# The Wilderness Simulation Model

## *A Historical Perspective*

BY JAN W. VAN WAGTENDONK

### Introduction

Recent application of simulation modeling to wilderness and river settings (Daniel and Gimblett 2000; Gimblett et al. 2000, 2002) has revived interest in the Wilderness Simulation Model (WSM) first developed by Smith and Krutilla (1976) and based on an idea by Stankey (1972). Stankey hypothesized that visitors' satisfaction with a wilderness experience was inversely related to the number of encounters they had with members of other parties. Fisher and Krutilla (1972) conceptualized this idea into a model that established the optimum level of use in a wilderness area to be the point at which the incremental benefit of an additional party is just offset by the decrease in the benefits of the parties encountered. The practical application of this concept required that an empirical relationship between the benefits enjoyed during an outing and the number of parties encountered be measured and that a means for estimating encounters be developed. Numerous sociological studies were launched to examine the relationship between benefits and encounters, but, other than laborious fieldwork, no means existed for enumerating encounters.

In order to overcome this obstacle, researchers from Resources for the Future began to develop a computer model that would simulate visitor travel behavior in a wilderness and record encounters between parties. The WSM was a simulation program written by Heck and Webster (1973) in the General Purpose Simulation System language running on an IBM mainframe computer.

Visitor data required to run the model included weekly, daily, and hourly distributions of use; party-size distributions; and mode of travel mix. For example, small parties on horseback were distinguished from large hiking parties. Area information included the trail segments and campsites in the network and the time it took parties of different sizes to hike or ride each trail segment in each direction. Finally, the various routes that might be taken were enumerated along with their probability of being selected. The WSM scheduled parties of different sizes and types to arrive on different weeks, days of the week, and hours of the day, assigning each party a route that included the trails over which they traveled and the campsites they used. The WSM recorded the number of encounters for each party, with whom each encounter occurred, the location of those encounters, and the types of encounters (meeting, overtaking, or camp). Output from the WSM included numerous tables showing encounters by party type, location, trip length, and total use level.

**Article author Jan van Wagtendonk. Photo by Don Barry.**

Prototype testing of the WSM was conducted on the Spanish Peaks Primitive Area (Smith and Krutilla 1976) and the Adirondack Forest Reserve (Smith and Headly 1975). Subsequently, the model was enhanced by Resources for the Future under contract with the U.S. Forest Service (Shechter 1975). This new WSM model was applied to the Desolation Wilderness in California (Shechter and Lucas 1978) and to the complex of wilderness areas surrounding and including Yosemite National Park (van Wagtendonk 1979). Modification of the WSM for river settings allowed it to be applied to the Green and Yampa Rivers in Dinosaur

**Figure 1—The Yosemite Wilderness is located in the central Sierra Nevada, an area of granite peaks and glaciated valleys. Photo courtesy of the National Park Service.**

Monument (Lime et al. 1978) and to the Colorado River in Grand Canyon National Park (Underhill et al. 1986). A final application of the WSM to a trail system was done by Potter and Manning (1984) on the Appalachian National Scenic Trail in Vermont. The studies related to Yosemite National Park are presented here as a case study to illustrate the process of using the WSM.

## Yosemite National Park

Simultaneous with the effort to apply the WSM to the Desolation Wilderness, scientists and managers at Yosemite National Park began assembling the necessary information to run the WSM (van Wagtendonk 1979). The Yosemite Wilderness was designated in 1984 and encompasses 704,638 acres (281,855 ha) of the park (see Figure 1). Contiguous wilderness areas include the 112,227-acre (44,891-ha) Emigrant Wilderness on the Stanislaus National Forest, the 48,601-acre (19,440-ha) Hoover Wilderness on the Toiyabe and Inyo National Forests, and the 93,958-acre (37,583-ha) Ansel Adams Wilderness on the Inyo and Sierra National Forests. There are 55 trailheads with 695 miles (1,112 km) of trail and 375 campsites in the Yosemite Wilderness. An additional 46 trailheads feed 416 miles (666 km) of trail and 197 campsites on Forest Service wilderness areas adjacent to the park. Use in the Yosemite Wilderness in 1975 was 219,000 visitor-nights (van Wagtendonk 1981).

