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VEHICLE BEHAVIOR IN AND AROUND COMPLEX SOURCES AND RELATED COMPLEX SOURCE CHARACTERISTICS

VOLUME VII

RECREATIONAL AREAS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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SECTION I

CONCLUSIONS

1. A general methodology has been developed which permits relating parameters descriptive of traffic behavior associated with developments (complex sources) to the available descriptive characteristics of the complexes themselves. These relationships are subsequently to be used by the sponsor to develop guidance for relating the complex's characteristics to air quality.

2. The methodology has been successfully applied to the last (recreational areas) of seven types of complexes, with quantitative results presented in this task report.

SECTION II

RECOMMENDATIONS

It is recommended that, as planned, the project officer employ this methodology to develop guidance for relating the traffic characteristics of recreational areas to typical and peak air pollution concentrations.

SECTION III

INTRODUCTION

OBJECTIVE AND SCOPE

The ability to estimate traffic characteristics for proposed developments and the resulting effects on air quality is an important prerequisite for promulgating State Implementation Plans which adequately address themselves to the maintenance of NAAQS. Prior to estimating the impact of a development (complex source) on air quality, it is necessary that traffic characteristics associated with the source be identified and related to parameters of the development which can be readily identified by the developer a priori. The purpose of this study is to identify traffic characteristics associated with specified varieties of complex sources and to relate these characteristics to readily identifiable parameters of the complexes. The end product of this task will then be used to develop an Air Pollution Technical Document which will provide guidance to enable control agencies to relate readily identifiable characteristics of complex sources to air quality.

The work is being performed in seven sub-tasks. Each sub-task is devoted to examining vehicle behavior and its relationship to readily obtainable parameters associated with a different variety of complex source. The seven categories of complex sources are:

1. Shopping centers (Report EF-263)
2. Sports complexes (stadiums) (Report EF-265)
3. Amusement parks (Report EF-268)
4. Major highways (Report EF-267)
5. Recreational areas (e.g., State and National Parks) - The present report
6. Parking lots (e.g., Municipal) (Report EF-266)
7. Airports (Report EF-264)

This, the seventh task report, describes the methodology developed, and the analysis and results of its application to recreational areas.

APPROACH

Due to internal constraints, the sponsor has been forced to impose a tight schedule on this project, permitting only two to three weeks for the analysis and reporting of each sub-task. Accordingly, the employment of readily available traffic design information for each type of complex has been suggested as the general approach.

The approach was designed to permit the development of answers to the following questions posed by the sponsor, using available traffic design and behavior data, and available data on parameters of the complex:

1. How much area is allotted or occupied by a single motor vehicle?
2. How much or what percentage of the land occupied by the complex source (and the source's parking facilities) can potentially be occupied by vehicles? What is the usual percentage?
3. What portion of the vehicles within the complex are likely to be running at any given time during a 1-hour period? During an 8-hour period? We are interested in both peak and typical circumstances here.
4. What is the typical and worst case (slowest) vehicle speed over 1-hour and 8-hour periods?
5. How are moving and parked vehicles distributed within the complex property? (e.g., uniformly?)
6. What are the design parameters for each type of complex which are likely to be known by the prospective developer beforehand?
7. Which ones of the design parameters in number 6 can be most successfully related to traffic and emissions generated by the complex? What is the best estimate for relationships between readily obtainable parameters and emissions?
8. What are the relationships of parking "lot" design to parking densities and vehicle circulation? What represents a typical design and/or a design which has highest parking densities, lowest vehicle speeds, longest vehicle operating times?
9. What meteorological conditions (i.e., atmospheric dilutive capacity) are likely to occur during periods of peak use? What use level is likely to occur during periods of worst meteorology (i.e., atmospheric dilutive capacity?).

The technical approach developed and implemented in this report consists of first structuring a methodology for describing engine operating modes which considers both the principal modes in automobile operation in and around complexes, and the emission significance of each mode. In our analysis this leads to an important emphasis on engine operating time, with only secondary significance attached to operating speed and distance.

For the complex being studied, an analysis is made of the typical movements of vehicles, and their movements under conditions of congestion, caused by peak traffic loads or by awkward design elements of the complex, or both. This highlights the traffic operational modes which have greatest effect on running times, and assists in defining the elements or parameters of the complex which influence these running times most.

The running times in critical modes are found to be dependent on the usage rate of the complex as a percent of capacity. In addition, absolute values of usage as a function of time are needed as direct input for estimating emissions. Therefore, data on usage patterns of the complex by season, day of the week, and hour of the day are collected and related to capacity parameters. The results are used in two important ways:

1. To develop quantitative relationships between running times and various percent-usage parameters; and
2. To provide general usage patterns from which the usage pattern for a complex of interest can be inferred, if no measured data are available.

Basic parametric values are then derived which define typical base line running times and use rates; these are used both to provide a point of departure for the peak case calculations, and as input to the estimate of typical conditions.

For any parameter of capacity (e.g., parking, entrance, exit), resulting increases in running time for each mode are estimated as they may be functions of the exceedance of that capacity. The base running time is then used in conjunction with typical use rates to generate typical combinations of running times and numbers of vehicles running. Finally, peak (1-hour and 8-hour) use rates are compared to capacities in order to calculate, using the above derived functionalities, the associated peak values of number of vehicles running, and running times.

It may often be possible, in addition, to develop and provide qualitative guidelines which can provide further insight into factors which may aggravate or alleviate congestion. These are provided separately from the quantitative relationships.

Finally, the meteorological conditions associated with the occurrence of the peak "(vehicle number) (running time)" values are defined; in addition, periods of the most adverse meteorological conditions are determined, and the use rate data examined to determine associated use rates and running times.

The methodology described above is considered to be completely general, and to apply to all the complex sources of concern here, with the exception of "major highway" case cited in Section III titled Objective and Scope. That special case is recognized in the work statement as an unusual one requiring different treatment in the context of the other six sources, and is in fact treated in a totally different manner in that report (No. EF-267).

The remainder of this report covers special considerations required in the case of recreational areas, and describes the implementation of this methodology for these complexes, and the results obtained.

Public recreational areas are the subject of extensive attention by federal, state and local administration, and are the subject of study and research by these agencies, and by other professionals in the fields of recreation, and the associated use rate, traffic and parking problems. Most of the data analyzed and presented in this study were obtained from the National Park Service (NPS), the National Recreation and Park Association (NRPA) (especially its National Conference on State Parks branch), and selected State Park Departments.

