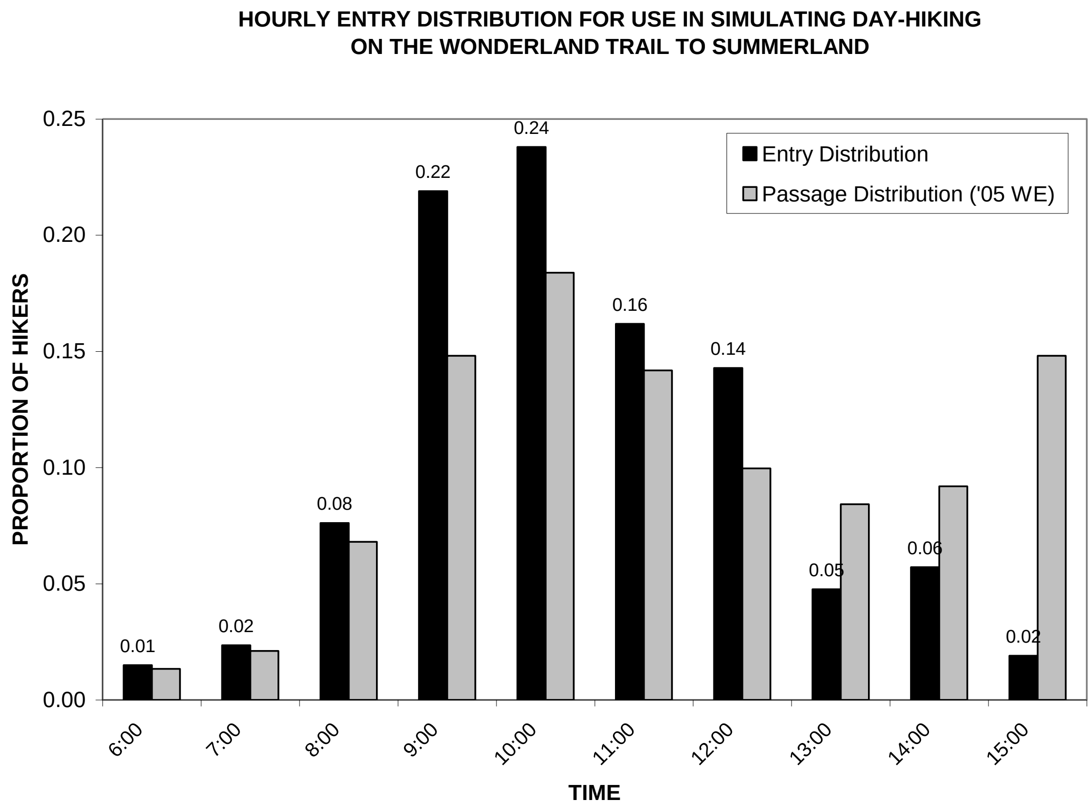

Figure 3. Hourly distribution of visitors entering the Wonderland Trail to Summerland for use in computer simulation model (2005 visitor passage distribution included for comparison).

2.3 Pauses/Stops: Wonderland Trail to Summerland

One aspect of visitor itineraries that was not described by the data collected in the waypoint studies was the amount of time that visitors were not actually hiking along the trail. Informal observation (and common sense) demonstrates that most visitors do not hike constantly, but stop to rest, eat or drink, or simply view the scenery. If the model is to provide useful information, it can not completely disregard those pauses or stops.

Because of the limited information available to estimate where and for how long visitors stopped, a number of simplifying assumptions were made in the representation of pauses and stops in this simulation model. The most important of these is that in the model, stops only occur at one location, the shelter where the trail enters the Summerland sub-alpine meadows. Even casual observation of visitors' behavior in Summerland shows that this assumption is commonly violated. However, the implications of this assumption are only critical if they substantially alter the number of hiking encounters between parties. Observation suggests that the short pauses made by visitors are unlikely to substantially alter the number of encounters between parties because faster hikers are likely to pass slower hikers regardless of short pauses. Longer stops are a different matter, but are also unlikely to invalidate the model. Recall that the model is intended to describe encounters that occur when both parties are hiking. Having all parties pause at the same location (for varying durations) would certainly inflate the number of non-hiking encounters that would occur while the parties were all bunched up in that location. However, the assumption's effect on the number of encounters that occur while both parties are hiking is not entirely clear. Observation of the situation suggests that such an effect would be small, but the model could be run with a variety of alternate assumptions to test their effect on encounters while hiking.

One factor that will affect the number of hiking encounters is the amount of time that simulated hiking parties spend stopped at the shelter. Although we did not ask hikers how many minutes they were not hiking during their visit, we can estimate that information based on information collected in the waypoint survey. One trail segment on the lower portion of the trail (between waypoints B and C; see Figure below) was an unlikely place for parties to pause or stop because it was traversed early in visitors' hikes and because it passed through a forested area in which there were few features or views that would invite hikers to stop. Based on the times recorded as visitors moved between the waypoints, their walking speed could be calculated (e.g., on the way up the average was 3.53 kilometers per hour, and on the way down 4.38 kilometers per hour). Because the average rate of elevation gain on that segment of trail was similar to the gain on the trail segment between the Summerland shelter and Panhandle Gap (between waypoints F and G), one could reasonably expect that hiking speeds (excluding stops) should be similar on both trail segments. Thus, in order to estimate the time that simulated visitors should spend stopped at the shelter, we subtracted the estimated amount of time necessary to hike the higher trail segment in both directions (based on their hiking speeds across the lower trail segment) from the time that they reported actually spending on the higher trail segment. This estimation procedure assumed: a) that the entire difference between the hiking speeds on the two trail segments was due to the time that parties spend stopped in Summerland, and b) that visitors who reached Panhandle Gap stopped for similar amounts of time as visitors who reached the Summerland shelter, but did not reach the Gap. Given that there appears to be no other basis for estimating the duration of stops for hiking parties, there is no ready alternative but to accept this assumption.

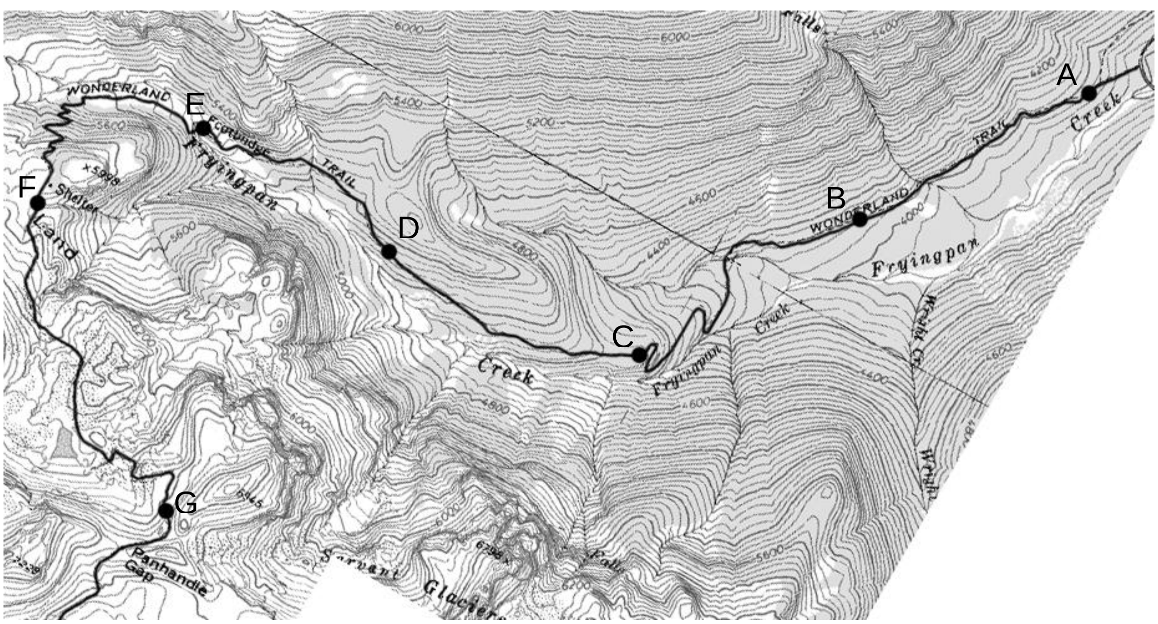

Figure 4. Locations of waypoint signs for Summerland Waypoint Survey.

The procedure used to estimate the duration of stops in Summerland actually produced separate estimates for stops taken on the way to Panhandle Gap and on the way back from the Gap. Simulating those stops separately in the model would have been problematic for a number of reasons including limitations of the modeling software and the lack of empirical information concerning how to assign pauses to simulated parties that do or do not reach Panhandle Gap. Thus, the simulation includes a simplifying assumption that a single stop representing the sum of stops in both directions will be taken when parties first reach the Summerland shelter. Based on the estimation procedure described above, these stops average 53.4 minutes with a standard deviation of 40.5 minutes.

The area in which hiker movement is simulated ends at Panhandle Gap (i.e., waypoint G). However, the model must include some provision for accurately representing the time some parties spent hiking beyond that point. This is done by representing that hiking time as a stop at point G. The duration of this stop is estimated based on the time difference parties recorded between their first and second time passing the waypoint. These durations averaged 50.5 minutes with a standard deviation of 47.2 minutes. This procedure constitutes a limitation of the model, because no encounters are simulated or recorded for parties hiking beyond Panhandle Gap. However, there are not likely to be many encounters between the relatively small number of parties who hike that far.

2.4 Hiking Speeds: Wonderland Trail to Summerland

Another factor that has a large effect on the number of encounters between hiking parties in the simulation is the speed (and range of speeds) at which hiking parties move along the simulated trail. This effect is obvious when one considers that hikers encounter parties that are: a) moving in the opposite direction, and b) moving in the same direction. The relative speed of the parties has a relatively small effect on the first type of encounter, but it has a large effect on the second type. To illustrate, imagine that all parties hike at the same speed – they would maintain perfect separation and never overtake each other. In contrast, if some parties hike much faster than others, then they will overtake many of the slower parties ahead of them.

Actual hiking speeds can be calculated from the waypoint study data and used in building the simulation model. In order to minimize the effects of stops and pauses on those speeds, only the trail segments prior to the Summerland shelter are used in the speed calculations. For each party that reached the shelter, the total time that they spent between the trailhead and the shelter (i.e., between waypoints A and F) in both directions was divided by the distance between those points in order to calculate a hiking speed. Using this procedure, the average hiking speed was 3.27 kilometers per hour with a standard deviation of 0.6.

The RBSim software does not currently allow random assignment of hiking speeds to parties. However, different types of hikers can be defined – each with a different hiking speed. For this simulation, four types of hiking parties were defined. The hiking speeds of each party type, and the number of parties assigned to each type were designed to produce a distribution of hiking speeds that approximated the distribution described by the waypoint survey.

The range of speeds found in the sample distribution were divided into four, roughly-equal intervals and the proportion of hiking parties within each interval was determined by examining the frequency table of hiking speeds. Based on this analysis, the simulation model assigned the following four hiking speeds to the indicated proportion of hiking parties:

Speed (kph)	Proportion of Hiking Parties
2.57	0.22
3.07	0.359
3.57	0.255
4.06	0.166

Table 1. Proportion of simulated hiking parties assigned to four hiking speeds in the Summerland computer simulation model.

Hiking speeds were not randomly distributed across all hiking parties in the waypoint survey. For example, hikers who reached Panhandle Gap hiked at higher speeds (3.53 kph) than hikers who reached the Summerland Shelter but not the Gap (3.14 kph; $t(257) = 5.251$, $p < .001$). Accordingly, the four hiking speeds listed above were assigned to simulated parties based on the range of actual speeds recorded by the waypoint survey. Thus, parties in the simulation do not travel at the exact speed that they recorded on the waypoint card, but do travel at a speed selected from four options to best represent their recorded speed.

2.5 Assumptions, Simplifications, and Limitations: Wonderland Trail to Summerland

The characteristics of the simulation described in this section have all been discussed in the earlier descriptions of the simulation model, its parameters, and how it was developed. These characteristics are summarized here (in approximate order of their importance) to ensure that readers are aware of them (particularly the limitations) before reading and interpreting the simulation results.

The first limitation of the simulation is that its results describe only use that occurs during the summer (i.e., all or mostly snow-free) hiking season.

A second limitation is that the simulation measures only encounters between parties that occur while both parties are hiking on the official trail between the Fryingpan Creek trailhead and Panhandle Gap during the summer hiking season. The simulation does not count encounters that occur while one or both parties are, a) stopped at a destination, b) hiking off the official trail, or c) hiking beyond Panhandle Gap.

A third limitation of the simulation is that although the number of parties entering is based on counts of both backpackers and day-hikers, the behavior of the simulated parties is based only on day-hikers and no distinction is made between types of parties when counting encounters.

A final limitation of the simulation is that the entry distribution is based only on weekend data. Some of the results below summarize simulation runs representing average weekday use and it is possible that those results would differ slightly if an entry distribution for weekdays had been estimated and incorporated into the simulation.

A number of simplifying assumptions were made in the course of designing the simulation. The extent to which these assumptions limit the generality of the simulation results is probably small. The assumptions include: a) all hiking parties entered between 6:00 A.M and 4:00 P.M., b) all stops by hiking parties were represented by a single stop when parties first reached the Summerland Shelter, c) the average duration of stops at the Summerland Shelter was the same for all hiking parties, d) the continuous range of actual hiking speeds was represented by a set of four discrete speeds.

2.6 Validation: Wonderland Trail to Summerland

The primary reason for simulating day-hiking on the Wonderland Trail to Summerland was to estimate the number of encounters between hiking parties. Thus, the best test of simulation validity would be to systematically record the number of actual encounters and compare those counts to the simulation estimates for days when a comparable number of hiking parties enter the trail. However, systematic counts of actual encounters have not been collected at this point in time.[1] In their absence, two other comparisons were used to assess the validity of the simulation.

The first assessment of validity compared the temporal distribution of the counts actually registered at the upper trail counter to the temporal distribution of simulated parties passing that same location. Because the data from the upper trail counter were not used in designing the simulation, they provided an independent test of the degree to which the hiking behavior of the simulated day-hiking parties corresponded to day-hikers’ actual behavior. The figure below includes bars showing three temporal distributions, 1) the distribution of simulated day-hiking parties, averaged across 150 simulated days (50 days each with 52, 36, and 17 entering parties); 2) the distribution of actual hikers observed in 2004; and 3) the distribution of actual hikers observed in 2005.

[1] High priority should be placed on model validation based on direct counts of hiking encounters. Such data constitute the best test of the model and might be efficiently collected using volunteer observers.

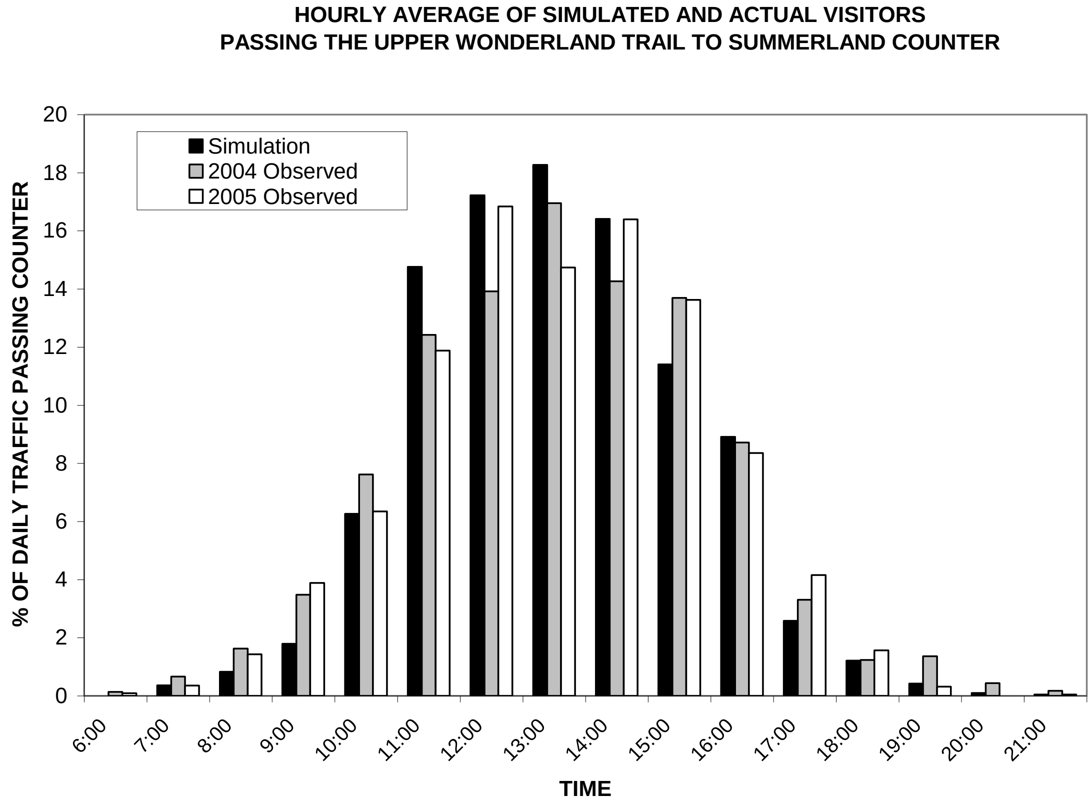

Figure 5. Simulated and observed distributions of visitors passing the upper trail counter on the Wonderland Trail to Summerland.

Visual inspection of the three temporal distributions showed that they were very similar. The distribution of simulated hikers appears to be shifted slightly left, toward earlier times, most likely because the simulated hiking speeds were the same for uphill and downhill travel. The discrepancies between the simulated and observed percentages for each hour ranged from 0.001 to 3.53 percent, and the average discrepancy was 1.02 percent. In comparison, the discrepancy between the 2004 and 2005 observed percentages ranged from 0.043 to 2.92 percent, and averaged 0.83 percent. In general, the simulation corresponded closely with the independent data recorded by the upper trail counter.

A second assessment of the simulation validity can be made by comparing the duration of the simulated day-hikes to the actual durations collected during the waypoint survey. Although the simulation was designed using information from the waypoint survey, the duration of simulated hikes was based on hiking speed and duration of stop calculations that did not make use of the total hike durations from the waypoint survey. The table below includes the averages and standard deviations for simulated and observed hike durations.

	Average Duration	Standard Deviation
Simulation	315	102
2004 Waypoint Study	312	108
2005 Waypoint Study	339	102

Table 2. Duration of simulated and observed hikes (in minutes).

The average simulated duration fell between the averages observed in 2004 and 2005, as did the standard deviation. Thus, the simulation corresponded closely with data that were recorded on at least a semi-independent basis during the waypoint study.

2.7 Simulation Results: Wonderland Trail to Summerland

This section describes three sets of results corresponding to simulation of: 1) a 95th percentile day, 2) an average weekend day, and 3) an average weekday. Some caution is advised regarding the results for the average weekday because the entry distribution used in constructing the simulation model was based only on weekends (see Section 2.5 above).

Each set of results is based on 50 iterations of the simulation model. This number of iterations was selected based on a method described by Itami, Zell, Grigel, and Gimblett (2005). In this method, a "short run" of the simulation is used to estimate the variability in one or more outcome measures, and that variability is used in calculations that determine the number of iterations necessary to reach a desired level of precision in the simulation results. In this case, the desired level of precision in estimating the average number of total encounters was a 95-percent confidence interval of plus-or-minus 2 encounters for the "95th percentile day" simulation. A "short run" of 15 iterations found that the variance in total encounters was 70.1, and that 50 iterations of the simulation would yield the desired precision. For the "average weekend" and "average weekday" simulations, 50 iterations produced even narrower confidence intervals, but the gain in precision was useful given the smaller values for total encounters estimated for those conditions.

2.7.1 Trail Encounters on a 95th Percentile Day

The 95th percentile day is one measure of what might be called "peak use". In most use distributions, a few extraordinary days lie far outside the normal range of use. Although managers may be concerned about the impact of such days, they fall outside the realm of general planning. For the purposes of the MORA VERP team, it was thought appropriate that simulation of peak use should focus on the use level higher than 95 percent of days, and lower than the 5 percent of busiest days. For the Wonderland Trail to Summerland, use on this 95th percentile day was 52 parties (see Section 2.1 above).

As described above, the simulation model was run 50 times in order to produce a 95-percent confidence interval for total daily encounters of plus-or-minus 2 encounters.

Total encounters. On average, simulated hiking parties encountered 31.1 other parties. The figure below shows the distribution of total encounters for the 2,600 simulated parties.

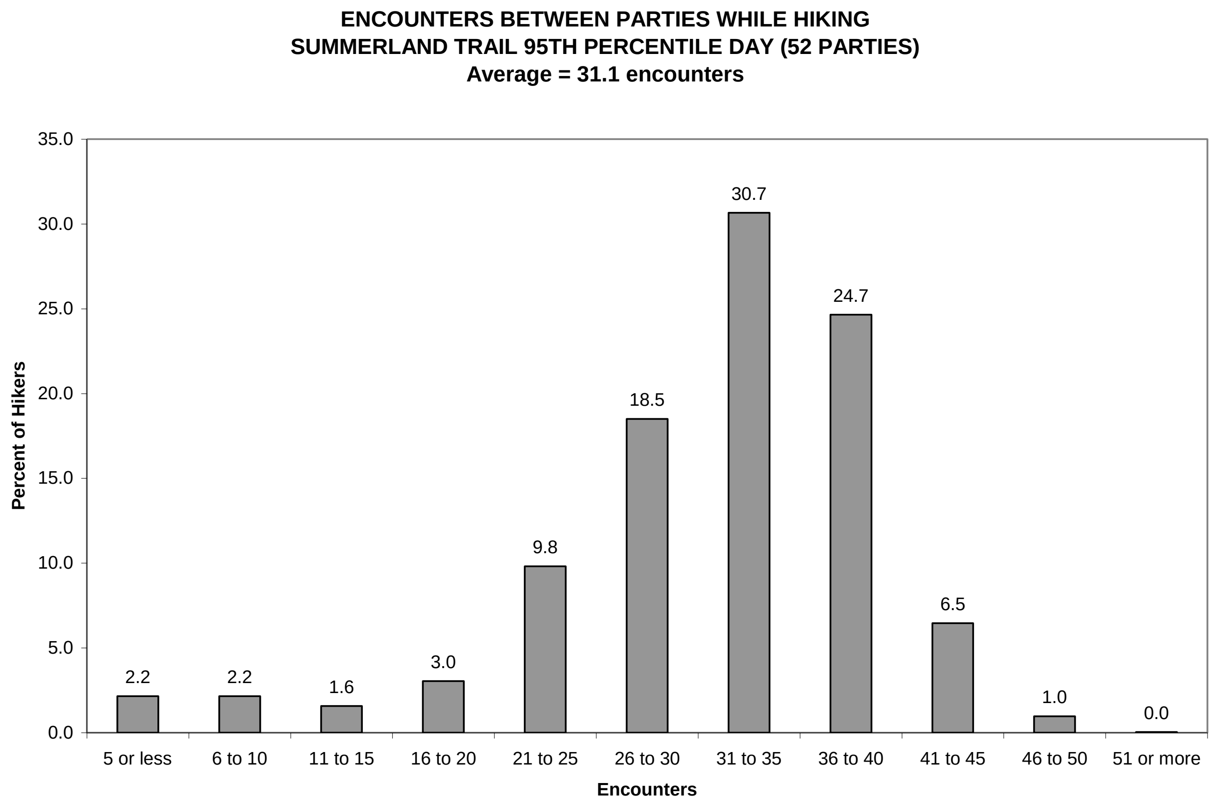

Figure 6. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on a 95th percentile day (52 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 6.5 other parties per hour. The figure below shows the distribution of encounters per hour for the 2,600 simulated parties.