**Figure 2—Backpackers and day hikers are the most common type of visitor in the Yosemite Wilderness. Photo courtesy of Yosemitefun.com.**

Wilderness use in the Yosemite complex has been regulated through the use of wilderness permits since 1971. Use permits were the primary data source for the WSM (van Wagtendonk 1978). Party size, mode of travel, arrival patterns, and the zones through which a party planned to travel were all obtained from the permit. Zone information was converted into routes using methods described by van Wagtendonk. Permits avoided the costs associated with visitor surveys and allowed all routes actually recorded to be simulated rather than just a sample of possible routes. The validity of the information on the permits and the travel behavior of parties that did not get permits were determined. In Yosemite, van Wagtendonk and Benedict (1980a) found that 92% of the parties had permits and that 62% of them made changes to their trips. The average trip was shortened by a half day and spatial changes were common.

A study was conducted in Yosemite to determine trail travel times for parties on 1-mile trail segments (van Wagtendonk and Benedict 1980b) as input to the WSM. It took an average of 34.8 minutes for backpacking parties, 36.4 minutes for day-hiking parties, and 27.3 minutes for horse-riding parties to travel all the sample trail segments (see Figure 2). Party size was not significant for all three types of parties, and slope-direction class was significant only for backpacking parties. For these parties, average times for uphill travel were greater than downhill travel, and time increased as slope increased.

Modifications to the WSM made from the Desolation Wilderness study allowed the Yosemite study to focus on trailheads, campsite encounters, and campsite use levels. The decision to concentrate on campsites was based on work by Absher and Lee (1981) that indicated the sociological effect of trail encounters depended more on the

behavior of the encountered party and the location of the encounter than on the number of encounters (see Figure 3). A single encounter with an ill-behaving party could have a much greater impact than meeting numerous parties exhibiting acceptable behavior. In areas where people expected to meet others, the impact of an encounter was less than in areas where they were not expected (see Figure 4). Trailhead quotas were selected by Yosemite managers as the preferred method for rationing use because controls at the entry points allowed maximum freedom to visitors in the interior of the area (van Wagtendonk and Coho 1986).

The 20,000 wilderness permits issued in 1973 were used for the base-case simulation because travel behavior that year was not limited; use in subsequent years might have been affected after use limits were imposed (van Wagtendonk 1981). Two visitor use levels and two trailhead allocation patterns were examined and compared to the base case. The use levels were a 50% increase from the base case and a 50% decrease. The first trailhead allocation scenario was based on daily entry quotas derived from a computer program (van Wagtendonk and Coho 1986) that compared actual use levels in zones to desired levels and reallocated entries until no zone exceeded its limit. Desired zone use limits were based on van Wagtendonk (1986). The second trailhead scenario rounded the daily entry quotas up to the nearest number divisible by five.

Across all WSM simulations, the relationship between camp encounters per party-night and party-nights was positive and linear (see Figure 5). The resulting number of encounters was less than half that reported for the Desolation Wilderness. Two reasons accounted for this difference. First, a greater number of trailheads gave visitors more opportunities to disperse and, consequently, experience fewer encounters per party-night. Second, the wilderness permits provided thousands of potential routes compared to only hundreds from the diaries used for the Desolation Wilderness. This diversity of routes dispersed parties during the WSM simulations, resulting in fewer encounters per party-night.

**Figure 3—Encounters between stock parties and hikers can be positive if both groups are perceived as behaving properly. Photo by Scott Carpenter.**

Trailhead entries for the base-case simulations ranged from one person per day through the most lightly used trailheads to over 100 people per day through the three most popular trailheads. The simulations based on the trailhead visitor quotas reduced the peaks in use both temporally and spatially, but did result in increased visitor encounter levels in the more sparsely used areas. These results were similar to the results from the Desolation Wilderness, as would be expected when visitor use is dispersed.