SECTION IV

CHARACTERISTICS OF RECREATIONAL AREAS

Recreational areas are extremely varied in type, purpose, size, administrative control source, and degree of patronage (variously called number of visits, visitations or attendance). A certain amount of sorting has therefore been done in the available data to attempt to focus on those which appear to represent the largest degree of automotive traffic annually, and generally focussed in the smaller sized of total areas. The following material discusses some of the general aspects of recreational areas which are relevant to the traffic and parking problems.

Federal departments which are concerned with recreational areas in some way include Agriculture, Commerce, Defense, HEW, HUD, Interior, Labor, Transportation and Treasury. In addition, eleven independent federal agencies are concerned, as well as all fifty states (at various levels), and a very large number of agencies at the local level.

In order to render the problem more manageable, and to attempt to concentrate on the larger manifestations of the problem, the task statement elaborated on the term "Recreational Areas" by adding the parenthetical phrase "State and National Parks". Our analysis has convinced us that this is a proper approach - that it encompasses the principal area types which should be of concern, and defines an approach which should be applicable to any type of recreational area which might require analysis.

As will be seen in Section V on Recreational Area Parameters, the data on annual attendance represents information which is widely available, has potential for a variety of uses, and helps define, at least in part, the magnitude of the potential traffic and parking problem. It is of note to

add that recreational professionals typically use conversion factors for going from person-counts to vehicle-counts, and vice versa; for example a factor frequently encountered in the recreation areas of most importance here is of the order of 3.5 persons per vehicle. The data which follow are taken variously from statistics for the calendar and fiscal 1970, 1971 and 1972, selected either from 1970 for completeness for intercomparison, or from the later years for timeliness. For calendar 1972 there were 297 areas administered by the National Park System; of these, 248 reported visits totalling 211,621,100. Of the 297 areas, the majority (67%) were National Monuments (82), National Historical Sites (57), National Parks (38), and National Memorials (21). The remainder are divided among 19 other categories. The 37 reporting National Parks account for 53,953,900 (25.5%) of the total reported visits. In Tables 1 and 2 are shown the visitation and acreage data associated with all reporting National Parks (Table 1), and all reporting areas of any type in the National Park System (Table 2). In each case the areas are ranked in order of total annual visitations for 1972. The acreage data are included because, very broadly, the largest visitations coupled with the smallest areas represent the potentially more severe problems. The National Park (NP) Data from Table 1 are repeated in Table 2 in the appropriate ranking (note that the Great Smoky Mountains NP ranks first in Table 1, and fifth in Table 2). Fifteen of the Table 1 entries, through Glacier NP, appear in Table 2; the remainder variously include National Military Parks, Parkways, National Historical Parks, National Seashores, National Recreation Areas, and the like. The total of the visits listed in Table 2 represents 66.6% of all visits reported in the system. It should be noted, however, that the National Parkways are more appropriately included in the category of Major Highways, reported in No. EF-267 in this series.

The state park system is easiest considered, at least initially, in the context of the most complete published data, that compiled by the NPRA for calendar 1970 (subsequent reference is made to fiscal and calendar 1972 data obtained directly from selected state park departments). For all fifty states a total attendance of 484,189,207 is reported. The

Table 1. NATIONAL PARKS LISTED IN RANK ORDER OF TOTAL ATTENDANCE FOR 1972

Rank	Name	Acreage	1972 Attendance
1	Gt. Smoky Mts.	516,626	8,040,600
2	Platt	912	4,257,100
3	Olympic	896,599	3,031,700
4	Grand Teton	310,443	3,002,200
5	Hot Springs	3,535	2,738,300
6	Grand Canyon	673,575	2,698,300
7	Acadia	41,642	2,654,400
8	Rocky Mountain	262,191	2,519,600
9	Shenandoah	193,537	2,304,100
10	Yosemite	761,320	2,266,600
11	Yellowstone	2,221,773	2,251,700
12	Mammoth Cave	51,354	1,872,900
13	Everglades	1,400,533	1,773,300
14	Mt. Rainier	241,992	1,682,400
15	Glacier	1,013,101	1,392,200
16	Hawaii Volcanoes	229,616	1,389,100
17	Petrified Forest	94,189	1,229,000
18	Kings Canyon	460,331	1,058,000
19	Wind Cave	28,059	992,900
20	Zion	147,035	970,200
21	Sequoia	386,863	869,600
22	Carlsbad	46,753	856,100
23	Crater Lake	160,290	594,300
24	North Cascades	505,000	552,300
25	Mesa Verde	52,074	547,900
26	Lassen	106,934	505,900
27	Mt. McKinley	1,939,493	306,000
28	Haleakala	27,283	305,500
29	Big Bend	708,221	290,200
30	Virgin Islands	14,419	281,600
31	Capitol Reef	241,671	272,000
32	Arches	73,234	225,500
33	Redwood	56,201	104,300
34	Canyonlands	337,258	60,800
35	Guadalupe Mts.	81,677	39,200
36	Isle Royal	539,341	16,100
37	Bryce Canyon	36,010	2,000
			53,953,900

Table 2. ALL TYPES OF AREAS ADMINISTERED BY THE NATIONAL PARK SYSTEM (INCLUDING NATIONAL PARKS - TABLE 1) LISTED IN RANK ORDER OF ATTENDANCE FOR 1972 (THE HIGHEST 37 OUT OF 248 REPORTING).

Rank	Name	Acreage	1972 Attendance
1	Chickamauga/Chattanooga NMP	8,113	14,078,700
2	Blue Ridge Parkway	94,749	13,729,700
3	Natchez Trace Parkway	45,298	13,397,800
4	Colonial Nat'l. Hist. Park	9,430	8,529,300
5*	Great Smoky Mts. NP	516,626	8,040,600
6	Kennesaw Mt. Nat'l. Batt. Pk.	3,683	6,286,200
7	Cape Cod NS	44,600	4,972,300
8	Lake Mead NRA	1,936,978	4,888,600
9*	Platt NP	912	4,257,100
10	GW Mem. Parkway	7,142	3,605,300
11	Ozark NSR	72,101	3,289,700
12*	Olympic NP	869,599	3,031,700
13*	Grand Teton NP	310,443	3,002,200
14	Petersburg NB	2,731	2,964,900
15*	Hot Springs NP	3,535	2,738,300
16*	Grand Canyon NP	673,575	2,698,300
17*	Acadia NP	41,642	2,654,400
18	Jefferson NEM NHS	91	2,613,400
19	Gettysburg NC	21	2,609,100
20	Independence NHP	22	2,553,300
21*	Rocky Mt. NP	262,191	2,519,600
22*	Shenandoah NP (incl. Skyline Dr.)	193,537	2,304,100
23*	Yosemite NP	761,320	2,266,600
24*	Yellowstone NP	2,221,773	2,251,700
25	Lincoln Memorial	164	1,989,100
26	Mount Rushmore Nat'l. Mem.	1,278	1,911,600
27*	Mammoth Cave NP	51,354	1,872,900
28	Cape Hatteras NS	28,500	1,783,700
29*	Everglades NP	1,400,533	1,773,300
30	Assateague Island NS	39,630	1,698,600
31*	Mount Rainier NP	241,992	1,682,400
32	Gettysburg NMP	3,409	1,682,300
33	Washington Monument	106	1,613,500
34	Lake Meredith NRA	41,097	1,494,200
35	Cabrillo NM	123	1,422,100
36	White House	18	1,412,800
37*	Glacier NP	1,013,101	1,392,200