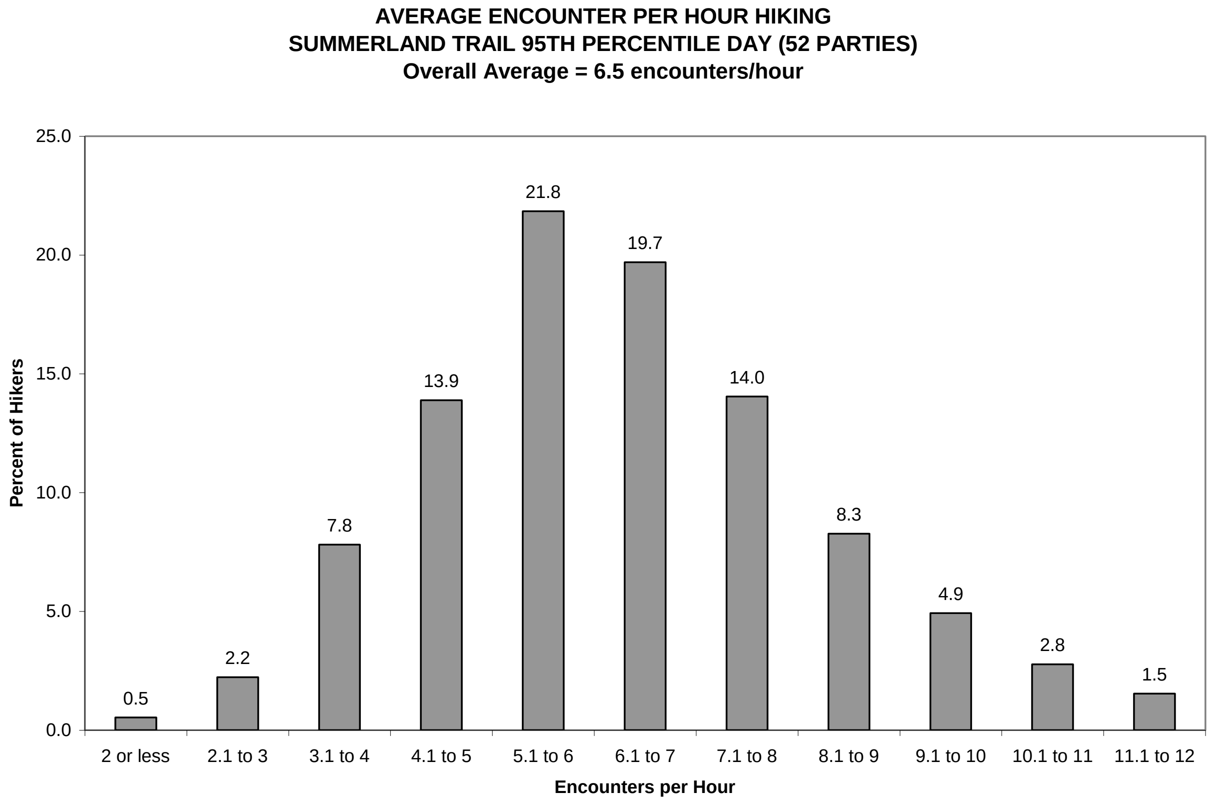

Figure 7. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on a 95th percentile day (52 total parties).

Given that parties that reached Summerland had trip durations that averaged 352 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 38.1 ([352/60] * 6.5). This figure is considerably larger than the average of 31.1 encounters for all parties, and it would be even more discrepant if the number of hiking parties that reach Summerland was smaller (82.3% of hiking parties reached Summerland; Vande Kamp 2009).

2.7.2 Trail Encounters on an Average Weekend Day

The 95th percentile day provides a useful description of peak use, but the difference between peak use and more routine use levels can also be informative. In this section we estimate the number of hiking encounters between parties on the Wonderland Trail to Summerland during an average weekend day. Use on such an average weekend day was 36 parties (see Section 2.1 above).

As described in section 2.7 above, the simulation model was run 50 times. In this case, 50 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 1.4 encounters.

Total encounters. On average, simulated hiking parties encountered 21.3 other parties. The figure below shows the distribution of total encounters for the 1,800 simulated parties.

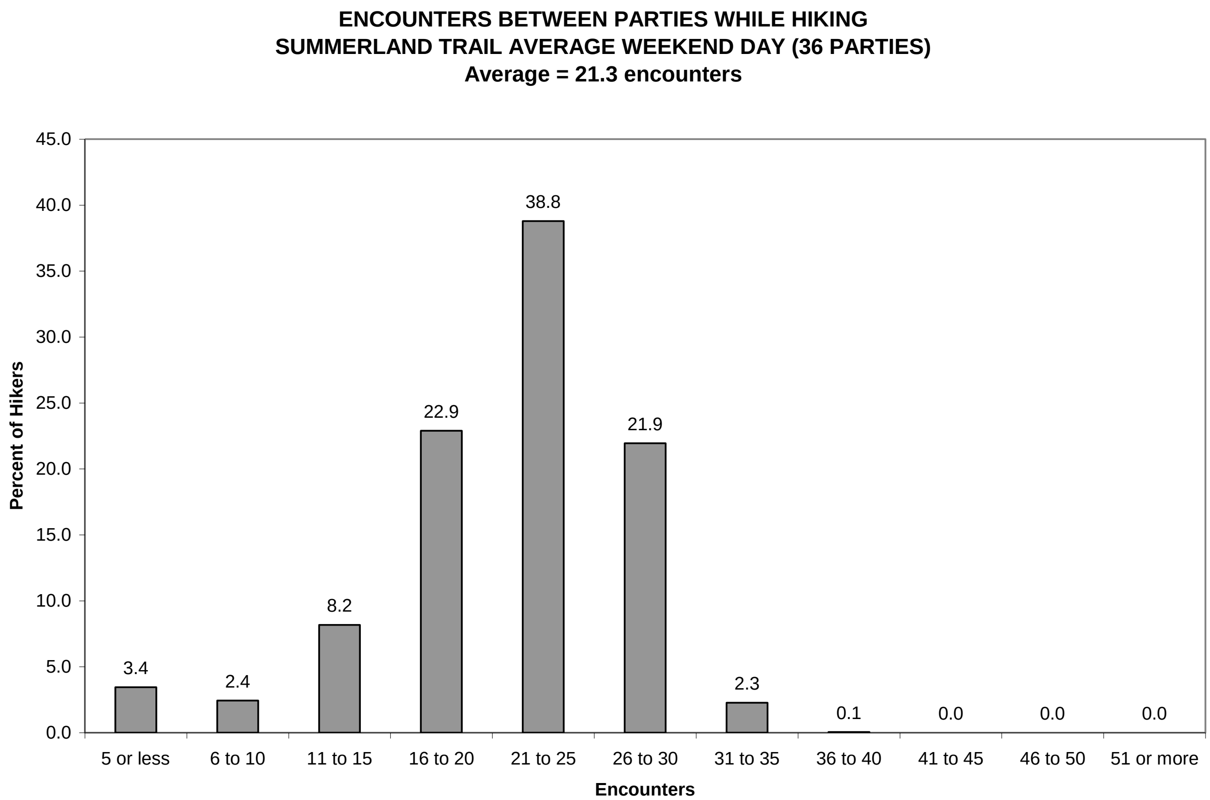

Figure 8. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekend day (36 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 4.4 other parties per hour. The figure below shows the distribution of encounters per hour for the 1,800 simulated parties.

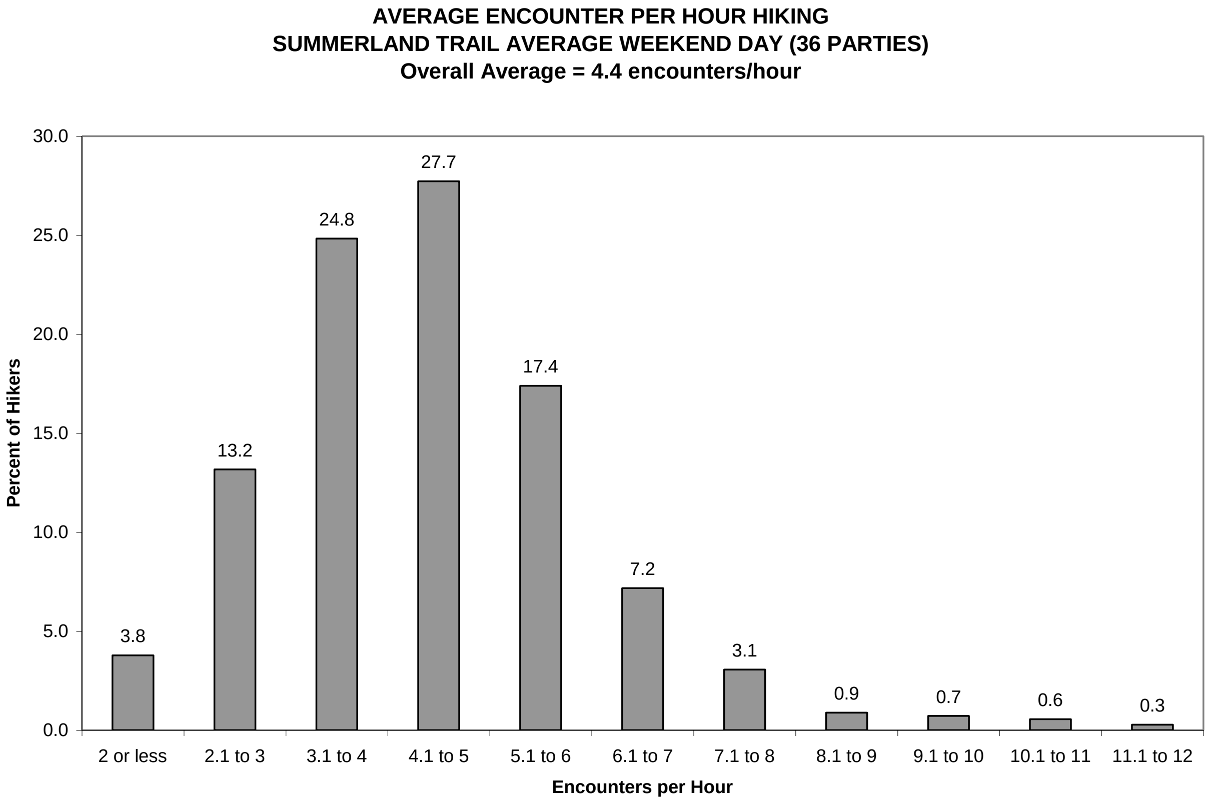

Figure 9. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekend day (36 total parties).

Given that parties that reached Summerland had trip durations that averaged 352 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 25.8 ([352/60] * 4.4). This figure is considerably larger than the average of 21.3 encounters for all parties, and it would be even more discrepant if the number of hiking parties that reach Summerland was smaller (82.3% of hiking parties reached Summerland; Vande Kamp 2009).

2.7.3 Trail Encounters on an Average Weekday

One final routine use level was simulated in order to provide additional information. In this section we estimate the number of hiking encounters between parties on the Wonderland Trail to Summerland during an average weekday. Use on such an average weekday was 17 parties (see Section 2.1 above). Some caution is advised regarding these results because the entry distribution used in constructing the simulation model was based only on weekends (see Section 2.5 above).

As described in section 2.7 above, the simulation model was run 50 times. In this case, 50 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 0.7 encounters.

Total encounters. On average, simulated hiking parties encountered 9.6 other parties. The figure below shows the distribution of total encounters for the 850 simulated parties.

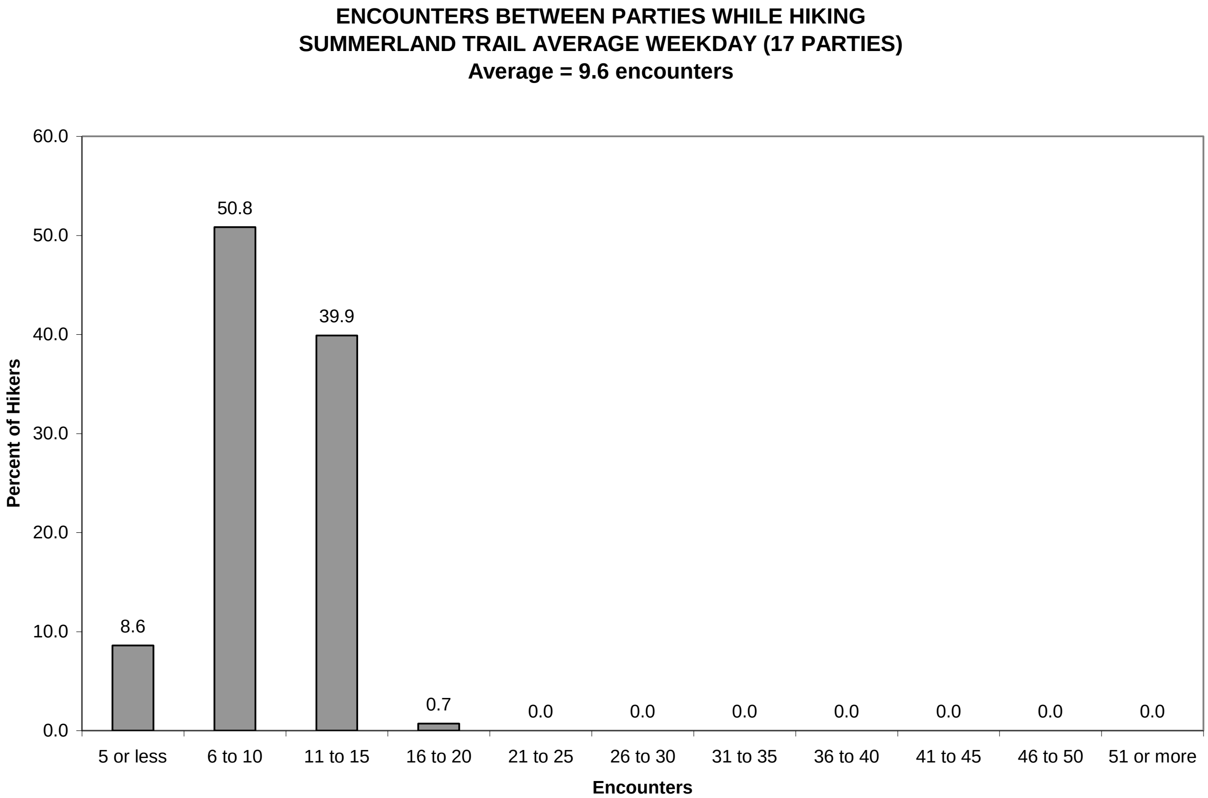

Figure 10. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekday (17 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 1.9 other parties per hour. The figure below shows the distribution of encounters per hour for the 850 simulated parties.

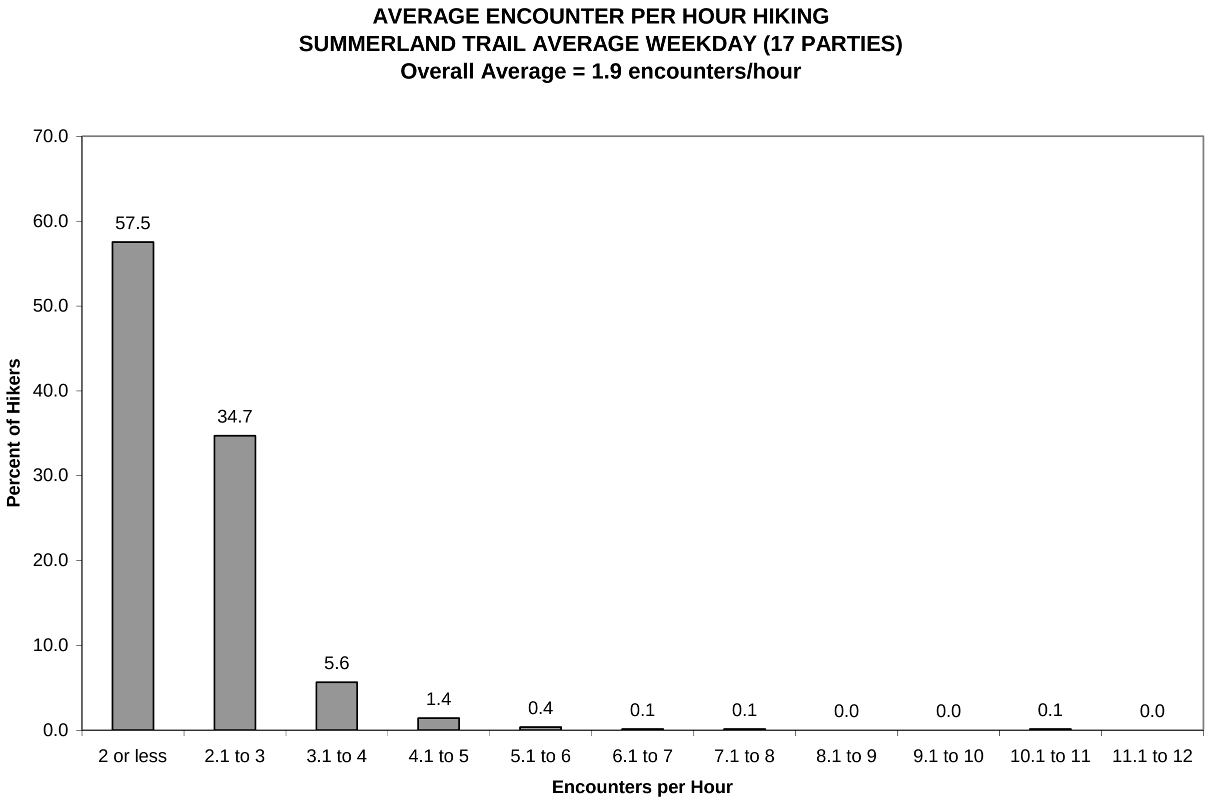

Figure 11. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekday (17 total parties).

Given that parties that reached Summerland had trip durations that averaged 352 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 11.4 ([352/60] * 1.9). As in the 95th percentile and weekend simulations, this figure is larger than the average for all parties (9.6 encounters), but it is questionable whether a difference of less than 2 encounters per trip would be meaningful to visitors. The difference would be more discrepant if the number of hiking parties that reach Summerland was smaller (82.3% of hiking parties reached Summerland; Vande Kamp 2009).

2.7.4 Trail Encounters and Use Levels

The number of encounters between hiking parties estimated using the simulation of the Wonderland Trail to Summerland showed a nearly perfect linear relationship with the number of hiking parties that were put into the simulation (*r* = .999; Average Total Encounters equals approximately 0.58 * Daily Hiking Parties). The strength of the correlation is unsurprising in retrospect, given that the simulation uses the same pool of hiking itineraries in the same proportions for the 52, 36, and 17 party simulations. However, the relationship is not entirely an artifact of the simulation procedure. The waypoint studies showed little evidence that hiking itineraries were dramatically different at high and low use levels, and in the absence of such differences, encounters should be determined entirely by the number of hiking parties. The strength of the relationship between encounters and use levels provides a strong argument that visitor counts can be used to monitor encounters between hiking parties and to thereby monitor conditions related to desired visitor experiences.

2.7.5 Encounters per Hour on Distal Trail Segments

Modeling the Wonderland Trail to Summerland provides information about use levels on a particular trail in the Transition Trail zone, but can also provide information relevant to the Semi-primitive Trail zone. Currently, the Wonderland Trail enters the Semi-primitive Trail zone after the Summerland Shelter. This is an unfortunate choice in relation to visitor experience because more encounters between simulated hiking parties occurred on the trail segments just past the shelter (13.7 encounters per hour on 95th percentile days) than on any of the trail segments currently in the Transition Trail Zone (a maximum of 9.9 encounters per hour). The zoning would more closely correspond to current use patterns if the Transition Trail zone was extended to Panhandle Gap. The trail segments immediately prior to Panhandle Gap averaged 3.7 encounters per hour on simulated 95th percentile days.

3. SIMULATING THE COMET FALLS TRAIL

The Comet Falls Trail is a relatively short hike located in the southwestern area of MORA. The park website states, “320 ft. Comet Falls is a popular destination for many hikers.” The trail is not part of the Wonderland Trail, and is used primarily by day-hikers who wish to view the falls or continue upward to Van Trump Park. Day hikers access the trail from a trailhead near Christine Falls on the Longmire-Paradise Road. Parking capacity at the trailhead is 26 vehicles but can overflow along access drives and roadway shoulders (BRW 1994).

The trail climbs steadily through mature forest along Van Trump Creek until it reaches the base of Comet Falls at 1.9 miles. From there it switchbacks .6 miles uphill to the junction with the Rampart Ridge Trail. Van Trump Park is to the right, where the trail winds through the meadows before ending in .5 miles.

Any simulation is a limited representation of reality. One of the primary limitations of the simulation model describing the Comet Falls Trail (and also of the models representing other transition trails) is the fact that it measures encounters between parties that are hiking, and does not count encounters that occur while one or both parties are stopped at a destination. Discussion below describes some reasons for accepting this limitation, but the issue is highlighted here so that readers are aware that the simulation model is focused on (and limited to) hiking encounters.

3.1 Description of Visitor Use: Comet Falls Trail

Studies of visitor use of the Comet Falls Trail include counts collected using electronic trail counters and itinerary information collected using waypoint surveys. The results of these studies are reported in the report titled *Visitor Use in the Management Zones of Mount Rainier National Park* (Vande Kamp 2009). These results describe use during the summer hiking season. Thus, summary statistics such as averages apply only to the summer hiking season. This seasonal limitation applies both to the studies of visitor use and the simulation model developed based on those studies.