Combined with the trailhead quota program, the simulation results provided the information needed by managers to implement quotas for the Yosemite complex of wilderness areas. In that sense, the simulator was a success. However, the cost of running simulations on a remote mainframe computer was expensive and limited the feasibility of further experiments.

## Future Applications

The WSM has proven its usefulness in applications from simple, linear river systems to large, heavily used wilderness areas. All of these studies showed that trail and camp encounters were directly related to total visitor

**Figure 4—Camping where no one else is expected to be adds to one's wilderness experience. Photo by Kent van Wagtendonk.**

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use levels and that management alternatives that reduce visitor use will lead to reduced user-user encounter levels. In addition, the WSM was effective for evaluating the temporal and spatial effects of various trailhead allocation patterns that were then applied to a complex of wilderness areas in California.

Recent advances in computer technology and behavioral science have rendered the WSM out of date. As early as 1985, Rowell (1986) presented a version of the WSM that ran on a personal computer and had the capability to be used interactively to geographically display outputs. The concepts developed by Rowell have been incorporated into newer models.

Wang and Manning (1999) used an object-oriented dynamic simulation package to model carriage-road use in Acadia National Park in Maine. Lawson et al. (2002) applied the same model to simulate user encounters at Arches National Park in Utah. A GIS was used to derive routes for the model, but graphical output was not part of the model. Gimblett et al. (2000) combined object-oriented technology with geo-referenced temporal data to dynamically simulate visitor behavior in a heavily used natural setting in Sedona, Arizona. Output from the simulator can be displayed in graphs and as two-dimensional or three-dimensional maps. Using an autonomous agent-based model, Daniel and Gimblett (2000) simulated river trips on the Colorado River in the Grand Canyon. Gimblett et al. (2002) plan to apply their model to derive patterns of dispersed use in the Ansel Adams and John Muir Wilderness areas in California, returning to one of the areas where the WSM was first applied. These innovative new models show how far the science of simulating wilderness has come in less than three decades. The old WSM is probably gone, but not forgotten.

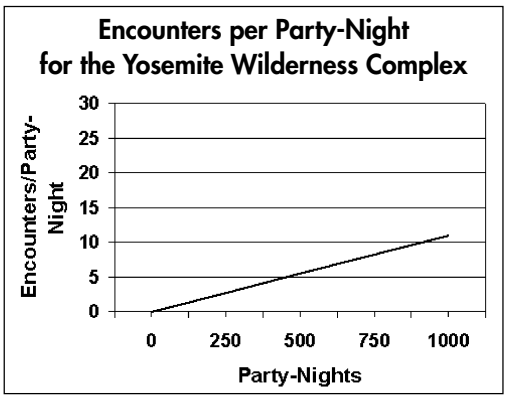


**Figure 5—Camp encounters as a function of party-night in the Yosemite Wilderness complex.**

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# Chief's Excellence in Wilderness Stewardship Research Award

Dr. Jan van Wagtendonk has been selected as this year's recipient of this research award to recognize his long-term commitment and accomplishments with direct application to wilderness stewardship.

Dr. van Wagtendonk, who works for the U.S. Geological Survey, and is stationed at Yosemite National Park in California, has been the leading researcher and advocate for wilderness science in the Department of the Interior for over 30 years. A highly productive research career has led to involvement in developing wilderness fire management and visitor use management programs for Yosemite National Park that have contributed substantially to interagency wilderness management programs in the Sierra Nevada. Jan has worked across boundaries enthusiastically, energetically, and effectively with surrounding National Forest wilderness managers. His work on fuels dynamics, fire prescriptions, remote sensing, and GIS applications to fire management have made major contributions to wilderness fire programs both in the Sierra Nevada and across the country. The *IJW* editorial board is pleased to jointly recognize Dr. van Wagtendonk for this award.