* National Park (NP) data repeated from Table 1.

comparable 1970 figure for the National Park System is 172,004,600. This comparison of between 2.5 and 3 to one between total state and total national is reported as characteristic over the years. What must be borne in mind, however, is that a very much larger number of areas is administered by the states (3,425 compared to 281 in 1970); the national total acreage is much larger (8,554,919 for the state park areas in 1970 compared to 30,050,867 for the national system in 1971).

Since our eventual interest is in individual parks with large attendance, we did an approximate weeding out to identify at least some of these in the state systems. First the states were ranked by total attendance at all state parks for 1970 (NRPA), with the results for the top 15 given in Table 3. The individual state agencies for the top-ranked five were contacted directly, and queried as to the identification and attendance figures for all recreation areas in their systems having over one million in attendance. These data are for calendar or fiscal 1972, as indicated, and are given in Table 4. We thus see that attendance at selected major state recreational areas rank with the higher attended areas in the national system (Table 2). The intent of this exercise is to establish the order of magnitude of the annual attendance data situation for both national and state recreational areas, and to use this information as a basis for the subsequent analysis.

As part of the general discussion on recreational areas, it is important to point out some general trends in park planning, especially transportation systems planning, of which we have been made aware in our discussions with transportation professionals of the National Park Service. First, there is a strong awareness within the service of highway access and parking problems which exist in some of the present park system areas, such as Mount Rushmore National Memorial and Assateaque Island National Seashore. Active programs are under way to attempt to relieve these problems by various remedial measures, such as parking at a distance and busing to the area.

Table 3. THE TOP FIFTEEN STATE PARK SYSTEMS
RANKED BY TOTAL ATTENDANCE FOR 1970

Rank	State	Acreage	No. of Areas	1970 Attendance
1	New York*	2,927,982	258	49,513,173
2	California	762,073	173	43,984,980
3	Ohio	138,020	56	32,626,896
4	Pennsylvania	273,450	202	31,457,581
5	Illinois	280.078	90	24,005,419
6	Kentucky	30,185	40	23,746,795
7	Oregon	80,707	221	22,952,384
8	Michigan	204,991	76	20,492,151
9	Washington	76,514	151	19,641,923
10	Oklahoma	88,224	67	17,659,932
11	Texas	71,433	70	14,721,063
12	Missouri	75,380	55	14,539,415
13	Iowa	34,906	80	11,415,918
14	Tennessee	48,445	29	10,683,096
15	Wisconsin	108,000	60	9,897,559
	Percent of Total for all States:			71.8%

* • New York Office of Parks and Recreation	247,887	204	45,239,970
• New York Department of Environmental Conservation (Division of Lands and Forests)	2,653,095	54	4,273,203

Table 4. FOR THE FIVE STATES WITH THE HIGHEST ANNUAL RECREATIONAL ATTENDANCE, THE RANKING OF ALL RECREATIONAL AREAS WITH ATTENDANCE OVER ONE MILLION IN CALENDAR 1972 (OHIO DATA FOR FISCAL 1973).

State	Rank	Area	1972 Attendance
New York	1	Jones Beach	12,079,000
	2	Niagara Reservation	3,804,000
	3	Allegheny State Park	1,123,000
California	1	Pismo State Beach	3,224,984
	2	San Mateo Coast State Beaches (seven beach areas)	2,480,764
	3	Folsom Lake State Park	1,944,464
	4	Bolsa Chica State Park	1,748,021
	5	Huntington State Beach	1,567,413
	6	Morro Bay State Park	1,488,495
	7	Anza-Borrego State Park	1,123,262
	8	Humboldt Redwoods State Park	1,023,244
Ohio	1	Hueston Woods State Park	2,681,785
	2	Grand Lake St. Mary's State Park	2,227,306
	3	Pymatuning State Park	2,056,384
	4	Rocky Forks State Park	1,968,755
	5	East Harbor State Park	1,680,119
	6	Salt Forks State Park	1,538,178
	7	Mohican State Park	1,364,043
	8	Mosquito State Park	1,344,798
	9	Deer Creek State Park	1,331,078
	10	Delaware State Park	1,301,934
	11	Dillon State Park	1,092,529
	12	Indian Lake State Park	1,058,832
Pennsylvania	1	Pymatuning State Park	4,536,778
	2	Presque Isle State Park	3,019,298
	3	Prince Gallitzin State Park	1,702,292
	4	Marine State Park	1,330,137
	5	Cook Forest State Park	1,113,488
	6	Independence Mall	1,044,606
Illinois	1	Illinois Beach State Park	1,511,164
	2	Rock Cut State Park	1,202,448
	3	Giant City State Park	1,114,963
	4	Eldon Hazlett/So. Shore Conser. Area	1,044,735
	5	Mississippi Palisades State Park	1,013,479

In addition, a new Alternate Transportation System Program for the NPS received an appropriation for studies of various areas of the system to determine the suitability and feasibility of implementing innovative approaches to solving transportation problems. Detailed information has been developed for 21 areas, and studies have been begun on some of them; additional funds have been appropriated to operate transportation systems now existing in eleven areas. In general terms the alternate systems attempt to replace the use of private vehicles with public transportation of a variety of types; such system development and use would be expected to include planning study of the air quality impact, which would presumably be significantly less than that of the replaced vehicles. The one proviso we would offer is as follows: if the alternate system involves a shift of the vehicle and parking activity to a place removed from the recreational area (as some do), then that new site should be examined for its vehicular pollution potential.

This analyses is addressed to vehicular access to, and use of, the facility and/or its parking areas, wherever they may be located.