For the purposes of modeling, the descriptive information of primary interest concerns the absolute number of hikers to be modeled, and the times at which they begin their hikes (i.e., the entry distribution). This section focuses on the absolute number of visitors using the trail and the distribution of entry times is discussed in the next section.

Trail counters record hiker passages. Thus, most day-hikers to Comet Falls will be counted twice. In addition, the model simulates the movements of hiking parties rather than individual hikers. Because of these factors, the trail counter results must be translated into counts of hiking parties. The method used to translate counts of hiker passages to counts of hiking parties is quite simple. Passages are first divided by 2, based on the assumption that each hiker passed the counter twice, and then divided by 3.24, the average party size recorded by the 2004 waypoint survey.

One potential problem with this method of estimating the number of hiking parties is that it mixes information from the waypoint survey, which includes only day-hikers, with the trail counter data, which include both day-hikers and backpackers. Given that the simulation should model interactions between all parties, not just day-hikers, and because there is little information available to support estimates of the number of backpackers or the times at which they hike this section of trail, the simulation includes a simplifying assumption that all use of the trail can be estimated by modeling backpackers in the same manner as day-hikers. This simplifying assumption incorporates three secondary assumptions: 1) the proportion of backpackers hiking the trail in each direction is approximately equal, 2) the party size of backpackers is not sufficiently different from 3.24 that it will invalidate the simulation results, and 3) the times that backpackers travel the trail are not sufficiently different from day-hikers that they will invalidate the simulation results. Informal reports by survey workers suggest that the number of backpackers was very small in relation to the number of day-hikers, probably because the Comet Falls Trail is not part of the Wonderland Loop. Thus, the listed assumptions concerning backpackers are thought to be appropriate.

The following use estimates are derived from the trail counts of hiker passages. Average use of the trail on weekdays is estimated to be 15 parties (47 hikers). On weekends, average use is estimated to be 32 parties (103 hikers). Busy days are commonly represented by selecting the level of use on the day that was busier than 95 percent of all the observed days. Use on this 95th percentile day is estimated to be 44 parties (142 hikers).

The prevalence of off-trail hiking among day-hikers can have important implications for the estimation of encounters between parties based on simulation models. It is much simpler to estimate the encounters between parties using a linear trail system than encounters when parties are moving at random across the landscape. Informal observation suggests that the physical characteristics of the Comet Falls trail make off-trail hiking difficult and rare in most locations other than the immediate vicinity of the falls and in Van Trump Park beyond the end of the official trail. Based on these observations, the simulation model incorporates a simplifying assumption that all hiking parties remain on the official trail, and no attempt is made to incorporate off-trail routes into the simulated itineraries. The precise effect of this assumption on the model estimates of encounters between parties is unknown. However, the simulation model includes pauses for hikers at the two areas in which off-trail hiking is thought to be most likely. Thus, encounters in those areas are, effectively, defined out of the simulation. Because Comet Falls is a focal attraction of the hike, encounters with off-trail hikers in the immediate vicinity of the falls may be qualitatively different than encounters while hiking along the trail. If they are qualitatively different, it makes sense to exclude them from the simulation, but also suggests that such encounters may merit future studies concerning their impact on the visitor experience.

3.2 Entry Distribution: Comet Falls Trail

The second type of descriptive information essential for building simulation models is the frequency distribution of hikers entering the trail across the time of day. The fact that trail counters do not differentiate between hikers moving in different directions on the trail also complicates the estimation of these entry distributions. For example, the figure below shows the hourly distribution of hiker passages recorded on weekdays and weekends by the electronic trail counter located near the trailhead. Without additional information about rates of visitor entry, the overlap between the entry and exit distributions makes it impossible to determine the hourly distribution of only those visitors who are beginning their hikes.

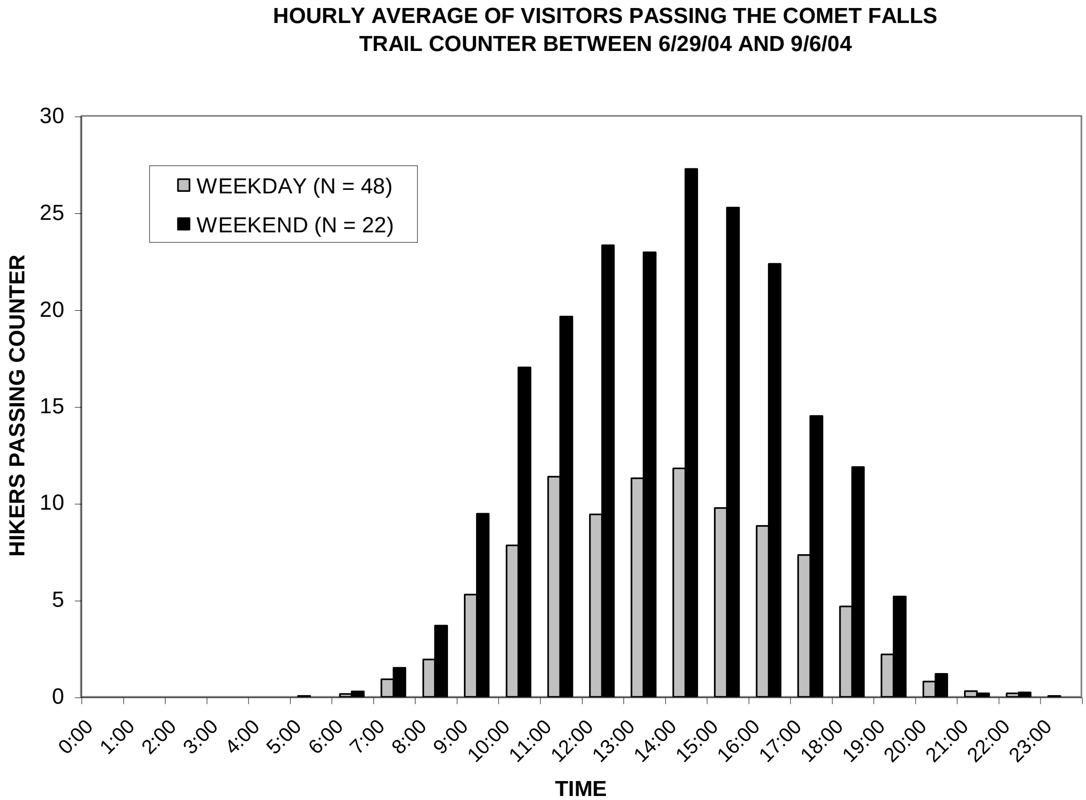

Figure 12. Hourly weekend and weekday distributions of visitors passing the Comet Falls trail counter (near the trailhead) in 2004.

The waypoint surveys provide an additional source of information to be used in combination with the trail counter data to estimate entry distributions. Because the waypoint surveys were given only to hikers beginning their hikes, and included the time of contact, entry distributions are available for the hours when the surveys were conducted. Extrapolating to earlier hours based on the trail counter data, a full distribution can be estimated.

The figure below shows the hourly distribution of hiking parties that were contacted during the 2004 waypoint surveys.[2] Because surveys were conducted between 8:00 and 6:00, this distribution can not serve as the full entry distribution for the simulation. Thus, we must also consider the possibility of hikers entering before and after the observed period.

[2] At Comet Falls, the number of days surveyed in the waypoint study was not thought sufficient to accurately describe separate weekday and weekend distributions.

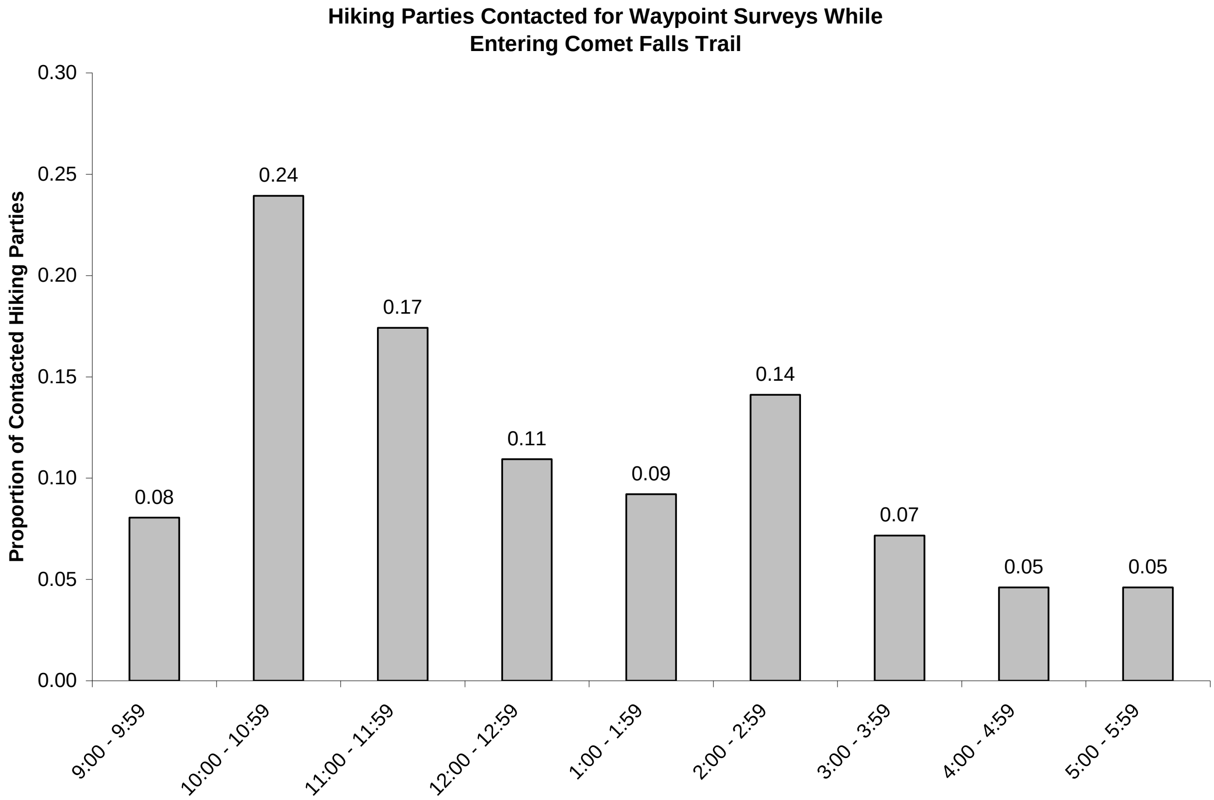

Figure 13. Hourly proportion of parties contacted for waypoint surveys on the Comet Falls Trail in 2004.

Use before 9:00 is estimated based on the trail counter data. If we assume that all counts prior to 9:00 record hikers entering the trail, then we can estimate entries between 8:00 and 9:00 to be 50 percent of the entries between 9:00 and 10:00. Likewise, entries between 7:00 and 8:00 can be estimated as 37 percent of the entries between 9:00 and 10:00. Based on the extremely low number of passages recorded by the trail counter prior to 7:00, a simplifying assumption is made that no hikers enter prior to that time.

The proportion of hiking parties contacted for the waypoint surveys between 4:00 and 6:00 was very low, and was thought unlikely to increase in later hours based on informal observation of the trailhead and the pattern of data recorded by the trail counter. Thus, a simplifying assumption is made that no hiking parties enter the trail after 6:00.

The figure below shows the entry distribution initially used in constructing the simulation model of visitor use on the Comet Falls Trail. The distribution is represented in terms of the proportion of visitors entering during each hour because the simulation might be run with different total numbers of hiking parties entering. The distribution of hiker passages recorded by the trail counter during the same hours in 2004 is included in the figure for comparison purposes.

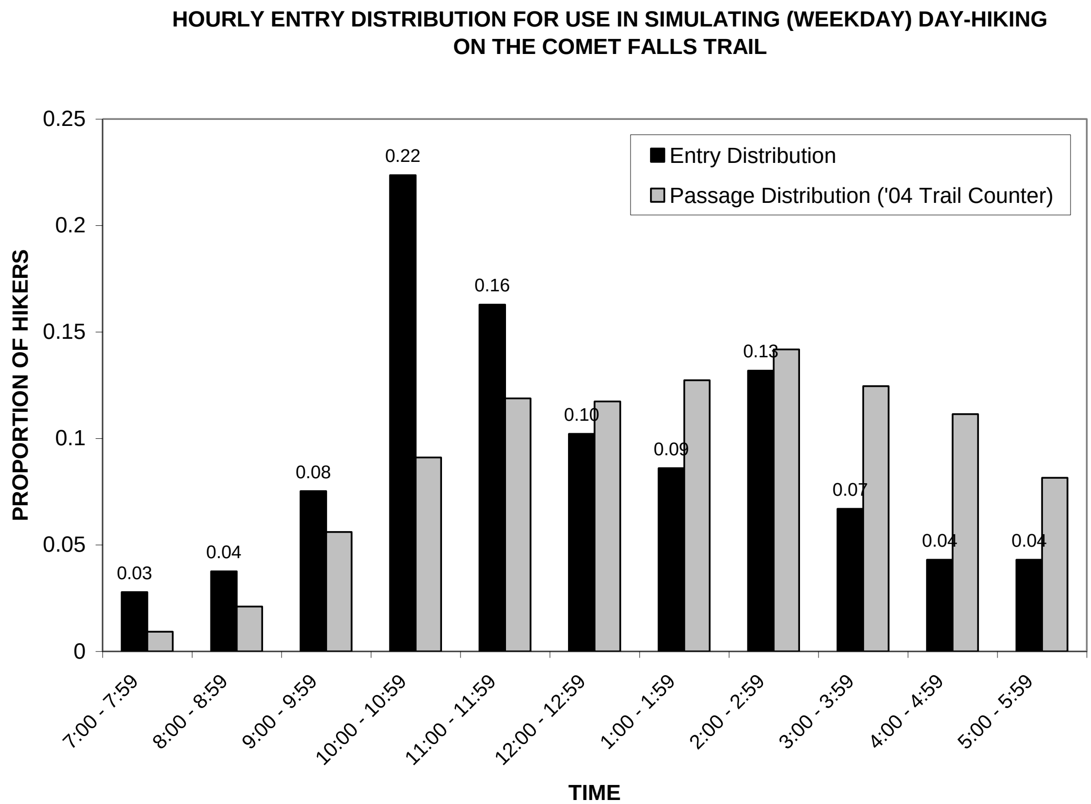

Figure 14. Hourly distribution of visitors entering the Comet Falls Trail initially used in computer simulation model (2004 visitor passage distribution included for comparison).

Validity tests of the simulation results suggested that this entry distribution was better suited to estimating weekday use than weekends (see Section 3.6 below). Thus, the process of defining an entry distribution was repeated, this time focusing only on the waypoint results from weekend days. This was not done initially because of the small number of weekend days sampled during the waypoint study (i.e., 6). However, it was thought appropriate to accept the low statistical power in light of the validity test results, and to construct a new entry distribution for use in simulating weekend use. The initial distribution shown above was used to simulate weekday use.

The figure below shows the entry distribution used in the simulation model of weekend visitor use on the Comet Falls Trail. The distribution is represented in terms of the proportion of visitors entering during each hour because the simulation might be run with different total numbers of hiking parties entering. The distribution of hiker passages recorded by the trail counter during the same hours in 2004 is included in the figure for comparison purposes.

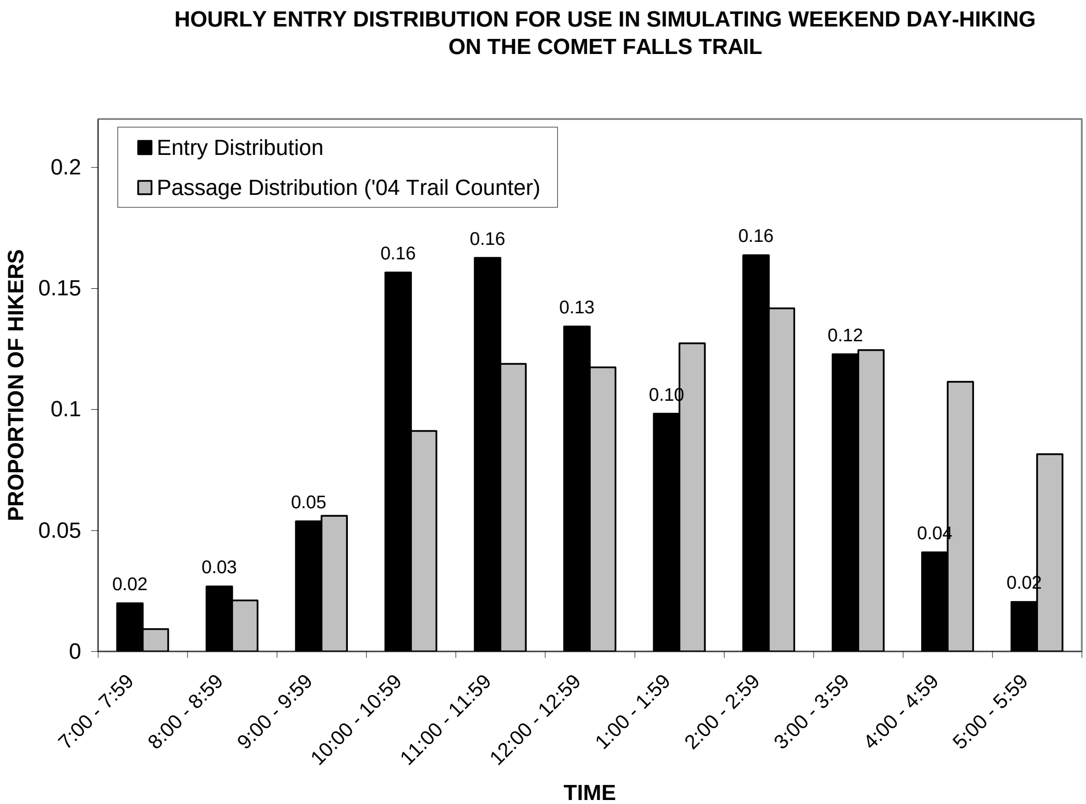

Figure 15. Hourly distribution of visitors entering the Comet Falls Trail for use in computer simulation model (2004 visitor passage distribution included for comparison).

3.3 Pauses/Stops: Comet Falls Trail

One aspect of visitor itineraries that was not described by the data collected in the waypoint studies was the amount of time that visitors were not actually hiking along the trail. Informal observation (and common sense) demonstrates that most visitors do not hike constantly, but stop to rest, eat or drink, or simply view the scenery. If the model is to provide useful information, it can not completely disregard those pauses or stops.

Because of the limited information available to estimate where and for how long visitors stopped, a number of simplifying assumptions were made in the representation of pauses and stops in this simulation model. The most important of these is that in the model, stops only occur at one location, Comet Falls. Even casual observation of visitors' behavior on the Comet Falls Trail shows that this assumption is commonly violated. However, the implications of this assumption are only critical if they substantially alter the number of hiking encounters between parties. Observation suggests that the short pauses made by visitors are unlikely to substantially alter the number of encounters between parties because faster hikers are likely to pass slower hikers regardless of short pauses. Longer stops are a different matter, but are also unlikely to invalidate the model. Recall that the model is intended to describe encounters that occur when both parties are hiking. Having all parties pause at the same location (for varying durations) would certainly inflate the number of non-hiking encounters that would occur while the parties were all bunched up in that location. However, it should have little or no effect on the number of encounters that occur while both parties are hiking.

One factor that will affect the number of hiking encounters is the amount of time that simulated hiking parties spend stopped at the falls. Although we did not ask hikers how many minutes they were not hiking during their visit, we can estimate that information based on information collected in the waypoint survey. Waypoint E was located close to, but before, Comet Falls (see Figure below). If we assume that those parties who passed waypoint E, but not waypoint F, did not hike beyond the vicinity of Comet Falls, then the difference between the two times recorded for waypoint E can be used to estimate the duration of the stop at Comet Falls. Based on this estimation procedure, stops at Comet Falls averaged 32.4 minutes with a standard deviation of 44.3 minutes.

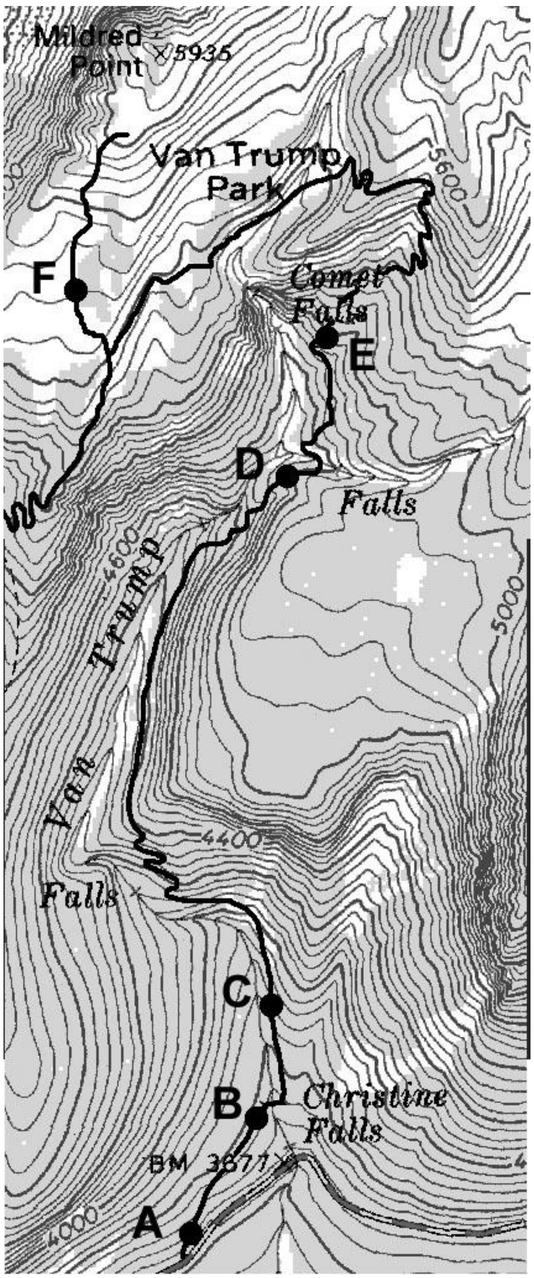

Figure 16. Locations of waypoint signs for Comet Falls Waypoint Survey.