SECTION V

RECREATIONAL AREA PARAMETERS

The important parameters in characterizing recreational area traffic patterns are attendance rates and temporal - daily, weekly and seasonal - variations in attendance. Recreational traffic and parking planners are urged by specialists in the field to take into account: seasonal weekend patterns of peak parking; turnover (average time for people to participate or watch and then leave in their cars); availability of multiple-use areas and other parking areas or fields to handle overflow; relationship between the size and capacity of the recreation facility and of its proposed parking area(s); any proximity to a large urban center with its attendant demand; capacity of highway access to the area and peak hours of highway loading; any available mass transit; and employee parking needs.

Quoting further from the NRPA's "Parking for Recreation": "The quantitative determination of parking needs is rarely a simple matter of finding out how many drivers will want to park at a proposed facility at a given time. Building for maximum demand generally results in astronomical waste. Even in the design of modern expressways which are so vital to the economic life of our nation, no attempt is made to accommodate the highest peaks of demand. Generally, we design to satisfy the traffic that can be expected in the so-called 30th highest hour of the design year for the road. This means that for those 29 hours during the year in which traffic is still heavier than in the 30th highest, congestion of a most uncomfortable nature is frankly and calmly anticipated and planned for. To do otherwise would involve construction of the most improbably extravagant scope.

The formulae for fixing recreational parking demand which are given in this text are empirical and must be applied with due consideration of local geography, social mores and habits, and economics. Two plus two do not always equal four. The most careful computation may be provided by time to have been in error.

If the planner is fated to err, it should be on the side of economy. If a compelling demand for expansion of facilities is demonstrated, it is generally feasible to get the funds to satisfy it. On the other hand, nothing is more embarrasing politically than an underpatronized facility. Choose a site which will permit expansion, plan so as to be able to accommodate it, but build conservatively."

Extensive examples of attendance have been given in Section IV for most of the largest state and national parks (in terms of annual attendance), and the presumption is made that estimates of these figures will be generated in the natural course of development of any large new recreational area (or a significant expansion of an existing area). The opening of a new section in an existing area is a frequently encountered process of expansion of a park system to allow for increased use.

SEASONAL ATTENDANCE

Average variation in seasonal attendance in the National Park System is seen in Table 5. Attendance, or visitation, is concentrated in the summer months, with June, July and August accounting for 42% of the total. Adding May and September increases this figure to 61%. The pattern holds in general for most parks, and is probably a good representation for state parks as well. However, some significant variations occur such as certain southern areas (e.g., Everglades NP) or where fall color tours cause a second peak in October (e.g., Shenandoah NP). Variations for the National Parks are exemplified in Table 6, which employs the concept of the monthly peak load factor, which is defined in this case

as the ratio of the peak to the average attendance. Thus if all twelve months' visits were identical in number the load factor for each would be one; if all visits occurred in one month, that month would have the maximum possible peak value of twelve. Thus, the larger the load factor, the more concentrated is public use in a short period. The appendix contains monthly percentage use values for all areas in the National Park System.

Table 5. AVERAGE MONTHLY VISITATION PATTERN, NATIONAL PARK SERVICE, 1972

Month	Percent of Total Attendance
January	3
February	4
March	6
April	8
May	9
June	12
July	16
August	14
September	10
October	8
November	5
December	5

Table 6. LOAD FACTORS AND AVERAGE VISITS PER DAY IN PEAK VISITATION MONTH 1961, 1970, AND 1971

	1961			1970			1971		
	Peak Visitation Month	Load Factor 1/	Average Daily 2/	Peak Visitation Month	Load Factor 1/	Average Daily 2/	Peak Visitation Month	Load Factor 1/	Average Daily 2/
Acadia	July	2.9	12,097	August	2.8	21,231	August	3.1	20,169
Arches	September	1.8	463	June	2.5	1,223	July	2.1	1,158
Big Bend	August	1.7	406	April	1.7	827	April	1.7	1,189
Bryce Canyon	July	2.9	2,087	July	2.9	2,723	August	2.6	2,677
Canyonlands	--	--	--	June	3.1	288	April	2.1	326
Capitol Reef	September	1.7	628	August	2.8	1,681	July	2.4	1,606
Carlsbad Caverns	July	2.6	4,117	July	2.7	5,258	July	2.7	5,727
Crater Lake	August	3.6	4,007	August	3.6	5,141	August	3.5	5,227
Everglades	February	1.5	2,483	January	1.8	6,254	February	1.7	6,413
Glacier	July	4.8	9,542	July	4.5	14,991	August	4.1	14,394
Grand Canyon 3/	July	2.5	8,482	July	2.5	15,438	July	3.8	15,146
Grand Teton	August	3.6	14,596	July	3.9	35,301	July	3.8	33,816
Great Smoky Mountains	July	2.7	35,068	July	2.4	43,049	July	2.6	49,233
Guadalupe Mountains	--	--	--	--	--	--	July	2.4	177
Haleakala	August	1.7	305	August	1.6	865	August	1.7	1,177
Hawaii Volcanoes	July	1.9	3,838	September	1.5	3,355	August	2.0	5,319
Hot Springs	July	2.5	5,920	July	1.9	10,490	July	1.7	11,651
Isle Royale	August	5.2	90	August	5.8	223	August	4.8	205
Kings Canyon	July	2.8	5,722	August	2.8	7,548	August	2.8	6,662
Lassen Volcanic	August	3.6	4,511	August	3.4	4,231	August	3.3	4,028
Mammoth Cave	August	2.4	3,391	August	2.3	10,534	July	1.9	8,825
Mesa Verde	August	3.4	2,096	July	3.3	4,704	August	3.3	4,551
Mount McKinley 4/	July	4.4	214	July	5.8	716	July	3.9	609
Mount Rainier	July	2.9	12,400	August	2.8	14,608	August	3.2	15,004
North Cascades	--	--	--	August	2.5	1,991	August	3.0	1,766
Olympic	August	3.3	13,524	August	3.0	18,584	August	2.8	14,113
Petrified Forest	July	2.6	4,716	July	2.8	8,665	July	3.0	8,585
Platt	July	2.9	9,241	July	2.1	9,071	June	2.0	22,815
Redwood 5/	--	--	--	--	--	--	August	--	339
Rocky Mountain	August	4.4	18,009	August	3.5	22,194	August	3.4	22,725
Sequoia	July	2.6	4,332	August	2.8	6,587	July	2.7	6,410
Shenandoah	August	2.2	11,620	August	2.1	13,322	July	2.1	13,538
Virgin Islands	July	1.5	124	March	1.5	524	August	1.4	923
Wind Cave	July	2.6	4,827	August	2.6	7,050	August	2.7	7,849
Yellowstone	July	4.3	17,777	July	4.0	24,877	July	3.9	22,385
Yosemite	July	2.7	8,758	August	2.3	13,866	July	2.3	15,263
Zion	August	2.3	3,745	August	2.4	5,815	July	2.4	6,326

(See following page for Footnotes to Table 6)

FOOTNOTES TO TABLE 6

1/ Load factor - Total visits in peak visitation month divided by average monthly visitation.

2/ Average daily - Average number of visits per day in peak visitation month.

3/ The 1970 data for Grand Canyon National Park reflect corrections submitted to the Washington Office in 1971. The corrections are not reflected in the monthly public use reports for 1970 and 1971.

4/ The completion of the Anchorage-Fairbanks Highway in the Fall of 1971 generated a large increase in off season travel to Mount McKinley National Park. Consequently, the load factor for 1971 is distorted and does not necessarily reflect the true seasonal travel pattern for Mount McKinley National Park.

5/ Redwood National Park began their visitation data series in July 1971 and a load factor could not be calculated on a twelve month base.

ATTENDANCE BY [OF WEEK AND HOUR OF DAY

In broad terms, e highest values of attendance will occur on weekends, with a tendency of the maxima to be arrivals by midday Saturday and/or Sunday, and departures late those same days. This is a broad generality, however, which applies primarily to day trips to those areas noted for swimming, picnicking and scenic driving, and to others as well. These activities are characteristic of many of the highly attended areas. Attendance patterns should be defined for any proposed new or expanded development. Typical total one day travel trips to park areas, as distributed over a weekend, are shown in Table 7. Appendix B presents a number of additional data sets which are considered typical of weekday and hourly traffic for recreational areas in Missouri. These data may be combined with average expected durations of stay (4 hours is frequently cited as a typical value), to convert entrance times (visits or attendance) to exit times to obtain the combinations of entrances and exits as functions of time of day.

Table 7. HOURLY DISTRIBUTION BY PERCENT OF TOTAL WEEKEND TRIPS TO ALL STATE PARKS

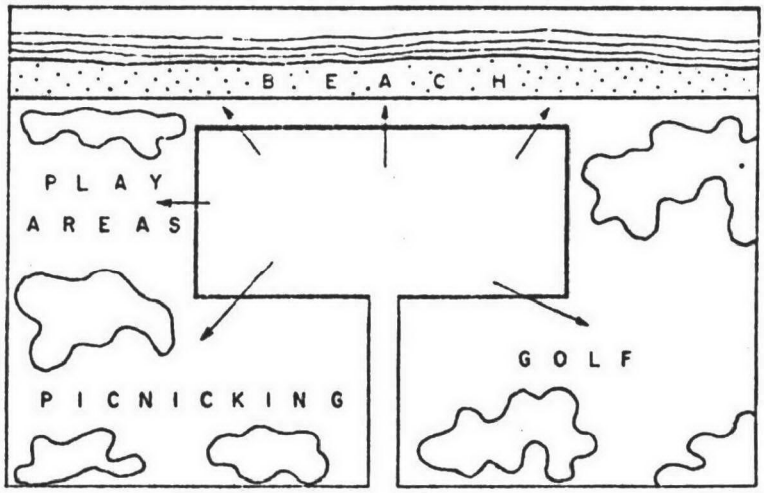
TIME OF DAY	PERCENTAGE OF TOTAL TRIPS		
	FRIDAY	SATURDAY	SUNDAY
8-9		1 13	0.74
9-10		1.47	2 98
10-11		2.87	7.22
11-12		2 85	10 86
12-1		2 53	12 57
1-2		2.79	11.11
2-3		2 85	9 98
3-4		2 03	6 41
4-5	1.15	1.78	4 30
5-6	1.38	1 49	2 22
6-7	1 57	1 36	0 09
7-8	1.59	0 82	0.05
8-9	1 17	0.49	0.02

PARKING FACILITIES

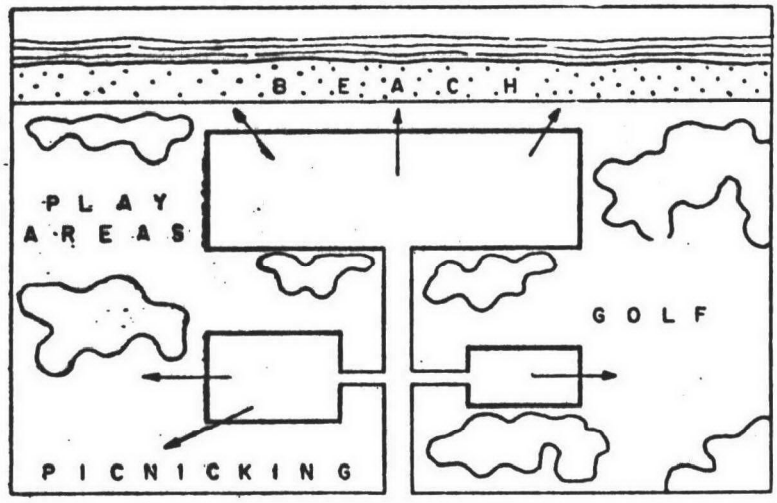
The quotation from "Parking for Recreation" given in the beginning of this section gives some general principles of parking for recreational areas. More specific indications are given in the following material, most of which is extracted from that document.

Depending on the landscaping employed, parking for such areas will usually consist of from one to a number of separated areas providing space for cars at the rate of from 110 to 150 cars per acre of parking area.

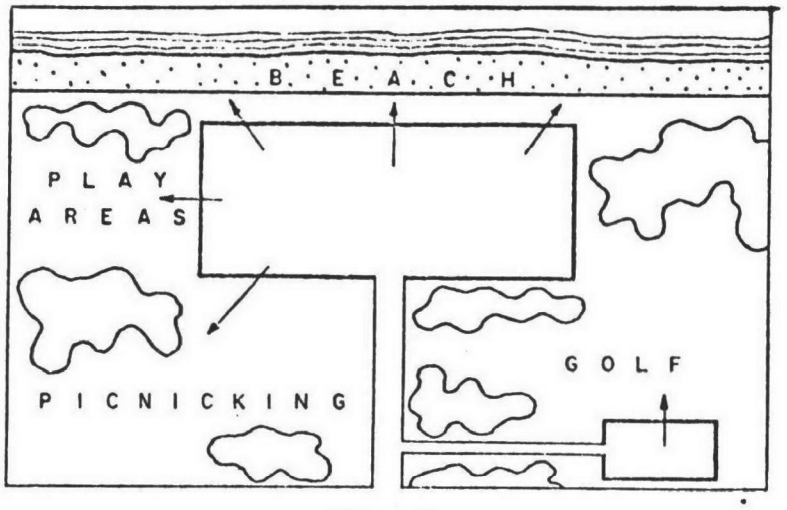
There are two basic ways, plus two variations on them, to arrange parking at a recreation center. Parking may be centralized as in Plan A. It may be dispersed as in Plan B to provide parking fields at each different type of recreational facility within the larger recreation center. It may be handled as a combination of the first two plans as in Plan C, or it may be dispersed and allowed to overflow as in Plan D.