The area in which hiker movement is simulated ends where the official trail enters Van Trump Park (i.e., waypoint F). However, the model must include some provision for accurately representing the time some parties spent hiking beyond that point. This is done by representing that hiking time as a stop at point F. The duration of this stop is estimated based on the time difference parties recorded between their first and second time passing the waypoint. These durations averaged 68.6 minutes with a standard deviation of 42.7 minutes. This procedure constitutes a limitation of the model, because no encounters are simulated or recorded for parties hiking beyond the entrance of Van Trump Park. However, there are not likely to be many encounters between the relatively small number of parties who hike that far.

3.4 Hiking Speeds: Comet Falls Trail

Another factor that has a large effect on the number of encounters between hiking parties in the simulation is the speed (and range of speeds) at which hiking parties move along the simulated trail. This effect is obvious when one considers that hikers encounter parties that are: a) moving in the opposite direction, and b) moving in the same direction. The relative speed of the parties has a relatively small effect on the first type of encounter, but it has a large effect on the second type. To illustrate, imagine that all parties hike at the same speed – they would maintain perfect separation and never overtake each other. In contrast, if some parties hike much faster than others, then they will overtake many of the slower parties ahead of them.

Actual hiking speeds can be calculated from the waypoint study data and used in building the simulation model. In order to minimize the effects of stops and pauses on those speeds, only the trail segments prior to Comet Falls were used in the speed calculations. For each party that reached the falls, the total time that they spent between the trailhead and the shelter (i.e., between waypoints A and E) in both directions was divided by the distance between those points in order to calculate a hiking speed. Using this procedure, the average hiking speed was 2.11 kilometers per hour with a standard deviation of 0.47. This speed was considerably slower than that observed at Summerland, probably because the trail is considerably steeper and because it is used by more casual hikers.

The RBSim software does not currently allow random assignment of hiking speeds to parties. However, different types of hikers can be defined – each with a different hiking speed. For this simulation, four types of hiking parties were defined. The hiking speeds of each party type, and the number of parties assigned to each type were designed to produce a distribution of hiking speeds that approximated the distribution described by the waypoint survey.

The range of speeds found in the sample distribution were divided into four, roughly-equal intervals and the proportion of hiking parties within each interval was determined by examining the frequency table of hiking speeds. Based on this analysis, the simulation model assigned the following four hiking speeds to the indicated proportion of hiking parties:

Speed (kph)	Proportion of Hiking Parties
1.43	0.214
1.89	0.238
2.17	0.310
2.73	0.238

Table 3. Proportion of simulated hiking parties assigned to four hiking speeds in the Comet Falls computer simulation model.

Hiking speeds were not randomly distributed across all hiking parties in the waypoint survey. Accordingly, the four hiking speeds listed above were assigned to the range of actual speeds recorded by hiking parties. Thus, parties in the simulation do not travel at the exact speed that they recorded on the waypoint card, but do travel at a speed selected from four alternatives to best represent their recorded speed.

3.5 Assumptions, Simplifications, and Limitations: Comet Falls Trail

The characteristics of the simulation described in this section have all been discussed in the earlier descriptions of the simulation model, its parameters, and how it was developed. These characteristics are summarized here (in approximate order of their importance) to ensure that readers are aware of them (particularly the limitations) before reading and interpreting the simulation results.

The first limitation of the simulation is that its results describe only use that occurs during the summer (i.e., all or mostly snow-free) hiking season.

A second limitation is that the simulation measures only encounters between parties that occur while both parties are hiking on the official trail between the trailhead and the way-trail to

Van Trump Park during the summer hiking season. The simulation does not count encounters that occur while one or both parties are, a) stopped at a destination, b) hiking off the official trail, or c) hiking beyond waypoint F on the way-trail to Van Trump Park.

A third limitation of the simulation is that although the number of parties entering is based on counts of both backpackers and day-hikers, the behavior of the simulated parties is based only on day-hikers and no distinction is made between types of parties when counting encounters. This limitation is probably of lesser importance for Comet Falls than for the other transitions trails modeled for this document because a smaller proportion of users are backpackers.

A number of simplifying assumptions were made in the course of designing the simulation. The extent to which these assumptions limit the generality of the simulation results is probably small. The assumptions include: a) all hiking parties entered between 7:00 A.M and 6:00 P.M., b) all stops by hiking parties were represented by a single stop when parties first reached Comet Falls, c) the average duration of stops at Comet Falls was the same for all hiking parties, d) parties that reached Comet Falls but did not reach Van Trump Park did not hike beyond the vicinity of Comet Falls, e) the continuous range of actual hiking speeds was represented by a set of four discrete speeds.

3.6 Validation: Comet Falls Trail

The primary reason for simulating day-hiking on the Comet Falls Trail was to estimate the number of encounters between hiking parties. Thus, the best test of simulation validity would be to systematically record the number of actual encounters and compare those counts to the simulation estimates for days when a comparable number of hiking parties enter the trail. However, systematic counts of actual encounters have not been collected at this point in time.[3] In their absence, two other comparisons were used to assess the validity of the simulation.

The first assessment of the simulation validity was made by comparing the temporal distribution of the counts actually registered by the trail counter to the temporal distribution of simulated parties passing that same location. Because the data from the trail counter were used in designing the entry distribution for the simulation[4], the data do not provide a fully independent test of the degree to which the hiking behavior of the simulated day-hiking parties corresponded to day-hikers' actual behavior. Nonetheless, the correspondence between the simulation and the observed data fosters can increase confidence in the validity of the simulation. The figures below includes bars showing two temporal distributions, 1) the distribution of simulated day-hiking parties, averaged across 30 simulated average weekdays or weekend days; and 2) the distribution of actual hikers observed in 2004 on weekdays or weekend days.

---

[3] High priority should be placed on model validation based on direct counts of hiking encounters. Such data constitute the best test of the model and might be efficiently collected using volunteer observers.

[4] The use of the trail counter data was limited – they were used as a basis for extrapolating waypoint study data to the time period from 7:00 to 9:00.

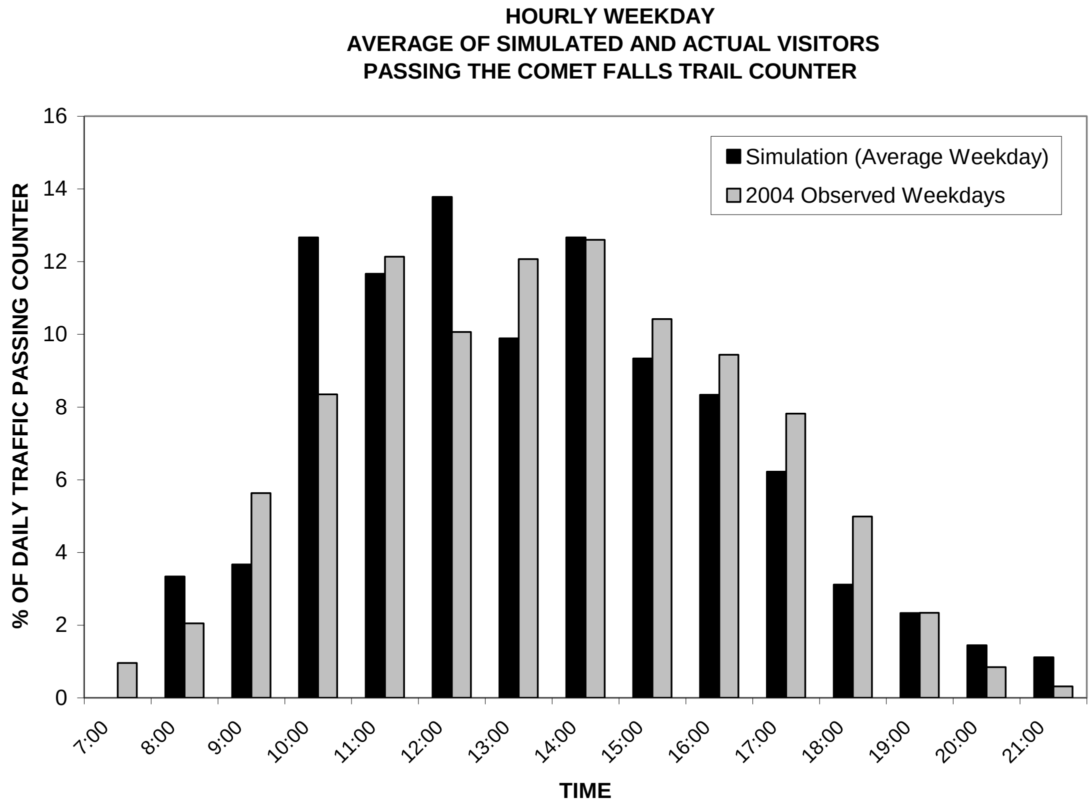

Figure 17. Simulated and observed distributions of visitors passing the Comet Falls trail counter on weekdays – initial simulation model.

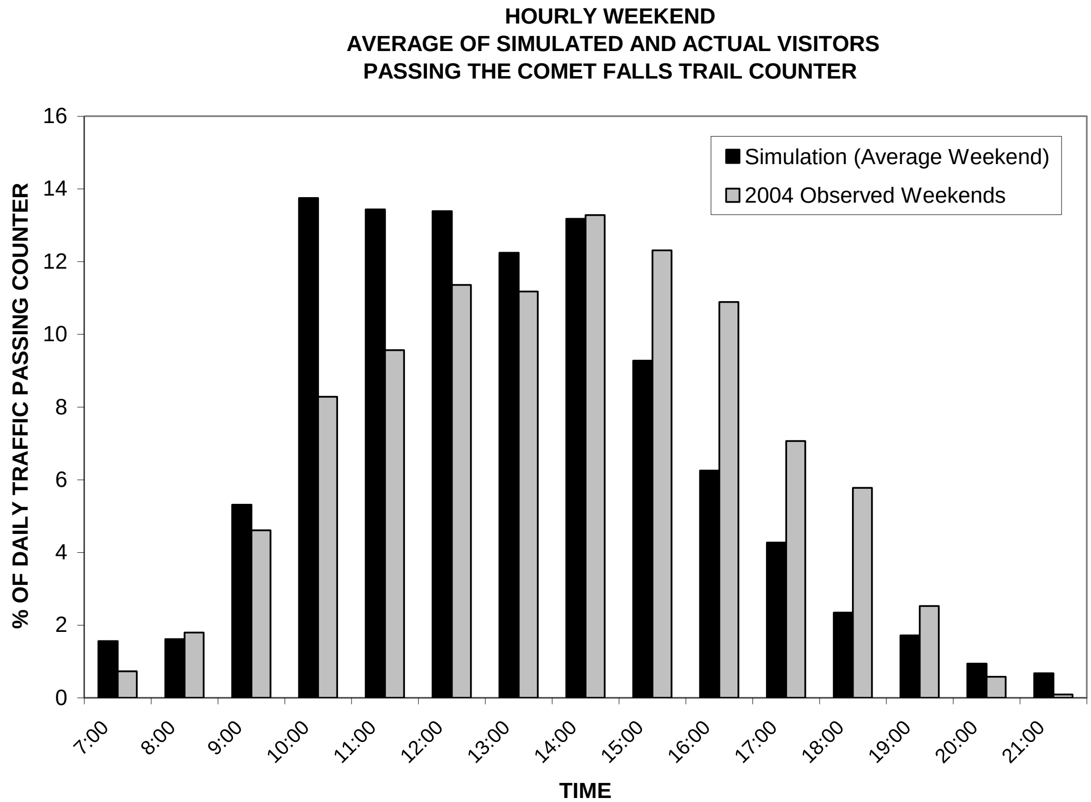

Figure 18. Simulated and observed distributions of visitors passing the Comet Falls trail counter on weekend days – initial simulation model.

Visual inspection of the temporal distributions showed that on weekends, the visitor passages for the simulation and observed distributions differed considerably, whereas the weekday distributions were quite similar. Given that the primary purpose of the simulation model was to estimate encounters during peak times, the entry distribution used in simulating weekends was recalculated based only on waypoint data collected only on weekends (see Section 3.2 above). The figure below includes the temporal distributions of, 1) day-hiking parties simulated using the recalculated entry distribution, and 2) actual day-hikers observed in 2004 on weekend days.

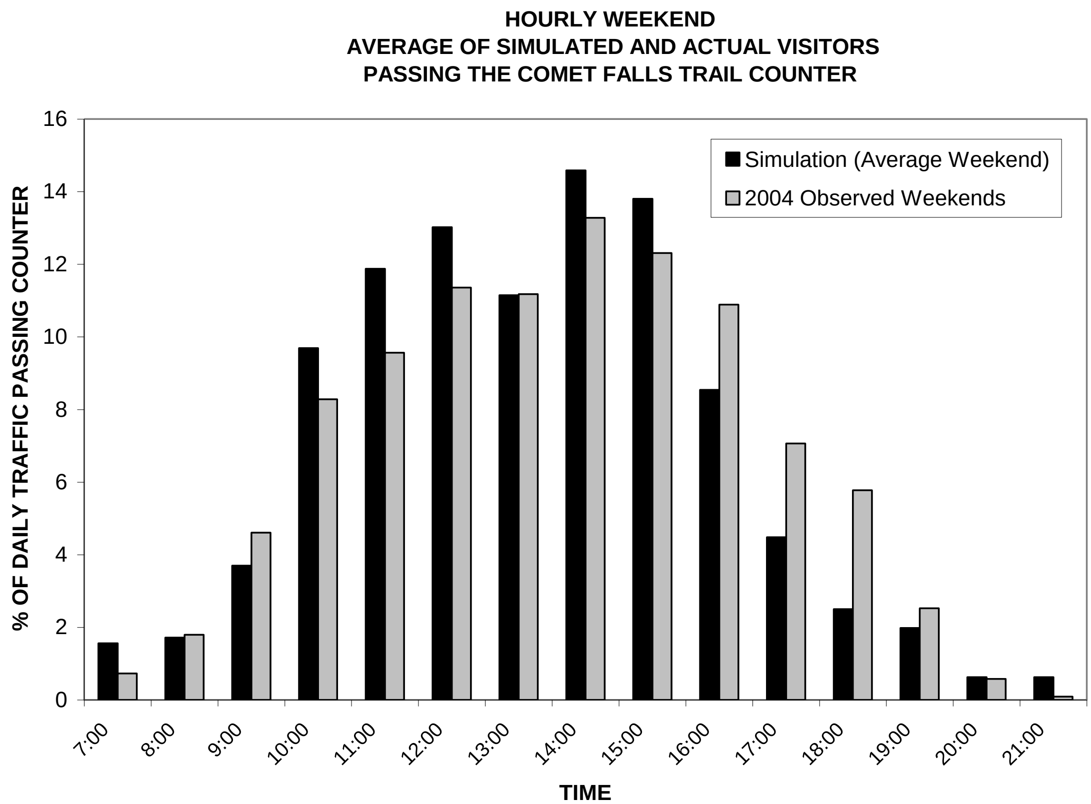

Figure 19. Simulated and observed distributions of visitors passing the Comet Falls trail counter on weekend days – final simulation model.

The figure shows that the recalculated distribution of simulated weekend hikers corresponded much more closely with the observed distribution. The distribution of simulated hikers appears to be shifted slightly left, toward earlier times. However, this should have little or no effect on the number of encounters between hiking parties. In any case, the discrepancies between the simulated and observed percentages for each hour on weekends were small, ranging from 0.03 to 3.28 percent, and the average discrepancy was only 1.29 percent. The corresponding discrepancies on weekdays were slightly larger, ranging from 0.00 to 4.32 percent, with an average discrepancy of 1.47 percent. In general, the simulation of weekends and weekdays corresponded closely with the data recorded by the trail counter.

A second assessment of validity compared the duration of the simulated day-hikes to the actual durations collected during the waypoint survey. Although the simulation was designed using information from the waypoint survey, the duration of simulated hikes was based on hiking speed and duration of stop calculations that did not make use of the total hike durations from the waypoint survey. The table below includes the averages and standard deviations for simulated and observed hike durations.

	Average Duration	Standard Deviation
Simulation	133	82
2004 Waypoint Study	139	88

Table 4. Duration of simulated and observed hikes (in minutes).

The average and standard deviation for trip durations in the simulation were very similar to those observed in 2004. Examination of the simulated and observed trip durations suggested that the small difference in the average duration (4.3%) was probably due to minor variations in the number of longer trips (note that longer trips have a disproportionate effect on the average duration). Also, the difference in the standard deviations was primarily due to decreased variability in the duration of stops at Comet Falls, and was thus unlikely to substantially alter estimates of hiking encounters. Given that the simulation was intended to record hiking encounters that were minimally affected by small differences in trip duration or variability in stop durations, these discrepancies were deemed acceptable. In general, the average hike duration in the simulation corresponded closely with data that were recorded on at least a semi-independent basis during the waypoint study.

3.7 Simulation Results: Comet Falls Trail

This section describes three sets of results corresponding to simulation of a 95th percentile day, an average weekend day, and an average weekday. Each set of results is based on 30 iterations of the simulation model. This number of iterations was selected based on a method described by Itami, Zell, Grigel, and Gimblett (2005). In this method, a "short run" of the simulation is used to estimate the variability in one or more outcome measures, and that variability is used in calculations that determine the number of iterations necessary to reach a desired level of precision in the simulation results. In this case, the desired level of precision in estimating the average number of total encounters was a 95-percent confidence interval of plus-or-minus 1.5 encounters for the "95th percentile day" simulation. A "short run" of 15 iterations found that the variance in total encounters was 23.72, and that 30 iterations of the simulation would yield the desired precision. For the "average weekend" and "average weekday" simulations, 30 iterations produced even narrower confidence intervals, but the gain in precision was useful given the smaller values for total encounters estimated for those conditions.

3.7.1 Trail Encounters on a 95th Percentile Day

The 95th percentile day is one measure of what might be called "peak use". In most use distributions, a few extraordinary days lie far outside the normal range of use. Although managers may be concerned about the impact of such days, they generally fall outside the realm of general planning. For the purposes of the MORA VERP team, it was thought appropriate that simulation of peak use should focus on the use level higher than 95 percent of days, and lower than the 5 percent of busiest days. For the Comet Falls Trail, use on this 95th percentile day was 44 parties (see Section 3.1 above).

As described above, the simulation model was run 30 times in order to produce a 95-percent confidence interval for total daily encounters of plus-or-minus 1.5 encounters.

Total encounters. On average, simulated hiking parties encountered 10.4 other parties.

The figure below shows the distribution of total encounters for the 1,320 simulated parties.

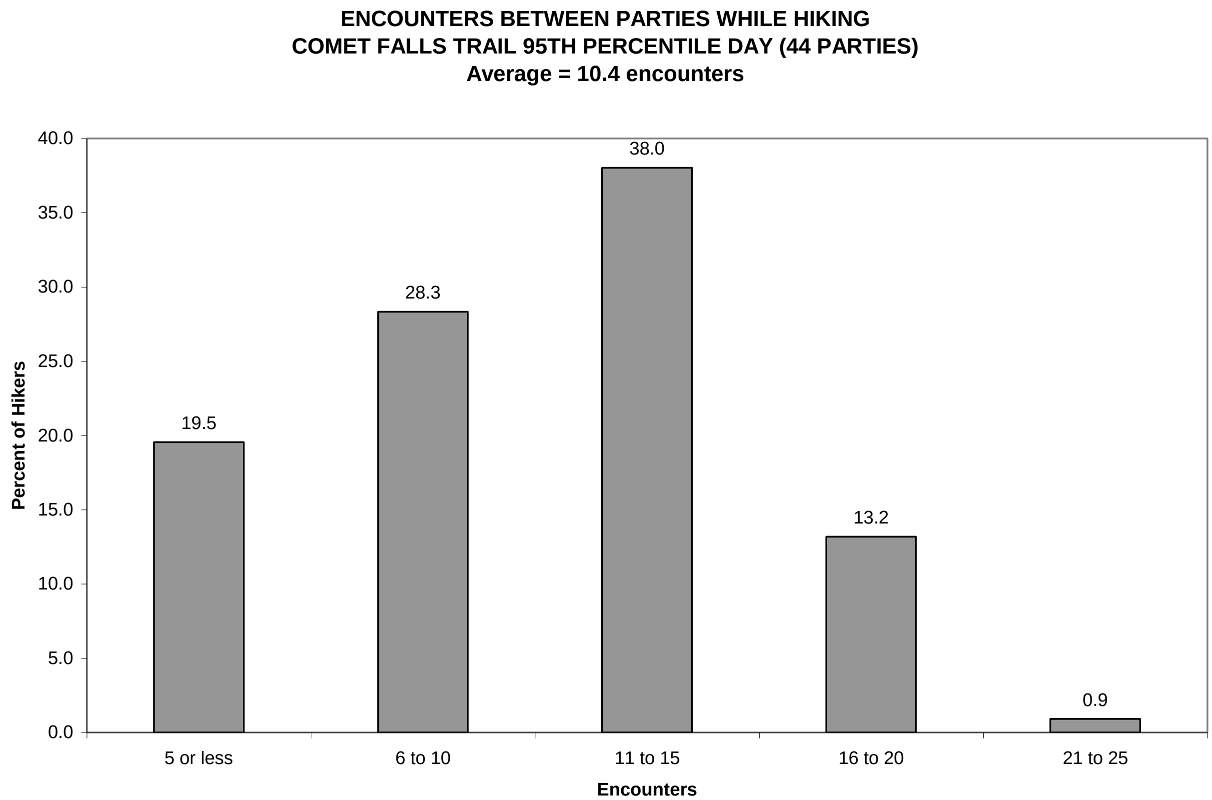

Figure 20. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on a 95th percentile day (44 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 6.3 other parties per hour. The figure below shows the distribution of encounters per hour for the 1,320 simulated parties.