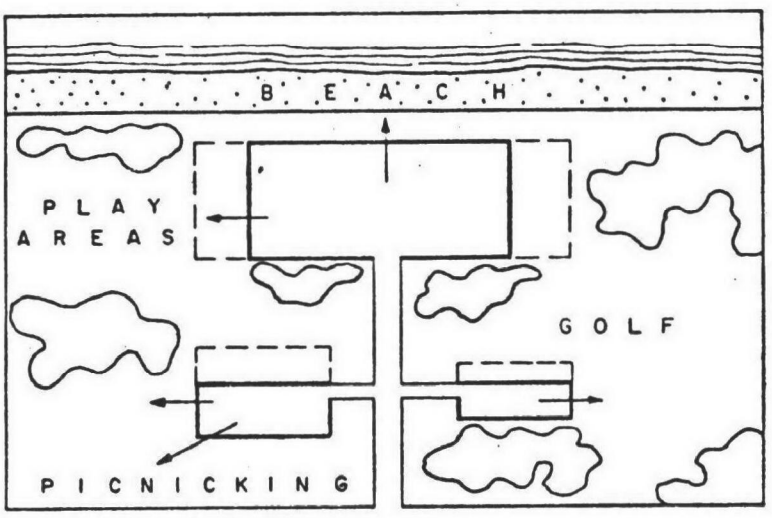
Plan A
Centralized parking is least costly of all parking schemes.



Plan B
Parking at each facility is more convenient for uses but more difficult to operate.



Plan C
Parking for one specialized facility is often necessary.



Plan D
Adjacent overflow grass or gravel areas will take care of peak days. It is better to under build than to over build, particularly if there is more than average space available.

Planners of small recreation centers, which often have only one facility, will have no trouble selecting the right approach to parking; namely, the centralized parking area that provides all the parking necessary. But in large recreation centers, parking schemes and parking needs can be complex. The various alternatives for parking layouts should be studied carefully before deciding how to arrange the areas and how much of them should be paved.

A. Centralized Parking

In centralized parking, the overflow of parking traffic from one type of recreation is absorbed by available parking space allocated to other types of recreation that are not drawing large crowds at the same time. This consideration can be very important in construction costs. If the parking area is to be paved, a central parking field will be a good deal cheaper than multiple fields because it can be smaller than the sum of the areas of the multiple fields, when designed for peak capacity.

In a centralized parking lot, serving combined facilities in the recreation center, all the visitors can park quickly without searching for a parking area that would otherwise be serving their particular recreational interest. But the big central field's drawbacks are: 1) its often forbidding and awkward appearance in the over-all landscape; and 2) the problem it presents in moving people from their cars to recreation.

If the distance from car to recreation is long, the walk will be arduous and will make the recreational facility much less attractive. Solving the problem by operating buses from parking to recreation at some distance is an alternative that works in special cases. For instance, buses have been used in a number of ski areas in the National Park System where parking fields near the ski lifts were not practical because of the steep and mountainous terrain. Cut and fill earthwork and blasting bedrock at the base of the lifts would have been far to expensive. In cases like this, the facility usually supplies enough buses to handle near-peak capacity crowds, plus parking space for buses and drivers. Bus fees should ordinarily pay for their operation.

B. Total Capacity Paved Parking at Each Facility

In large recreational centers, where activities may be widely separated, the public will not only appreciate but will pay for the opportunity to park close to the activity they are interested in. The diagram above (B) illustrates such an arrangement - a parking field for each facility, adequate to accomodate peak parking demands.

In a big recreation area, various activities may often be one-half mile from each other, and separate parking fields are a better answer - for a number of different activities - than bus service from a central field. At New York City's Jones' Beach, which stretches along the Atlantic for six miles, a number of separate parking fields are provided to handle this great length. The Overlook fields there, right back of the beach and with a good view of the ocean, fill up first. The larger parking fields which are considered less desirable because of their distance from the beaches fill up last. Several small fields are less obtrusive in the landscape than one large field, but they have three drawbacks: 1) they are harder to control; 2) they cost more to build; and 3) they can make finding a parking space on a busy day a lot more troublesome for people who are not familiar with parking patterns at that particular facility. Carrying picnic baskets and beach chairs and watching youngsters to and from a large central field is drudgery whether a big distance between car and recreation is covered by walking or on a crowded bus.

However, as pointed out above, construction, maintenance, and operation can be much more expensive in multiple parking fields (especially if they are paved) than they are in a central parking field.

C. Combined Centralized and Single Facility Parking

Only the largest recreation centers will use the huge scope of Plan B, individual parking fields at each facility; and smaller centers will normally use the centralized field. Recreation centers in between may combine the two schemes for the most effective solution to their parking problems. In this case a central field for most of the facilities will have all the

advantages mentioned in A. But where one or two facilities, like a golf course a mile away from the central parking field, need their own space for parking, they should have them. The extra cost of decentralization in such instances can easily be offset by parking or other fees paid by appreciative vistors who won't have to walk a mile.

D. Overflow Parking at Each Facility

When parking for a big recreation center is clearly handled best by a number of fields, one at each type of recreation, the planner must decide whether to provide peak capacity paved parking areas or smaller paved areas with provision for overflow cars on turf or gravel surfaced fields. Peak capacity of a parking field is equal to the number of cars bringing the maximum number of people to the facility on a peak day, at the peak hour, plus 10%. The 10% will provide space for turnover as visitors come and go during the peak hour. The field will be filled on only a few days of the year, so it seldom makes sense to pave all the area. Paved areas can provide parking for normal days and good level turf or gravel will handle overflow on peak days.

Overflow areas like this can cut initial construction costs, but they may increase maintenance and operating costs since on peak days extra personnel will have to control and supervise parking in the overflow areas, unless they are permanently staked out and marked.

Actually, an overflow area need not be turf or gravel, it can be a paved softball diamond, for instance, or the winter storage area of a marina which is almost empty during the sailing season. Multiple use overflow areas like this, however, are often not very practical; usually, just at the time that the area is needed for parking, the greatest demand for the same area for recreation occurs.