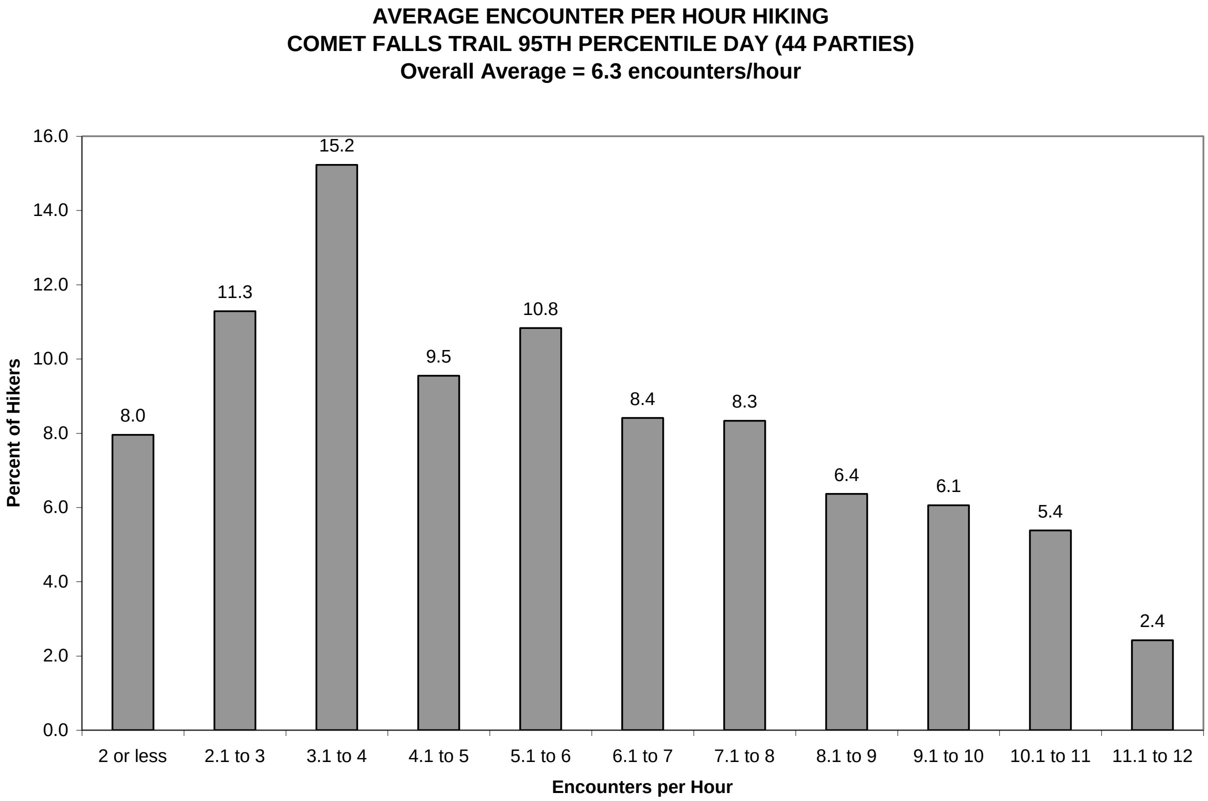

Figure 21. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on a 95th percentile day (44 total parties).

Given that parties that reached Van Trump Park had trip durations that averaged 239 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 25.1 ([239/60] * 6.3). This figure is more than twice as large as the average of 10.4 encounters for all parties, primarily because most hikers do not reach Van Trump Park and spend a considerably shorter time hiking the Comet Falls Trail.

3.7.2 Trail Encounters on an Average Weekend Day

The 95th percentile day provides a useful description of peak use, but the difference between peak use and more routine use levels can also be informative. In this section we estimate the number of hiking encounters between parties on the Comet Falls Trail during an average weekend day. Use on such an average weekend day was 32 parties (see Section 3.1 above).

As described in section 3.7 above, the simulation model was run 30 times. In this case, 30 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 1.1 encounters.

Total encounters. On average, simulated hiking parties encountered 7.2 other parties. The figure below shows the distribution of total encounters for the 960 simulated parties.

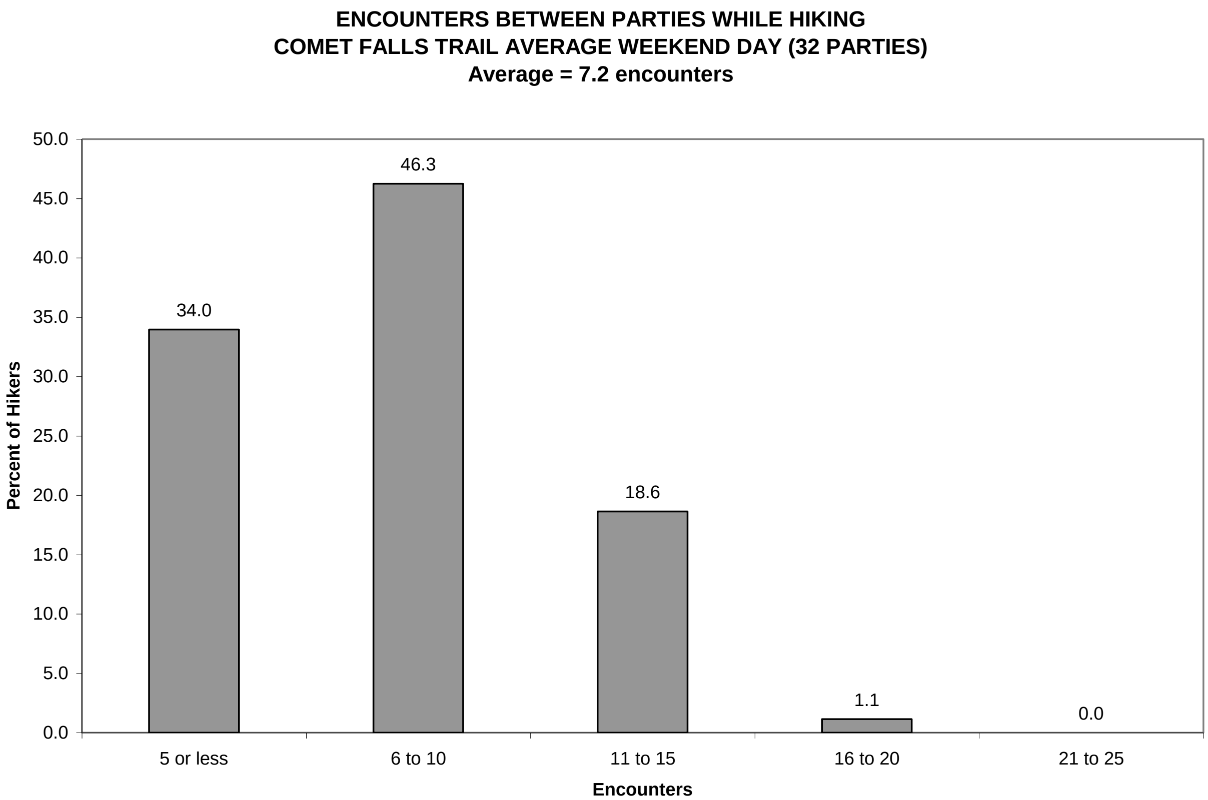

Figure 22. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekend day (32 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 4.4 other parties per hour. The figure below shows the distribution of encounters per hour for the 960 simulated parties.

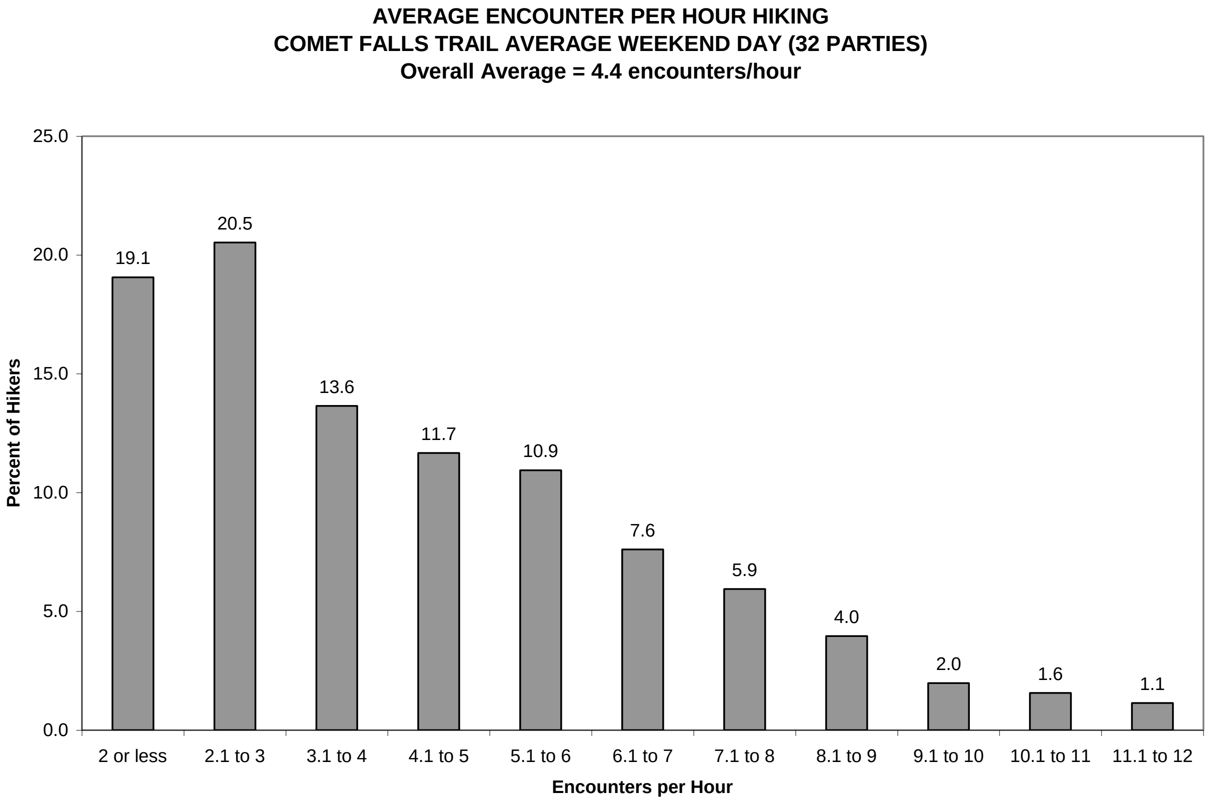

Figure 23. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekend day (32 total parties).

Given that parties that reached Van Trump Park had trip durations that averaged 239 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 17.5 ([239/60] * 4.4). This figure is more than twice as large as the average of 7.2 encounters for all parties, primarily because most hikers do not reach Van Trump Park and spend a considerably shorter time hiking the Comet Falls Trail.

3.7.3 Trail Encounters on an Average Weekday

One final routine use level was simulated in order to provide additional information. In this section we estimate the number of hiking encounters between parties on the Comet Falls Trail during an average weekday. Use on such an average weekday was 15 parties (see Section 3.1 above).

As described in section 3.7 above, the simulation model was run 30 times. In this case, 30 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 0.6 encounters.

Total encounters. On average, simulated hiking parties encountered 3.0 other parties. The figure below shows the distribution of total encounters for the 450 simulated parties.

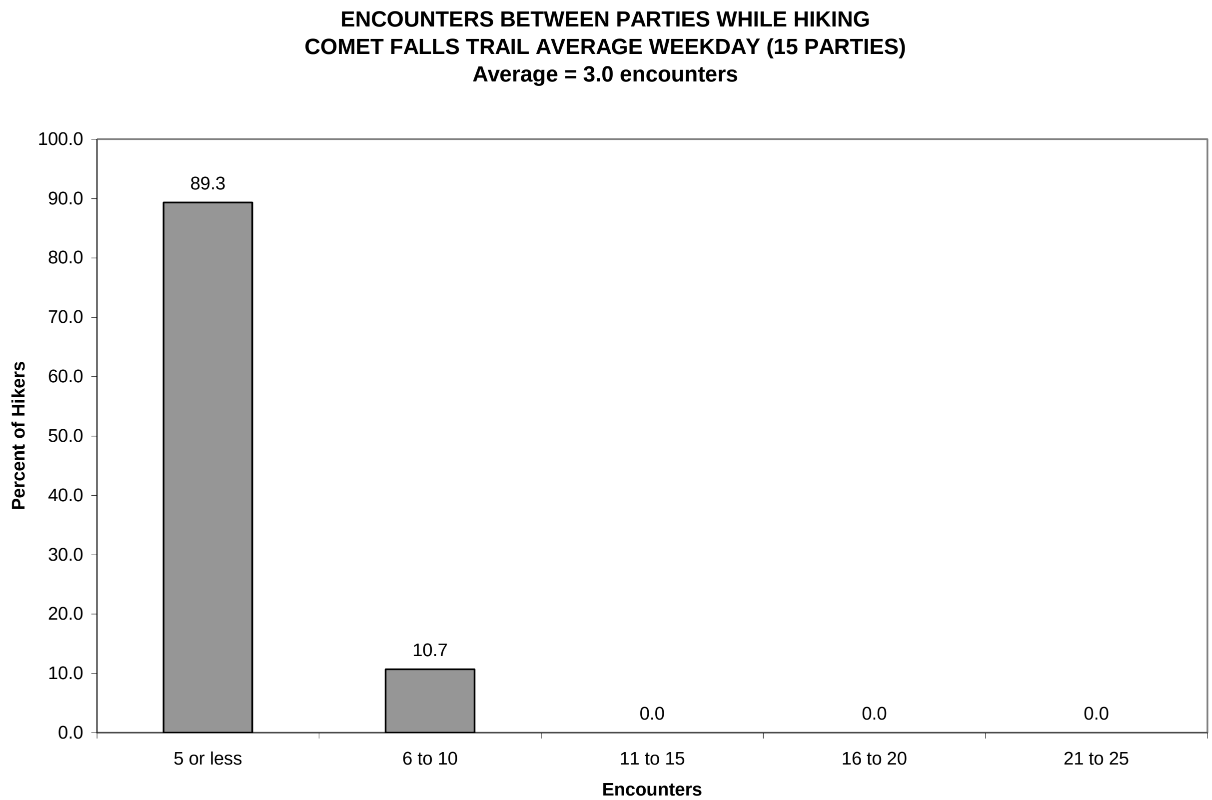

Figure 24. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekday (15 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 1.7 other parties per hour. The figure below shows the distribution of encounters per hour for the 450 simulated parties.

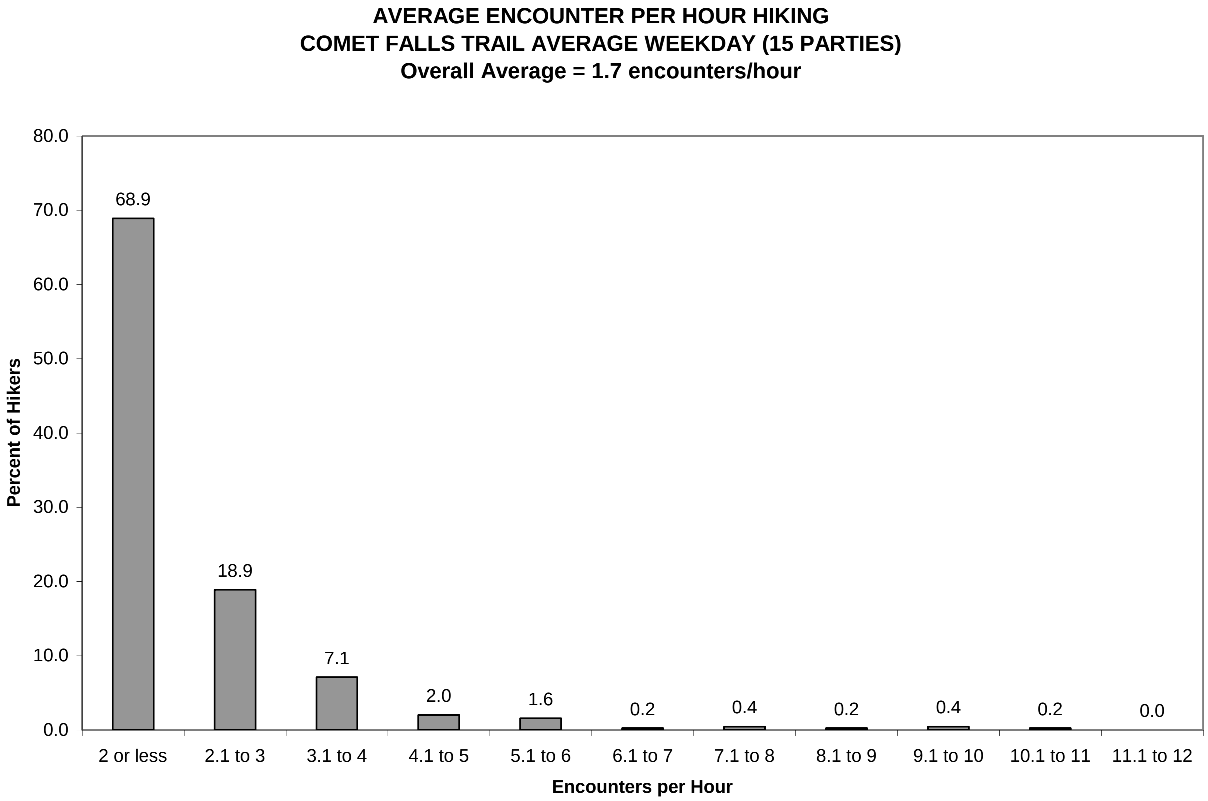

Figure 25. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekday (15 total parties).

Given that parties that reached Van Trump Park had trip durations that averaged 239 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 6.8 ([239/60] * 1.7). As in the 95th percentile and weekend simulations, this figure is more than twice as large as the average for all parties (3.0 encounters), primarily because most hikers do not reach Van Trump Park and spend a considerably shorter time hiking the Comet Falls Trail.

3.7.4 Trail Encounters and Use Levels

The number of encounters between hiking parties estimated using the simulation of the Comet Falls Trail showed a nearly perfect linear relationship with the number of hiking parties that were put into the simulation (r = .999; Average Total Encounters equals approximately 0.22 * Daily Hiking Parties). The strength of the correlation is unsurprising in retrospect, given that the simulation uses the same pool of hiking itineraries in proportions that are identical for the 44, 32-party simulations, and nearly identical for the 15-party simulations. However, the relationship is not entirely an artifact of the simulation procedure. The waypoint studies showed little evidence that hiking itineraries were dramatically different at high and low use levels, and in the absence of such differences, encounters should be determined entirely by the number of hiking parties. The strength of the relationship between encounters and use levels provides a strong argument that visitor counts can be used to monitor encounters between hiking parties and to thereby monitor conditions related to desired visitor experiences.

3.7.5 Encounters per Hour on Distal Trail Segments

Modeling the Comet Falls Trail provides information about use levels on a particular trail in the Transition Trail zone, but can also provide information relevant to the Semi-primitive Trail zone. Currently, the Comet Falls Trail enters the Semi-primitive Trail zone immediately after Comet Falls. This change in zoning corresponds quite closely with the simulation model of current use patterns – the trail segment beginning less than 400 meters from Comet falls averaged 3.1 encounters per hour during simulated 95th percentile days.

3.7.6 Parties at One Time at Comet Falls

The Comet Falls Trail is somewhat unusual among MORA day-hiking trails in that it has an attraction located at a very small geographic location (i.e., Comet Falls) that is the destination and experiential focus of many hikes. Although the simulation was developed primarily to estimate hiking encounters between parties, it can also provide estimates of the number of hiking parties that are likely to be present at comet falls. The figure below shows the hourly averages for parties-at-one-time at Comet Falls for the different conditions that were simulated.

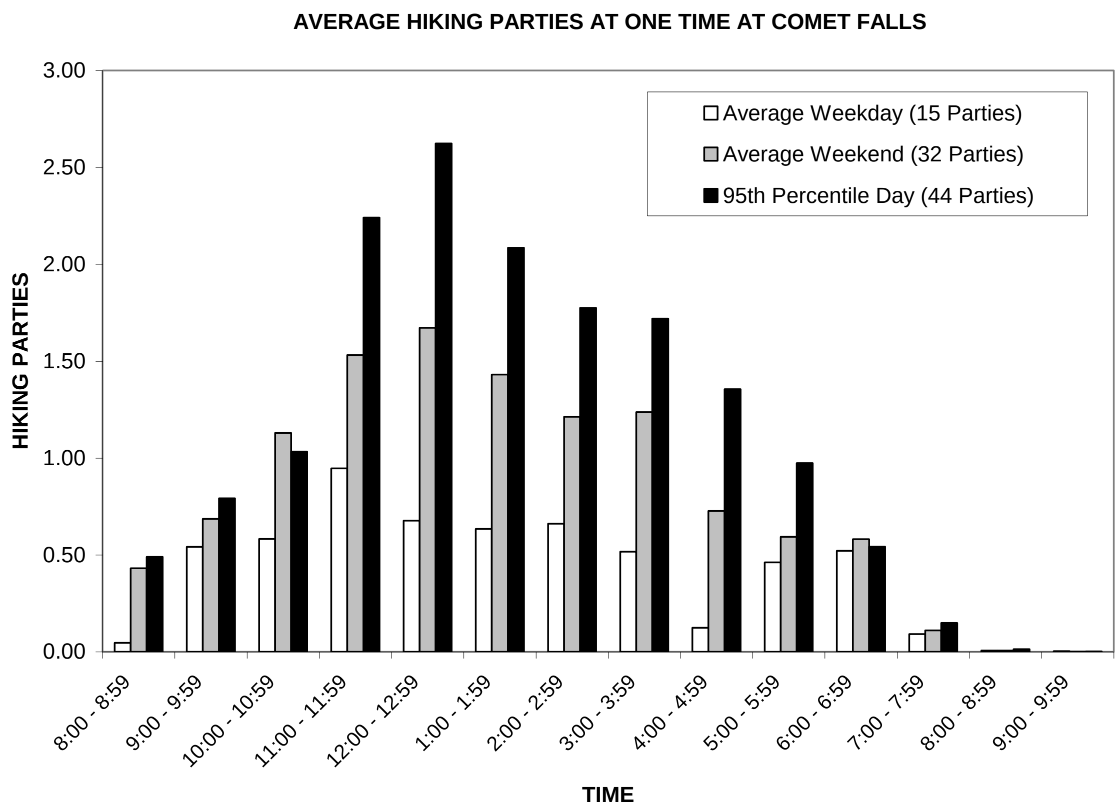

Figure 26. Number of hiking parties at one time at Comet Falls averaged across 50 simulations of a 95th percentile day, average weekend day, and average weekday.

During the busiest hour on weekends (12:00 to 12:59), an average of 2.62 parties were present on 95th percentile days and 1.67 parties were present on average weekend days. On average weekdays, the average parties-at-one-time was never greater than 1, suggesting that on weekdays, many parties had the opportunity to be alone at Comet Falls.[5]

[5] Validation of the estimated PAOT at Comet Falls could be validated by systematic counts of PAOT linked with electronic trail counts of hikers. If PAOT estimates are used in managers' decisions, such validation should be given a high priority.

4. SIMULATING THE SPRAY PARK TRAIL

The Spray Park Trail is a popular day-hiking destination in the northwest corner of MORA. Although it is not officially designated as part of the Wonderland Trail, it intersects the Wonderland Trail at each end and can be used by backpackers who wish to hike all or part of the Wonderland Trail loop. Day hikers access the trail from a trailhead near Mowich Lake at the terminus of the Mowich Lake Road. Parking capacity is limited primarily by the willingness of visitors to hike from their vehicles to the trailhead because parking along the road shoulder commonly extends for a considerable distance prior to the road terminus.