SITE FACTORS

There is an obvious relationship between the parking area and its approaches. The traffic generated by a recreation area can be determined and roads designed to move a given number of cars in a given length of time. The rate of speed at which cars will be going will be low. Tighter curves, steeper grades, and reduced sight distances, which are not possible on high-speed roadways, are adequate and satisfactory, at least to a degree. With such criteria the road can be designed to follow existing terrain more closely, eliminating excessive cut and fill.

Even though earthmoving on a large scale is one of the least expensive unit costs in a construction project, the alternatives to extensive grading should be studied. In rough terrain smaller parking fields arranged on a series of terraces may be a better solution. It is desirable in parking design to balance cut and fill and avoid the need to borrow or remove earth, increasing total cost. However, a balance is rarely struck.

The location of parking areas often has a greater effect on the total design of the recreation center than decisions relating to other elements in the design. A parking site should be evaluated and selected with the following requirements in mind.

Existing topography must permit construction without excessive difficulty or cost, still permitting ready access to the recreation area. The parking area may be the logical place to give visitors a general view of the entire development. A careful study of topographic maps, aerial photographs, and reconnaissance on foot are necessary before any decision can be made.

ACCESS

Finally, relative ease of access to and exit from the area and its parking facilities is as important to recreational areas as it is to all the other complex sources studied, to prevent congestion and the consequent extensive idling times which can generate excessive emissions.

SECTION VI

TRAFFIC PARAMETERS

The methodology for describing traffic movement associated with this complex source, as outlined in Section VII, requires estimates of the average running time for the vehicles in the recreational area, and the volume of such traffic. Traffic parameters which should be used to develop these two values are discussed in this section.

PARAMETERS TO ESTABLISH TRAFFIC VOLUMES

Expected annual attendance is a figure to be expected from a developer; further, the estimated number of persons entering and leaving the recreational area by hour may be submitted by the developer, or estimated from related data such as that in this report. This data is converted to hourly traffic volume by dividing by average vehicle occupancy. Although this procedure for estimating traffic volume places much emphasis on a traffic parameter which is not very precise, it is a procedure which is used by recreational specialists to estimate expected traffic volume for a variety of purposes. An attempt should certainly be made to obtain an average vehicle occupancy (A.V.O.) value specifically for each park reviewed, and possibly even different values for particular times of the day or week.

The figure most commonly used in recreational area statistics is in the order of 3.5 persons per vehicle, although in special cases the estimate may deviate significantly from that.

This method of estimating traffic volume assumes that everyone arrives at the park by automobile. If this assumption is incorrect, the number of persons using other modes of transportation should be subtracted from the total attendance before calculating the estimated traffic volumes.

PARAMETERS TO ESTABLISH RUNNING TIMES

Concept of Emissions per Unit Time

In the immediate vicinity of recreational areas, maximum vehicle speeds rarely exceed 10 or 15mph, and average speeds are much lower.* The usual procedure for estimating motor vehicle emissions as a function of vehicle speed is not very accurate at these low speeds due to:

a. Difficulty in estimating average operating speed; and

b. Variation in observed emission rates per mile with slight change in average operating speed.

For recreational areas, analysis shows that traffic operations and their related emissions are better considered in units of time (grams/minute) rather than units of distance (grams/mile), for the following reasons:

1. The variations in emission per unit time at different speeds are relatively insignificant at the lowest speeds;** and

2. Traffic movement in the vicinity of a recreational area can be described more accurately and more easily in terms of minutes of running time than in terms of average speed, particularly when engine idling can predominate during congested periods.

Values for automotive pollutant emissions for 1972 in grams/minute at idle are available from A Study of Emissions from Light Duty Vehicles in Six Cities. They are summarized in Table 8. These test data compare well with emission factors calculated from the current edition of AP-42, when converted to grams/minute at various speeds and then extrapolated to zero speed.

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* If, access roads are up to several miles or more in length, and relatively uncurved and level, steady-state speeds in those portions may be higher - see "Approach" and "Departure" discussion.

** Less than 10 percent increase in CO and hydrocarbon emissions per minute from idle to 15mph.

Table 8. VEHICLE EXHAUST EMISSIONS AT IDLE IN GRAMS PER MINUTE*

Pollutant	Emissions, gm/min
Carbon monoxide	16.19
Hydrocarbons	1.34
Oxides of Nitrogen	0.11

* These values do not include emissions due to the cold start of engines or from evaporation of gasoline at the end of a trip ("hot soak"). If subsequent investigation of the relative magnitude of these emissions, compared to the totals generated by the methodology of this report, indicates that they are significant, appropriate values for each cold start and hot soak can be inserted as the total emissions for the start and stop modes, respectively. Since data for cold start and hot soak emissions would be reported per occurrence, there is no need to determine an associated running time or emission period for the modes.

In applying the recommended procedure of emission estimation, total emissions from the amusement park at any time would be the product of the number of vehicles, times average vehicle running time, times the appropriate emission factor from Table 8.

$E_{Total} = (V)\ (RT)\ (EF)$, where

V = Traffic volume during period of concern

RT = Average running time, minutes

EF = Emission factor, grams/minute.

Operational Modes at Recreational Areas

For purposes of analysis, traffic movement in the vicinity of a recreational area has been divided into the same eight operational modes that were specified for shopping centers, airports, and sports stadiums. These are summarized below. The schematic figures given in Section V show how and where these modes would apply.

Approach (A)* - The time or distance along the immediate access road during which traffic movement is affected by vehicles entering or leaving the park.

Entrance (I) - Waiting and service (entrance) time at the entranceway to the parking facility.

Movement in (MI) - Driving time or distance to the designated parking space (with supervised parking). This also includes waiting time in a queue within the parking area, or driving time to an overflow parking facility.

Stop (S) - Parking of the vehicle and shutoff of the engine.

Start (ST) - Starting of the engine and egress from the parking space.

Movement out (MO) - Driving time or distance from the parking space to the preferred exitway.

Exit (E) - Movement through the exitway, including waiting time in a queue.

Departure (D)* - The time or distance along the immediate access road that movement continues to be influenced by traffic from the recreational area.

The average running time in each of these modes can be quantified for a specific recreational area, or section of a recreational area, as a function of its physical dimensions, geographic layout, traffic control procedures, and traffic volume.