The Spray Park Trail is used to access Spray Falls and the subalpine meadows of Spray Park. From the trailhead, the trail descends .25 mile to a junction with the Wonderland Trail. The Spray Park Trail then continues east for two miles, up and down forested terrain, across Lee Creek and eventually to the junction with a spur trail to view Spray Falls. The next half mile to the first meadows of Spray Park is a steep climb up a series of switchbacks. More extensive meadows are found in another half mile.

Any simulation is a limited representation of reality. One of the primary limitations of the simulation model describing the Comet Falls Trail (and also of the models representing other transition trails) is the fact that it measures encounters between parties that are hiking, and does not count encounters that occur while one or both parties are stopped at a destination. Discussion below describes some reasons for accepting this limitation, but the issue is highlighted here so that readers are aware that the simulation model is focused on (and limited to) hiking encounters.

4.1 Description of Visitor Use: Spray Park Trail

Studies of visitor use of the Spray Park Trail include counts collected using electronic trail counters and itinerary information collected using waypoint surveys. The results of these studies are reported in the report titled *Visitor Use in the Management Zones of Mount Rainier National Park* (Vande Kamp 2009). These results describe use during the summer hiking season. Thus, summary statistics such as averages apply only to the summer hiking season. This seasonal limitation applies both to the studies of visitor use and the simulation model developed based on those studies.

For the purposes of modeling, the descriptive information of primary interest concerns the absolute number of hikers to be modeled, and the times at which they begin their hikes (i.e., the entry distribution). This section focuses on the absolute number of visitors using the trail and the distribution of entry times is discussed in the next section.

Trail counters record hiker passages. Thus, most day-hikers to Spray Park will be counted twice. In addition, the model simulates the movements of hiking parties rather than individual hikers. Because of these factors, the trail counter results must be translated into counts of hiking parties. The method used to translate counts of hiker passages to counts of hiking parties is quite simple. Passages are first divided by 2, based on the assumption that each hiker passed the counter twice, and then divided by 2.59 the average party size recorded by the 2004 waypoint survey.

One potential problem with this method of estimating the number of hiking parties is that it mixes information from the waypoint survey, which includes only day-hikers, with the trail counter data, which include both day-hikers and backpackers. Given that the simulation should model interactions between all parties, not just day-hikers, and because there is little information available to support estimates of the number of backpackers or the times at which they hike this section of trail, the simulation includes a simplifying assumption that all use of the trail can be estimated by modeling backpackers in the same manner as day-hikers. This simplifying assumption incorporates three secondary assumptions: 1) the proportion of backpackers hiking the trail in each direction is approximately equal, 2) the party size of backpackers is not sufficiently different from 2.59 that it will invalidate the simulation results, and 3) the times that backpackers travel the trail are not sufficiently different from day-hikers that they will invalidate the simulation results. Given the likelihood that the number of backpackers is relatively small in relation to the number of day-hikers, these assumptions are thought to be appropriate.

The following use estimates are derived from the trail counts of hiker passages.[6] Average use of the trail on weekdays is estimated to be 19 parties (49 hikers). On weekends, average use is estimated to be 58 parties (150 hikers). Busy days are commonly represented by selecting the level of use on the day that was busier than 95 percent of all the observed days. Use on this 95th percentile day is estimated to be 80 parties (207 hikers).

The prevalence of off-trail hiking among day-hikers can have important implications for the estimation of encounters between parties based on simulation models. It is much simpler to estimate the encounters between parties using a linear trail system than encounters when parties are moving at random across the landscape. Survey and observational data suggest that hiking off the official trail is much more common at Spray Park than at Summerland, with two-thirds of surveyed Spray Park visitors reporting that they left the official trail at some point during their visits (Vande Kamp, Johnson, and Swanson 1998). The waypoint survey data further suggest that off-trail hiking is only slightly concentrated on well-established way-trails, with only 3 and 8 percent of parties passing the waypoints located on two of the most prominent way-trails. Although the extent of off-trail hiking suggests that the simulation model should estimate encounters that occur off the official trail, the dispersed nature of that hiking makes it very difficult to do so. Trail encounters that occur on the short sections of the way trails leading to waypoint D and E in the 2004 waypoint study will be included in the model. However, due to the fact that we currently have no basis for describing or modeling other off-trail behavior of Spray Park hikers, the model also incorporates a simplifying assumption that all hiking parties otherwise remain on the official trail, and no attempt is made to incorporate other off-trail routes into the simulated itineraries. The precise effect of this assumption on the model estimates of encounters between parties is unknown. However, it is almost certain to produce underestimation of the total number of encounters between hiking parties, and that underestimation is likely to be larger for the Spray Park simulation than for simulations of areas in which hiking off the official trail is less common.

4.2 Entry Distribution: Spray Park Trail

The second type of descriptive information essential for building simulation models is the frequency distribution of hikers entering the trail across the time of day. The fact that trail counters do not differentiate between hikers moving in different directions on the trail also complicates the estimation of these entry distributions. For example, the figure below shows the hourly distribution of hiker passages recorded on weekdays and weekends by the electronic trail

[6] Because the Spray Park trail counter was installed for a relatively brief period of time, the figures for hiking use given here are not the directly measured observations of the trail counter, but predicted values based on a regression equation relating the number of vehicles entering the Nisqually and Stevens Canyon entrance to the daily counts made by the lower trail counter.

counter located near the trailhead. Without additional information about rates of visitor entry, the overlap between the entry and exit distributions makes it impossible to determine the hourly distribution of only those visitors who are beginning their hikes.

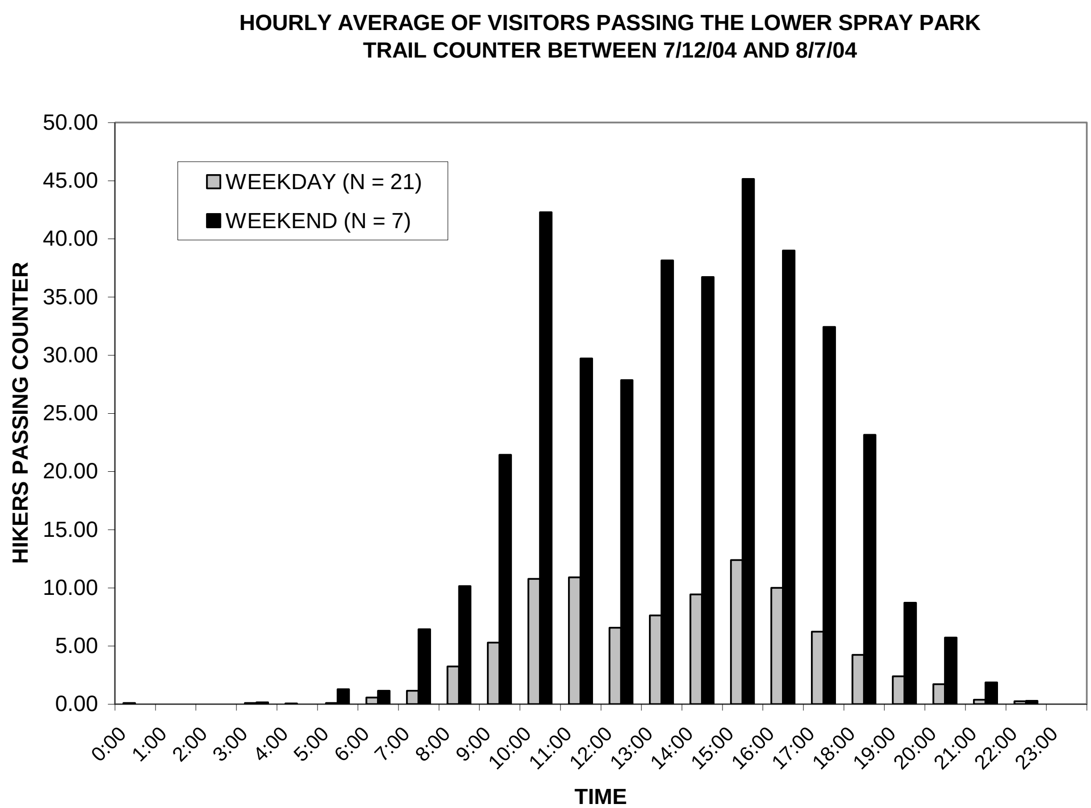

Figure 27. Hourly weekend and weekday distributions of visitors passing the lower Spray Park trail counter (near the trailhead) in 2004.

The waypoint survey provides an additional source of information to be used in combination with the trail counter data to estimate entry distributions. Because the waypoint survey was given only to parties beginning their hikes, and included the time of contact, entry distributions are available for the hours when the surveys were conducted. Extrapolating to earlier hours based on the trail counter data, a full distribution can be estimated.

The figure below shows the hourly distribution of hiking parties that were contacted during the 2004 waypoint survey. Because surveys were conducted between 9:00 and 5:00, this distribution can not serve as the full entry distribution for the simulation. Thus, we must also consider the possibility of hikers entering before and after the observed period.

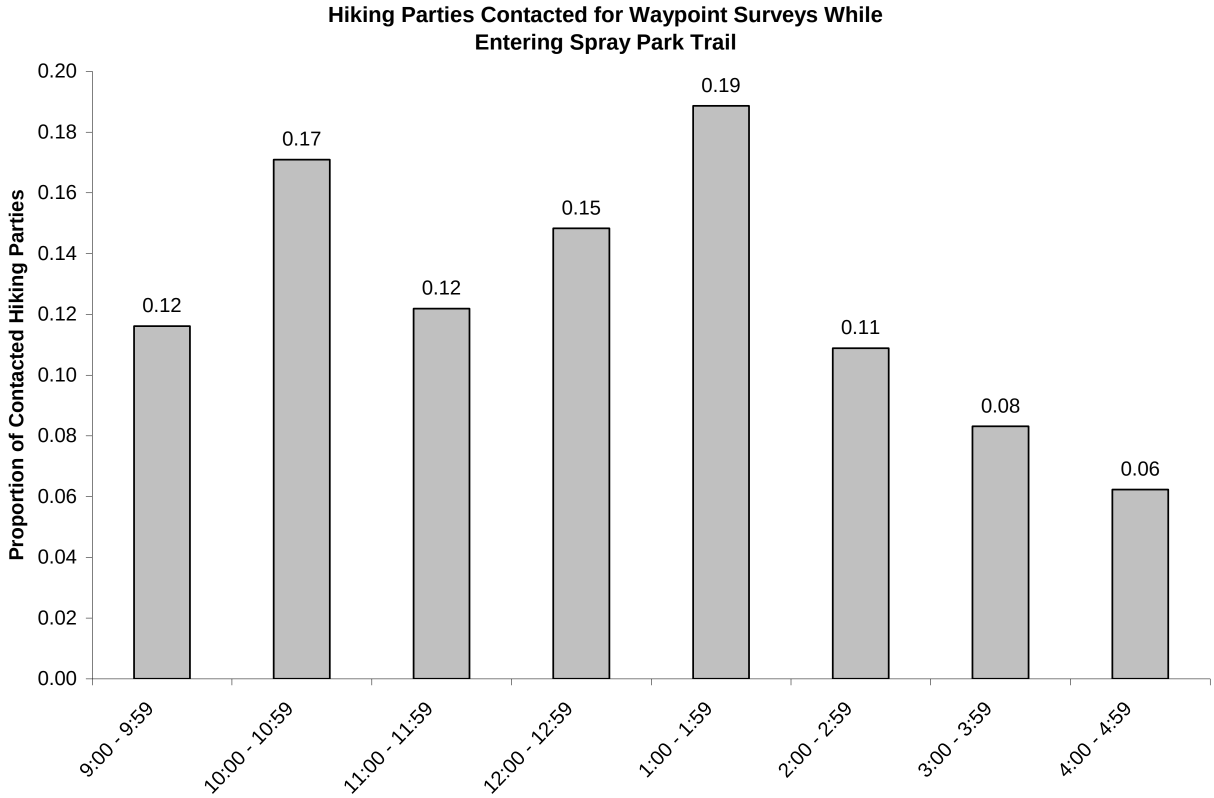

Figure 28. Hourly proportion of parties contacted for waypoint surveys on the Spray Park Trail in 2004.

Use before 9:00 is estimated based on the trail counter data. If we assume that all counts prior to 9:00 record hikers entering the trail, then we can estimate entries between 8:00 and 9:00 to be 81 percent of the entries between 9:00 and 10:00. Likewise, entries between 7:00 and 8:00 can be estimated as 65 percent of the entries between 9:00 and 10:00. Based on the extremely low number of passages recorded by the trail counter prior to 7:00, a simplifying assumption is made that no hikers enter prior to that time.

The proportion of hiking parties contacted for the waypoint surveys between 4:00 and 5:00 was low. In conjunction with informal observation of the trailhead and the pattern of data recorded by the trail counter it was thought that very few hikers entered the Spray Park Trail after 5:00. Thus, a simplifying assumption is made that no hiking parties enter the trail after 5:00.

The figure below shows the entry distribution used in constructing the simulation model of visitor use on the Spray Park Trail. The distribution is represented in terms of the proportion of visitors entering during each hour because the simulation might be run with different total numbers of hiking parties entering. The distribution of hiker passages recorded by the trail counter during the same hours in 2004 is included in the figure for comparison purposes.

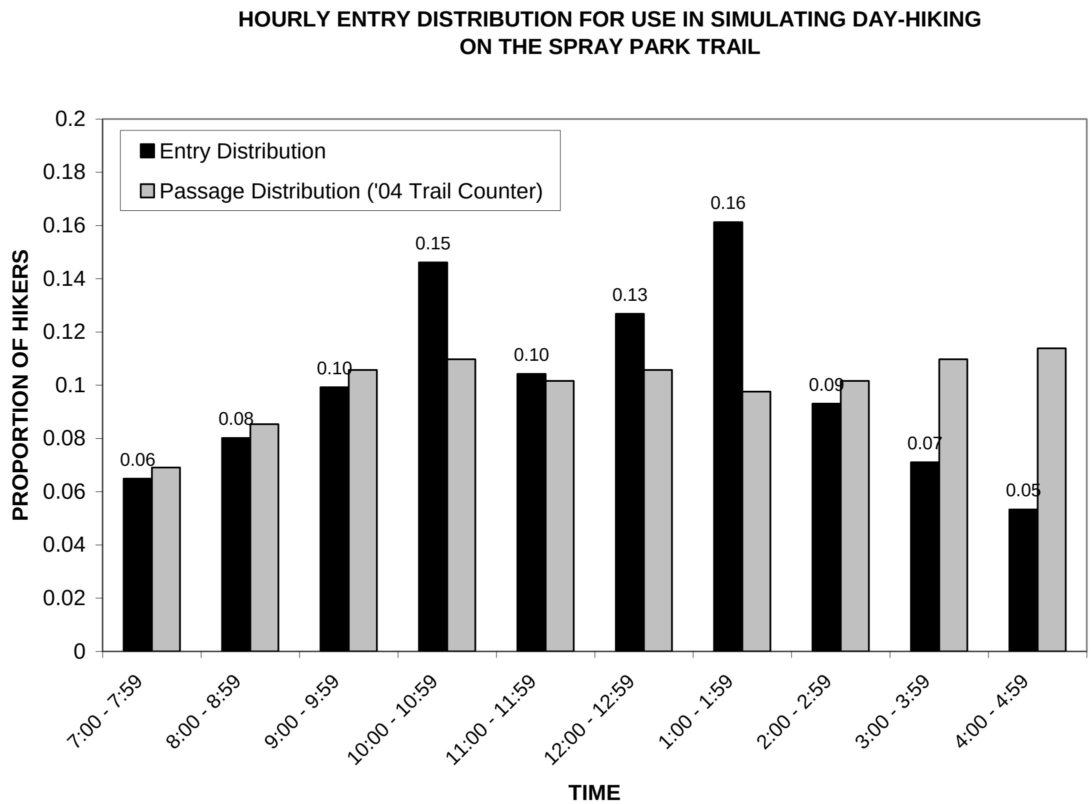

Figure 29. Hourly distribution of visitors entering the Spray Park Trail for use in computer simulation model (2004 visitor passage distribution included for comparison).

4.3 Pauses/Stops: Spray Park Trail

One aspect of visitor itineraries that was not described by the data collected in the waypoint studies was the amount of time that visitors were not actually hiking along the trail. Informal observation (and common sense) demonstrates that most visitors do not hike constantly, but stop to rest, eat or drink, or simply view the scenery. If the model is to provide useful information, it can not completely disregard those pauses or stops.

Because of the limited information available to estimate where and for how long visitors stopped, a number of simplifying assumptions were made in the representation of pauses and stops in this simulation model. The most important of these is that in the model, stops only occur at a limited number of locations. Specifically, stops occur at Spray Falls, at waypoints D and E, and at a spot in the meadow along the main trail between waypoint C and the way-trail to waypoint D (see Figure below). The procedures for estimating the duration of stops in each of these locations is described below.

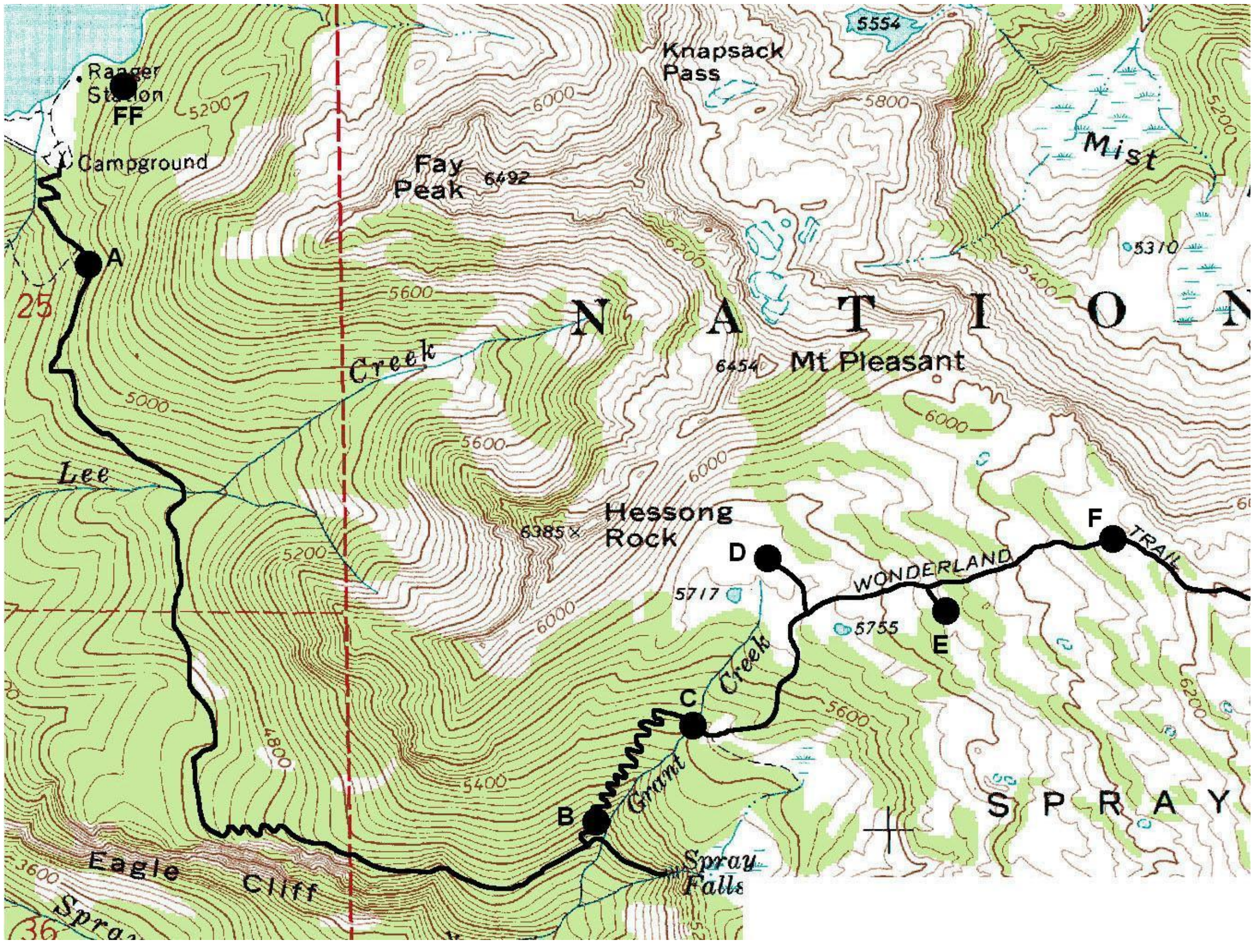

Figure 30. Locations of waypoint signs for Spray Park Waypoint Survey.

Two different types of stops occurred at Spray Falls, those for visitors who did not hike higher on the trail, and those who stopped at Spray Falls during longer hikes that reached Spray Park. The duration of these stops can be estimated by calculating the time interval between the two recorded times when hiking parties passed waypoint B. For parties that hiked no further than Spray Falls, stops averaged 45 minutes with a standard deviation of 19 minutes.[7] For parties that stopped at Spray Falls during hikes that reached Spray Park, stops averaged 26 minutes with a standard deviation of 12 minutes. Analyses of the trip durations for simulated parties and parties observed in the waypoint study showed that waypoint parties that turned around at Spray Falls spent approximately 30 minutes longer hiking than the time the simulation originally estimated. Much of this time probably was spent in short pauses or rest periods. Therefore, time at Spray Falls in the simulation was adjusted to an average of 75 minutes to better match the observed durations of stay.

Stops at waypoints D and E actually represent a time interval in which parties could have been in motion and/or stationary. Thus, these time intervals can be more accurately thought of as time in which hikers are not simulated. For waypoint D, the non-simulated durations averaged 94 minutes with a standard deviation of 49 minutes. For waypoint E, the non-simulated durations

[7] One outlier of 385 minutes was dropped from the averaged stops.

averaged 53 minutes with a standard deviation of 36 minutes.

The meadow stop was similar to waypoints D and E in that it was intended to represent intervals in which hiking parties were not hiking on the official trail, but could have been either hiking off-trail, or stationary. The specifications for this stop were selected based on comparisons between the total hike durations observed in the waypoint study and hike durations that were originally estimated by the simulation. These comparisons suggested that a stop of 111 minutes could be used to represent the average off-trail and stationary periods for hiking parties that entered Spray Park but did not reach Upper Spray Park, and that a stop of 83 minutes could be used to represent the average off-trail and stationary periods for hiking parties that reached Upper Spray Park. The location for the meadow stop was set at an arbitrary point approximately halfway from the meadow entrance to Upper Spray Park (i.e., halfway between waypoint C and F in the waypoint study).

Even casual observation of visitors' behavior on the Spray Park Trail shows that both stops and off-trail hiking violate the modeling assumption that they occur only in the specified locations. However, the implications of the simplifying assumption are only critical if they substantially alter the number of hiking encounters between parties. Observations, as well as survey data (Vande Kamp, Johnson, and Swanson 1998) suggest that many visitors leave the official trail in order to avoid encounters with other parties. Thus, the number of encounters for those parties is unlikely to substantially alter the overall number of encounters. Having all parties pause at a few locations (for varying durations) would certainly inflate the number of non-hiking encounters that would occur while the parties were all bunched up in that location. However, it should have little effect on the number of encounters that occur while both parties are hiking.

The simulation must somehow represent the actions of parties who hiked beyond waypoint F. In the waypoint study, the difference between the times those parties recorded for their first and second passing of waypoint F averaged 71 minutes with a standard deviation of 53 minutes. The model could have been designed to stop simulating the movement of hikers at waypoint F. However, because more than a third of parties passed waypoint F, and on average they spent more than an hour beyond that point, parties' movement and encounters with other parties were simulated up to a point approximately 760 meters past waypoint F, where the official trail continues through upper Spray Park before descending to Mist Park and Seattle Park. The times necessary for simulated parties to traverse this additional distance ranged from 28 to 52 minutes, with an average of 36 minutes. The additional time that some parties spent hiking beyond that point was represented as a stop at the end of the simulated trail with a duration of 35 minutes and a standard deviation of 35. As with waypoints D and E, as well as the meadow stop discussed above, this procedure constitutes a limitation of the model, because no encounters are simulated or recorded for parties hiking beyond the end of the simulated trail. However, extending the simulation past waypoint F mitigates the impact of the procedure, and encounters become less likely in that area due to the decreasing proportion of parties who hike that far.

4.4 Hiking Speeds: Spray Park Trail

Another factor that has a large effect on the number of encounters between hiking parties in the simulation is the speed (and range of speeds) at which hiking parties move along the simulated trail. This effect is obvious when one considers that hikers encounter parties that are: a) moving in the opposite direction, and b) moving in the same direction. The relative speed of the parties has a relatively small effect on the first type of encounter, but it has a large effect on the second type. To illustrate, imagine that all parties hike at the same speed – they would maintain perfect separation and never overtake each other. In contrast, if some parties hike much faster than others, then they will overtake many of the slower parties ahead of them.

Actual hiking speeds can be calculated from the waypoint study data and used in building the simulation model. In order to minimize the effects of stops and pauses on those speeds, only the official trail segments up to waypoint C are used in the speed calculations. For each party that reached the Spray Park, the total time that they spent between waypoint A and waypoint C in both directions was divided by the distance between those points in order to calculate a hiking speed. Using this procedure, the average hiking speed was 2.54 kilometers per hour with a standard deviation of 0.55.

The RBSim software does not currently allow random assignment of hiking speeds to parties. However, different types of hikers can be defined – each with a different hiking speed. For this simulation, four types of hiking parties were defined. The hiking speeds of each party type, and the number of parties assigned to each type were designed to produce a distribution of hiking speeds that approximated the distribution described by the waypoint survey.

The range of speeds found in the sample distribution were divided into four, roughly-equal intervals and the proportion of hiking parties within each interval was determined by examining the frequency table of hiking speeds. Based on this analysis, the simulation model assigned the following four hiking speeds to the indicated proportion of hiking parties:

Speed (kph)	Proportion of Hiking Parties
1.75	0.174
2.25	0.282
2.75	0.356
3.25	0.188

Table 5. Proportion of simulated hiking parties assigned to four hiking speeds in the Spray Park computer simulation model.

Hiking speeds were not randomly distributed across all hiking parties in the waypoint survey. Accordingly, the four hiking speeds listed above were assigned to the range of actual speeds recorded by hiking parties. Thus, parties in the simulation do not travel at the exact speed that they recorded on the waypoint card, but do travel at a speed selected from four options to best represent their recorded speed.

4.5 Assumptions, Simplifications, and Limitations: Spray Park Trail

The characteristics of the simulation described in this section have all been discussed in the earlier descriptions of the simulation model, its parameters, and how it was developed. These characteristics are summarized here (in approximate order of their importance) to ensure that readers are aware of them (particularly the limitations) before reading and interpreting the simulation results.

The first limitation of the simulation is that its results describe only use that occurs during the summer (i.e., all or mostly snow-free) hiking season.

A second limitation is that the simulation almost exclusively measures encounters between parties that occur while both parties are hiking on the official trail between the trailhead and a point approximately 760 meters past waypoint F, where the official trail continues through upper Spray Park before descending to Mist Park and Seattle Park. The only other encounters measured by the simulation are those that occur in approximately the first 400 meters of two way-trails where waypoint sign D and E were placed during the waypoint study. The simulation does not count encounters that occur while one or both parties are, a) stopped at a destination, b) hiking off the official trail, or c) hiking beyond a point approximately 760 meters past waypoint F.

A third limitation of the simulation is that although the number of parties entering is based on counts of both backpackers and day-hikers, the behavior of the simulated parties is based only on day-hikers and no distinction is made between types of parties when counting encounters.

A final limitation of the simulation is that the entry distribution is based primarily on weekend data. Some of the results below summarize simulation runs representing average weekday use and validation tests suggest that those results could differ slightly if an entry distribution for weekdays had been estimated and incorporated into the simulation.

A number of simplifying assumptions were made in the course of designing the simulation. The extent to which these assumptions limit the generality of the simulation results is probably small. The assumptions include: a) all hiking parties entered between 7:00 A.M and 5:00 P.M., b) all stops by hiking parties were represented by stops that occur only at Spray Falls, at waypoints D and E, and at a spot in the meadow along the main trail between waypoint C and the way-trail to waypoint D, c) the average duration of stops in Spray Park was the same for most hiking parties, d) parties that reached Spray Park but did not pass waypoints D or E spent an average of 53 minutes stopped at a destination or hiking off the official trail, e) the continuous range of actual hiking speeds were represented by a set of four discrete speeds.

4.6 Validation: Spray Park Trail

The primary reason for simulating day-hiking on the Spray Park Trail was to estimate the number of encounters between hiking parties. Thus, the best test of simulation validity would be to systematically record the number of actual encounters and compare those counts to the simulation estimates for days when a comparable number of hiking parties enter the trail. However, systematic counts of actual encounters have not been collected at this point in time.[8] In their absence, two other comparisons were used to assess the validity of the simulation.

The first assessment of the simulation validity was made by comparing the temporal distribution of the counts actually registered by the trail counter to the temporal distribution of simulated parties passing that same location. Because the data from the trail counter were used in designing the entry distribution for the simulation[9], the data do not provide a fully independent test of the degree to which the hiking behavior of the simulated day-hiking parties corresponded to day-hikers' actual behavior. Nonetheless, the correspondence between the simulation and the observed data fosters can increase confidence in the validity of the simulation. The figures below includes bars showing two temporal distributions, 1) the distribution of simulated day-hiking

---

[8] High priority should be placed on model validation based on direct counts of hiking encounters. Such data constitute the best test of the model and might be efficiently collected using volunteer observers.

[9] The use of the trail counter data was limited – they were used as a basis for extrapolating waypoint study data to the time period from 7:00 to 9:00.

parties, averaged across 50 simulated average weekdays or weekend days; and 2) the distribution of actual hikers observed in 2004 on weekdays or weekend days.

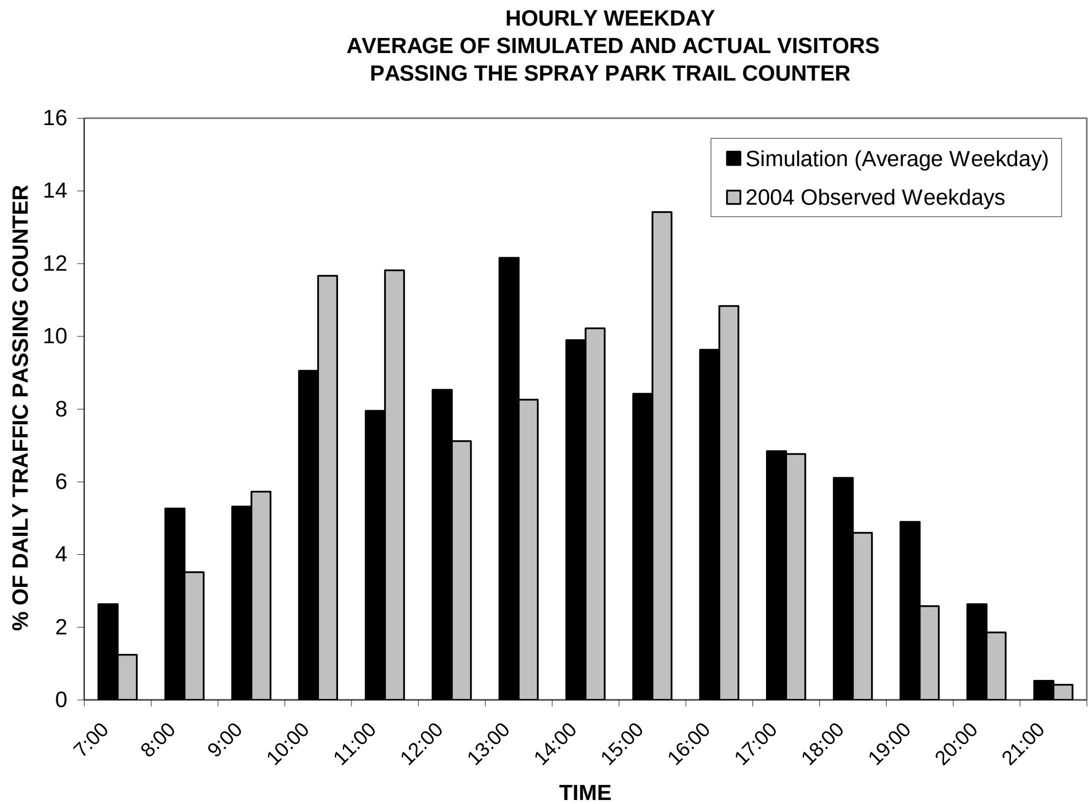

Figure 31. Simulated and observed distributions of visitors passing the Spray Park trail counter on weekdays.

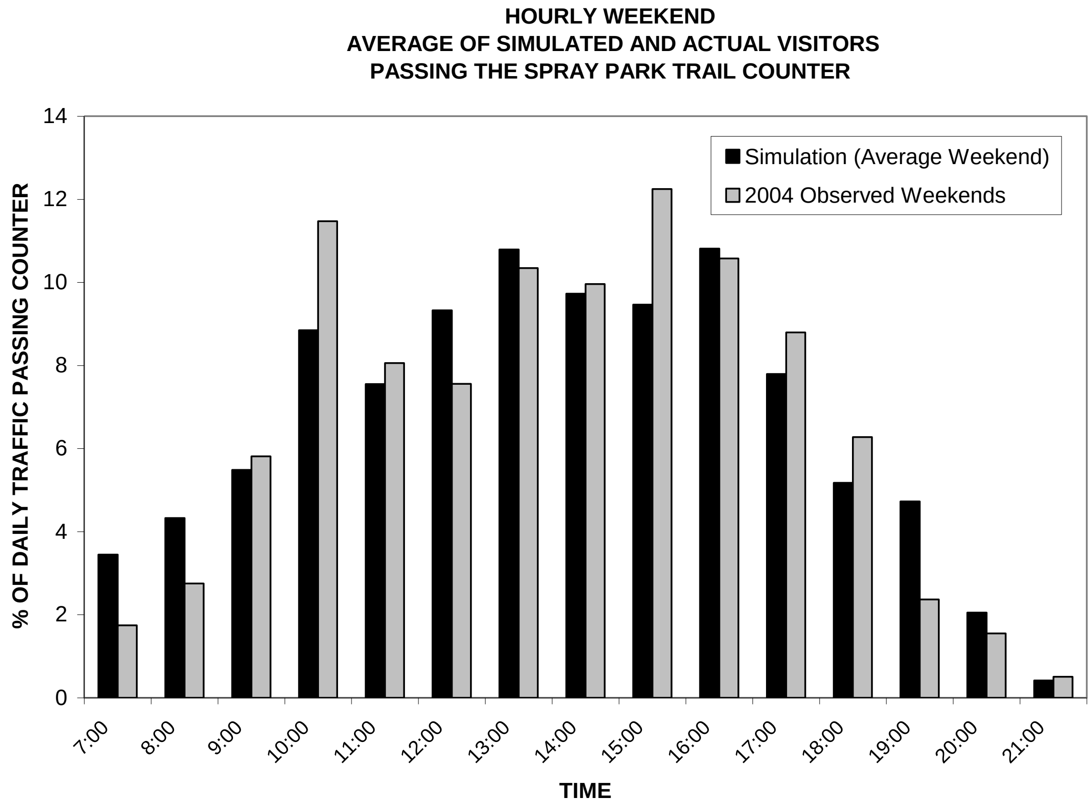

Figure 32. Simulated and observed distributions of visitors passing the Spray Park trail counter on weekend days.

Visual inspection of the temporal distributions for weekends showed that they were very similar. The discrepancies between the simulated and observed percentages for each hour were small, ranging from 0.09 to 2.78 percent, with an average discrepancy of only 1.15 percent. In general, the simulation of weekends corresponded closely with the data recorded by the trail counter.

The discrepancies between the simulated and observed distributions on weekdays were larger than those for weekends, ranging from 0.08 to 4.99 percent, with an average discrepancy of 1.78 percent. Because the primary purpose of the simulation was to estimate hiking encounters between parties during peak times, no effort was made to reduce these discrepancies by adjusting the entry distribution for weekdays. Thus, the results of the simulation model for average weekdays (see Section 4.7.3 below) should be used and interpreted with caution.

A second assessment of validity compared the duration of the simulated day-hikes to the actual durations collected during the waypoint survey. Although the simulation was designed using information from the waypoint survey, the duration of simulated hikes was based on hiking speed and duration of stop calculations that did not make use of the total hike durations from the waypoint survey. The table below includes the averages and standard deviations for simulated and observed hike durations.

	Average Duration	Standard Deviation
Simulation	263	76
2004 Waypoint Study	255	97

Table 6. Duration of simulated and observed hikes (in minutes).

The average and standard deviation for trip durations in the simulation differed slightly from those observed in 2004. Examination of the simulated and observed trip durations suggested that the small difference in the average duration (3.1%) was probably due to non-response bias in the waypoint data. Parties that made longer trips were less likely to have all the information needed to calculate the duration of their trips. The difference in the standard deviations most likely resulted because the variability in the simulated stops was lower than the true variation in the population. This discrepancy arises from an unavoidable limitation in the way the simulation randomly assigns stop durations. Given that the simulation was intended to record hiking encounters that were minimally affected by small differences in trip duration or variability in stop durations, these discrepancies were deemed acceptable. In general, the average hike duration in the simulation corresponded closely with data that were recorded on at least a semi-independent basis during the waypoint study.

4.7 Simulation Results: Spray Park Trail

This section describes three sets of results corresponding to simulation of a 95th percentile day, an average weekend day, and an average weekday. Each set of results is based on 50 iterations of the simulation model. This number of iterations was selected based on a method described by Itami, Zell, Grigel, and Gimblett (2005). In this method, a "short run" of the simulation is used to estimate the variability in one or more outcome measures, and that variability is used in calculations that determine the number of iterations necessary to reach a desired level of precision in the simulation results. In this case, the desired level of precision in estimating the average number of total encounters was a 95-percent confidence interval of plus-or-minus 2 encounters for the "95th percentile day" simulation. A "short run" of 15 iterations found that the variance in total encounters was 63.68, and that 50 iterations of the simulation would yield the desired precision. For the "average weekend" and "average weekday" simulations, 50 iterations produced even narrower confidence intervals, but the gain in precision was useful given the smaller values for total encounters estimated for those conditions.

4.7.1 Trail Encounters on a 95th Percentile Day

The 95th percentile day is one measure of what might be called "peak use". In most use distributions, a few extraordinary days lie far outside the normal range of use. Although managers may be concerned about the impact of such days, they generally fall outside the realm of general planning. For the purposes of the MORA VERP team, it was thought appropriate that simulation of peak use should focus on the use level higher than 95 percent of days, and lower than the 5 percent of busiest days. For the Spray Park Trail, use on this 95th percentile day was 80 parties (see Section 4.1 above).

As described above, the simulation model was run 50 times in order to produce a 95-percent confidence interval for total daily encounters of plus-or-minus 2 encounters.

Total encounters. On average, simulated hiking parties encountered 29.5 other parties. The figure below shows the distribution of total encounters for the 4,000 simulated parties.

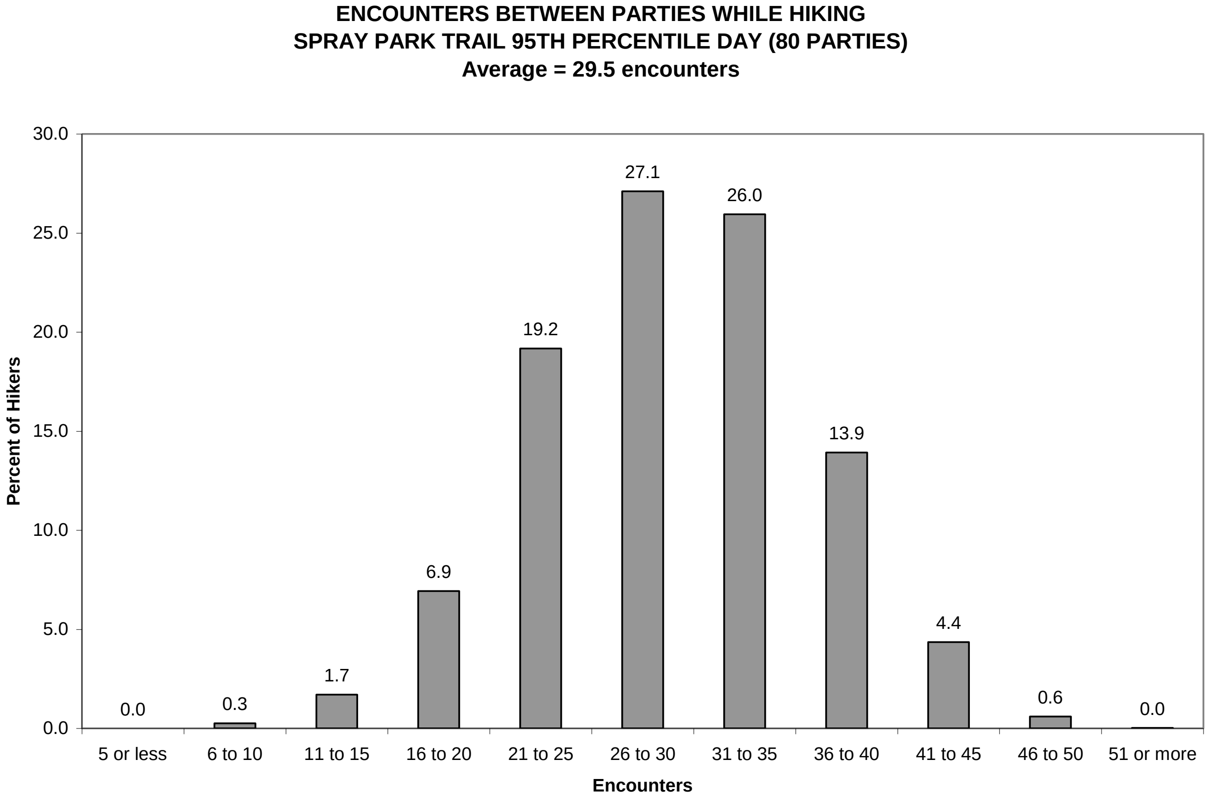

Figure 33. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on a 95th percentile day (80 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 7.3 other parties per hour. The figure below shows the distribution of encounters per hour for the 4,000 simulated parties.

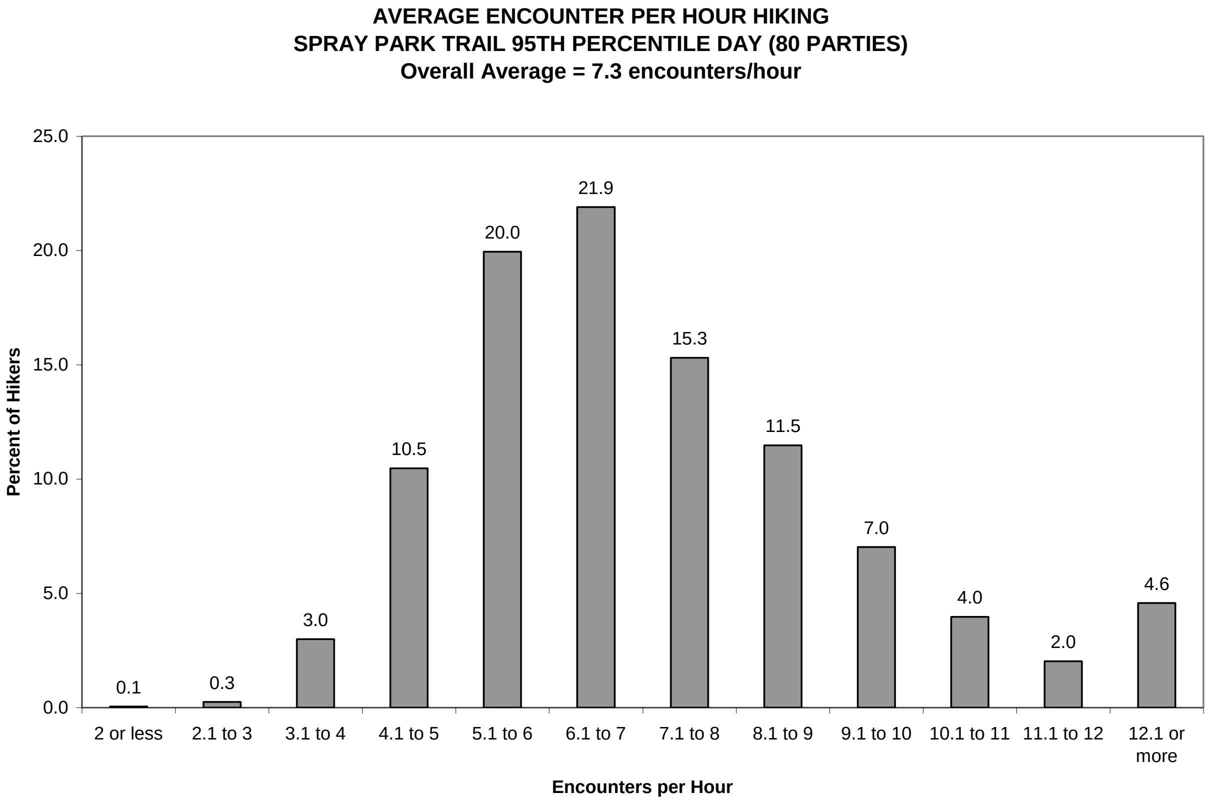

Figure 34. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on a 95th percentile day (80 total parties).

Given that parties that reached Upper Spray Park (i.e., that passed waypoint F) had trip durations that averaged 337 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 41.0 ([337/60] * 7.3). This figure is much greater than the average of 29.5 encounters for all parties, primarily because most hikers do not reach Upper Spray Park and spend a considerably shorter time hiking the Spray Park Trail.

4.7.2 Trail Encounters on an Average Weekend Day

The 95th percentile day provides a useful description of peak use, but the difference between peak use and more routine use levels can also be informative. In this section we estimate the number of hiking encounters between parties on the Spray Park Trail during an average weekend day. Use on such an average weekend day was 58 parties (see Section 4.1 above).

As described in section 4.7 above, the simulation model was run 50 times. In this case, 50 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 1.39 encounters.

Total encounters. On average, simulated hiking parties encountered 21.4 other parties. The figure below shows the distribution of total encounters for the 2,900 simulated parties.

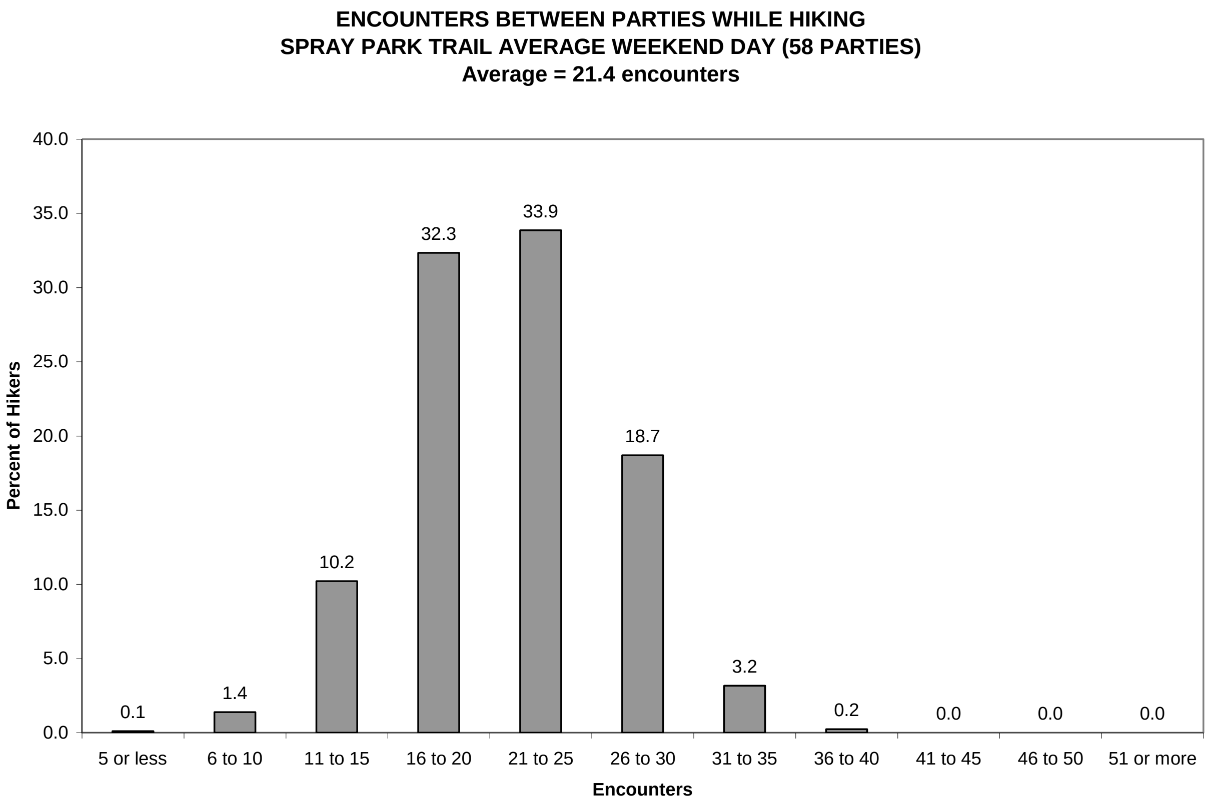

Figure 35. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekend day (58 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 5.3 other parties per hour. The figure below shows the distribution of encounters per hour for the 2,900 simulated parties.

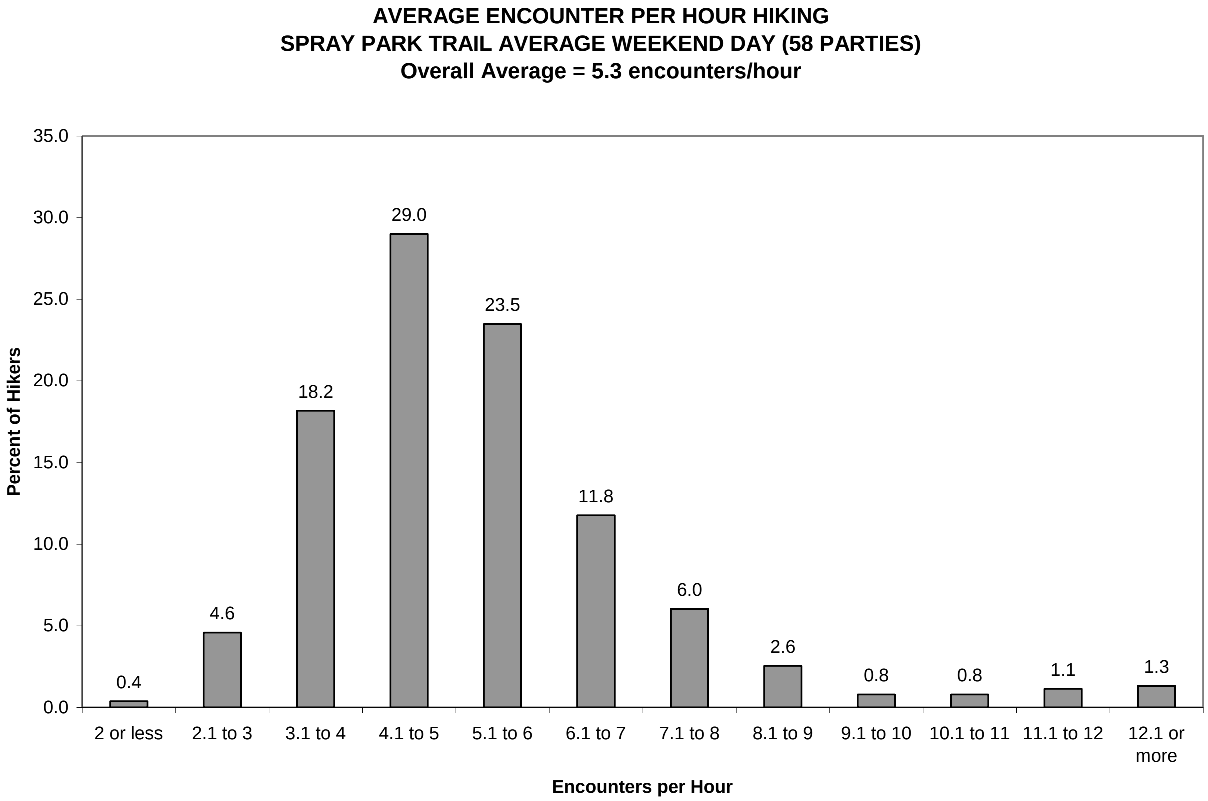

Figure 36. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekend day (58 total parties).

Given that parties that reached Upper Spray Park had trip durations that averaged 337 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 29.8 ([337/60] * 5.3). This figure is much greater than the average of 21.4 encounters for all parties, primarily because most hikers do not reach Upper Spray Park and spend a considerably shorter time hiking the Spray Park Trail.

4.7.3 Trail Encounters on an Average Weekday

One final routine use level was simulated in order to provide additional information. In this section we estimate the number of hiking encounters between parties on the Spray Park Trail during an average weekday. Use on such an average weekday was 19 parties (see Section 4.1 above).

As described in section 4.7 above, the simulation model was run 50 times. In this case, 50 iterations produced a 95-percent confidence interval for total daily encounters of plus-or-minus 0.51 encounters.

Total encounters. On average, simulated hiking parties encountered 6.9 other parties. The figure below shows the distribution of total encounters for the 950 simulated parties.

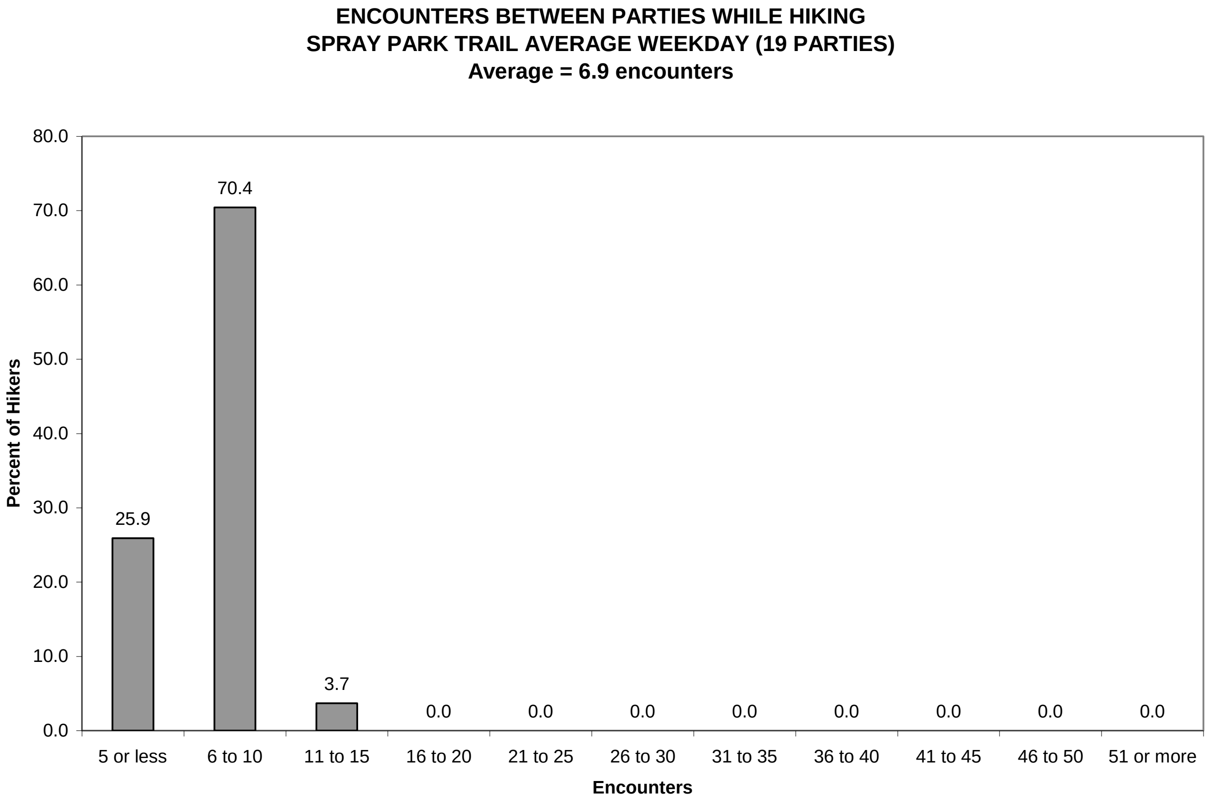

Figure 37. Percent of simulated hiking parties that experienced different numbers of total encounters with other parties on an average weekday (19 total parties).

Encounters per hour. In some situations, the total encounters per trip can be misleading. If visitors make two or more different kinds of hikes that differ greatly in length, the average number of total encounters may fail to represent any of those visitors. This source of confusion can be minimized by calculating the number of encounters per hour. On average, simulated hiking parties encountered 1.7 other parties per hour. The figure below shows the distribution of encounters per hour for the 950 simulated parties.

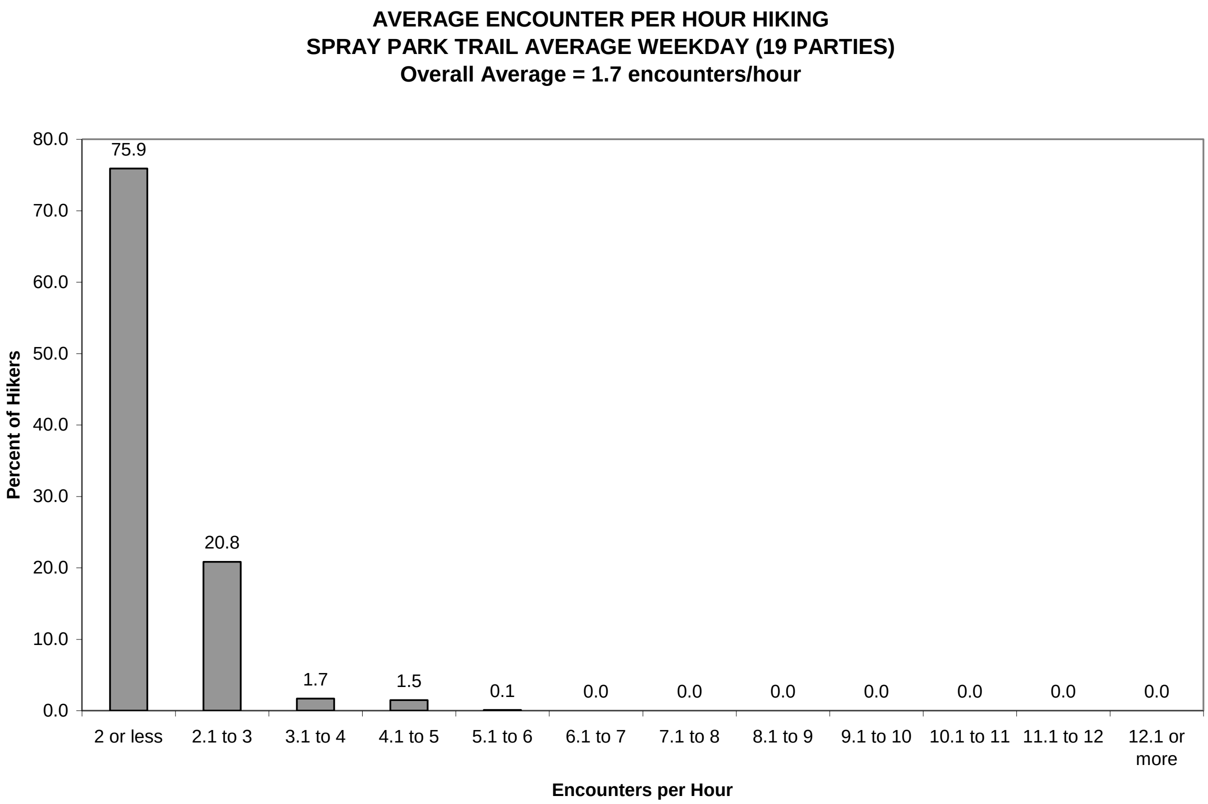

Figure 38. Percent of simulated hiking parties that experienced different numbers of encounters per hour with other parties on an average weekday (19 total parties).

Given that parties that reached Upper Spray Park had trip durations that averaged 337 minutes (Vande Kamp 2009), we would estimate that the total encounters for that sub-group would average 9.5 ([337/60] * 1.7). As in the 95th percentile and weekend simulations, this figure is, proportionally, much greater than the average of 6.9 for all parties. However, it is possible that a decrease of less than three total encounters would make little difference in the quality of visitor experiences.

4.7.4 Trail Encounters and Use Levels

The number of encounters between hiking parties estimated using the simulation of the Spray Park Trail showed a nearly perfect linear relationship with the number of hiking parties that were put into the simulation (r = .999; Average Total Encounters equals approximately 0.37 * Daily Hiking Parties). The strength of the correlation is unsurprising in retrospect, given that the simulation uses the same pool of hiking itineraries in identical proportions for the 80, 58, and 19-party simulations. However, the relationship is not entirely an artifact of the simulation procedure. The waypoint studies showed little evidence that hiking itineraries were dramatically different at high and low use levels, and in the absence of such differences, encounters should be determined entirely by the number of hiking parties. The strength of the relationship between encounters and use levels provides a strong argument that visitor counts can be used to monitor encounters between hiking parties and to thereby monitor conditions related to desired visitor experiences.

4.7.5 Encounters per Hour on Distal Trail Segments

Modeling the Spray Park Trail provides information about use levels on a particular trail in the Transition Trail zone, but can also provide information relevant to the Semi-primitive Trail zone. Currently, the Spray Park Trail enters the Semi-primitive Trail zone in upper Spray Park at a point where the trail begins descending. The trail segment immediately past this boundary averaged 5.8 encounters per hour on simulated 95th percentile days. Thus, the simulation suggests that use of the Semi-primitive Trail zone beyond upper Spray Park boundary is considerably higher than the use on comparable Semi-primitive Trail segments near Panhandle Gap on the Summerland Trail (3.7 encounters per hour) and past Comet Falls (3.1 encounters per hour) in the other simulation.

5. CONCLUSION

Simulation models were built describing visitor use on three different trails in the transition trail zone. The available methods for validating those models supported confidence in their validity and their estimates of encounters between hiking parties. However, the tests of validity were sub-optimal – direct measurement of hiking encounters and comparison of those observed measures to the encounters predicted by the simulation models would be the best means of establishing the models' validity.

5.1 Future Analyses

5.1.1 Buses and Pulsed Entries

In the immediate or distant future, some visitors may arrive at transition zone trails on shuttle buses rather than in private vehicles. Depending on the number of parties that simultaneously arrive at a given trail, this change in delivery of visitors might have important effects on the number of encounters between hiking parties. If MORA managers can define a range of possible delivery scenarios for any of the three trails simulated at this point, those scenarios could be portrayed by the simulation models and analyses could estimate their probable effect on encounters between hiking parties. The results of those analyses could help managers choose between delivery scenarios or the implementation of other actions (or lack thereof) when implementing shuttle transportation.

5.1.2 A Possible Basis for Estimating Encounters on Other Trails

Analyses of estimated encounters in each simulation model showed that they were very highly correlated with the number parties using the trail. Although this result is in no way surprising, it suggests that it may be possible to develop a "rule of thumb" equation to roughly estimate the number of encounters on any trail without producing a simulation model.

As a first step in exploring this possibility, a regression analysis was conducted to predict the encounters per hour predicted for the three visitation levels modeled for in each simulation (nine total estimates) based on a set of factors that was thought likely to affect those encounters. These factors included: 1) parties using the trail; 2) average hike duration; and 3) proportion of hikers entering during the peak entry hour. Such an analysis is problematic because the observations are not truly independent, but it is nonetheless notable that it accounted for 95 percent of the variability in the estimated encounters per hour. Specifically, the regression equation took the form:

$$\text{Enc./Hr.} = (\text{Parties} * 0.11) + (\text{Average Duration} * -0.15) + (\text{Peak Proportion} * 30.956) - 2.014$$

There is currently no strong argument that, in the absence of simulation models, this equation is a sound basis for estimating encounters on trails. However, its validity could be tested using models of other day hiking trails. For example, the Paradise Meadow simulation model could be run using only hikers that take out-and-back hikes to Myrtle Falls and the resulting estimates of encounters could be analyzed for consistency with the above equation. Depending upon the results of this (and other) attempts to test and/or improve the validity of the prediction equation (as well as tests of the validity of the simulation models themselves), managers might be equipped with a valuable tool for initial assessment and monitoring of encounters between hiking parties.

REFERENCES

BRW (1995). *Transportation Feasibility Study: Mount Rainier National Park.* Technical Report. 75 pp. plus appendices.

Cole, D. N. (2005). comp. *Computer simulation modeling of recreation use: current status, case studies, and future directions*. Gen. Tech. Rep. RMRS-GTR-143. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Hall, T. and B. Shelby. (1996). Who cares about encounters? Differences between those with and without norms. *Leisure Sciences 18*(1): 7-22.

Itami, R.M., D. Zell, F. Grigel & H.R. Gimblett. (2005).*Generating Confidence Intervals for Spatial Simulations: Determining the Number of Replications for Spatial Terminating Simulations*. In Zerger, A. and Argent, R.M. (eds) MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005, pp. 141-148. ISBN: 0-9758400-2-9.

Vande Kamp, M. E. (2003, March). *Simulation Software to Model Visitor Distribution at Mount Rainier National Park*. Paper presented at the computer simulation in recreation workshop, Tucson, AR.

Vande Kamp, M. E. (2009). *Visitor-Experience Indicators and Standards for the Wilderness Zones of Mount Rainier National Park.* Technical Report. Protected Area Social Research Unit, College of Forest Resources, University of Washington, Box 352100, Seattle, WA, 98195-2100. 65 pp.

Vande Kamp, M. E. (2009). *Visitor Use in the Management Zones of Mount Rainier National Park*. Technical Report. Protected Area Social Research Unit, College of Forest Resources, University of Washington, Box 352100, Seattle, WA, 98195-2100. 65 pp.

Vande Kamp M. E., Johnson, D. R., & Swanson, J. E. (1998). *Mount Rainier National Park 1993 Spray Park visitor survey*. Technical Report NPS/PNRUW/NRTR-98-04. Field Station/ Protected Area Research/USGS/BRD/FRESC. College of Forest Resources, University of Washington, Box 352100, Seattle, WA, 98195-2100. 294 pp.

Vande Kamp, M. E. & Zweibel, B. R. (2004). *A regression-based model of visitor use in the Paradise developed area of Mount Rainier National Park*. Technical Report. PNW/CESU, College of Forest Resources, Box 352100, University of Washington, Seattle, WA, 98195-2100. 38 pp.

van Wagtendonk, J. W. and Cole, D. N. (2005). *Historical development of simulation models of recreation use.* In Cole, D. N., comp. 2005. Computer simulation modeling of recreation use: current status, case studies, and future directions. Gen. Tech. Rep. RMRS-GTR-143. Fort

Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Technical Report NPS/CCSOUW/NRTR-2009-01
NPS 105/100443