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* For cases where the approach or departure may involve several minutes at higher steady-state speeds, the following 1972 emissions-per-minute data may be used:

Pollutant	Emissions per minute (gm/min) at steady-state speeds of:		
	20mph	30mph	40mph
CO	16	17	18
HC	1.4	1.5	1.9
NO_x	0.3	1.0	2.5

Base Running Time

There is an average minimum vehicle running time for each recreational area that is associated with periods of low or zero traffic congestion. This concept of a minimum or base running time is important because it usually is the most common operating condition at the area and because at most areas it is expected to be exceeded only during periods of relatively high traffic volume if at all. The base running time can be estimated from a plan of the recreational area, its parking facilities, and its access roads, with an additional knowledge of its traffic control procedures and probable driving patterns.

Relationship Between Running Time and Traffic Volume

As traffic volume increases, running times may become longer due to congestion. Some of the constraints to movement that may contribute to the longer running times are:

- Queues at parking and information booths, in the active parking area as cars move into their assigned parking spaces, and at other temporary or permanent traffic control points.
- Queues created as vehicles attempt to exit onto access roads.

Identification of Potential Critical Modes at Recreational Areas

Examination of the eight operational modes that were identified indicates that running times in some modes should generally be relatively constant, but that times in others may increase under peak attendance/traffic conditions. For recreational areas, the three modes whose times may be greatly affected by traffic congestion, in order of decreasing impact, are:

1. Entrance
2. Exit
3. Movement in

Time in the entrance mode may be affected by the collection of fees and/or the giving out of brochures as the vehicles enter parking lots at recreational areas.

Movement time into a parking space is a function of the maximum parking rate that can be accomplished by park employees as they direct traffic within the lot. If traffic flow into the lot is controlled by a ticket or other gate, running times in the parking lot should not increase much with increased traffic. However, sizeable queues may form during these periods in free parking lots. Time in the "movement in" mode expands incrementally when the main parking lot is filled and incoming traffic must all drive an additional distance to an overflow lot.

Exit time for a vehicle in a parking lot is a function of the egress capacity of the lot. As this is approached or exceeded, running time increases. Waiting times in the resulting queues contribute significantly to total running times. Exit queue lengths are moderate compared to those for the entrance mode because of the departure of vehicles over a longer period of time.

SECTION VII

ANALYSIS

In this section, three analyses are developed for converting available data into vehicle running times and numbers of vehicles running. The final step of combining all these intermediate results into a quantitative description of recreational area traffic behavior is then treated in Section VIII, Results.

ENTRANCE OR PARKING TIME

Time spent entering a parking lot or waiting to be directed to a parking space is a function of the rate at which vehicles are attempting to enter the lot, the number of entrance lines, and the average time required for service at the entrance (fee, brochure). Running time can be quantified with data on these three parameters by use of a methodology employing queueing theory. The hourly inflow rate is obtained from the projected traffic distribution pattern for the area. Average service time per vehicle ranges from about 0.10 minute, where parking is free or the fee is collected after the vehicle has parked, to 0.25 minutes in cases where there may be slow attendants, or a poor entrance configuration. This value is difficult to predict from design data, since it is much more closely related to operational features of the parking facility.

Estimates of running times for the entrance mode cannot be precise, especially considering the available input data. The equations employed here for waiting time in queue result from assumptions that vehicles are reaching the gate randomly over the time increment of concern, and are passing through the gate randomly. Errors in the estimates by use of these equations are thought to be relatively low.

For periods when traffic flow is less than gate capacity, the average running time (in minutes) in a queue is given by the equation:

$$RT = b \frac{a}{1-a} \text{ , where}$$

$$a = \text{utilization factor}$$

$$= \frac{\text{(vehicle inflow rate, veh/min) (b)}}{\text{(no. of entrance lines)}}$$

$$b = \text{average service time, min.}$$

For these periods when traffic flow exceeds gate capacity (a>1.0), the queue continues to build during each time increment by the amount that traffic volume exceeds capacity. Average running time for this situation can best be estimated by the tabular calculation procedure exemplified in Table 9. The procedure is illustrated with data for a two-hour peak traffic period (3:00p.m. - 5:00p.m.) with vehicles existing as shown in column 2, four entrance lanes, and an average service time of 0.1 minute.

EXIT TIME

Since visitors usually leave the recreational area over a period of a number of hours, it is unusual for congestion and excessive queueing to occur at the parking lot exits or on the access roads. However, if inadequate exit capacity for peak crowds is expected on special occasions, the queueing theory equation or tabular method presented above may also be used to estimate running times in the exit mode.

Generally, it is more direct to describe the exit constraint in terms of gate capacity rather than average service time. The "b" factor in the equation can still be easily quantified, since it is the average outflow time per vehicle or the number of exit gates divided by the total gate capacity in vehicles per minute.

Table 9. EXAMPLE QUEUE CALCULATION WHEN GATE CAPACITY IS EXCEEDED

1 Time Period		2	3	4	5	6	7
Starting	Ending	Entering Traffic Volume	Vehicles Serviced	ΔN	N at End of Period	$N_{AV.}$	RT, Min.
				col. 3-	col. 4+	$\frac{\text{col. 5+col. 5'}}{2}$	(b) (col. 6) Divided by No. of gates
				col. 2	col. 5' (line above)		
2:30	3:00	900	1200	-	-	-	(use equation)
3:00	3:30	1220	1200	+ 20	20	10	.25
3:30	4:00	1400	1200	+ 200	220	120	3.0
4:00	4:30	1600	1200	+ 400	620	420	10.5
4:30	5:00	1400	1200	+ 200	820	720	18.0
5:00	5:30	1100	1200	- 100	720	770	19.25
5:30	6:00	980	1200	- 220	500	610	15.25
6:00	6:30	750	1200	- 440	60	280	7.0

N = queue length, in cars

RT = average running time, in minutes

= (av. inflow time per vehicle, min.) (av. queue length)

"MOVEMENT-IN" TIME

Running time spent in reaching a parking space increases as a function of the number of vehicles already in the parking area, since the later arrivals must find their way to the more remote sections of the lot. The average running time in this mode for a day, then, should be proportional to the daily attendance. Actual values for a particular recreational area are estimated from driving distances as determined from a plan of the parking area.

For parking lots with no entrance booth, a queue may form at the point of active parking during periods of high inflow, rather than at the entranceway. However, the same queueing theory equation is still applicable.

The largest increase in running time for the "movement-in" mode occurs when the capacity of the main parking lot is exceeded and incoming cars must be diverted to an auxiliary or overflow area. Therefore, some quantitative analysis of number of parking vehicles at any time of the day is desirable. Vehicle accumulation can be derived from the hourly data on arrival and departure of visitors, or arrivals plus average stay-times. After these data have been converted to equivalent inflow/outflow of traffic, the number of vehicles in the parking lot at any time is the cumulative difference between these two hourly values. At the time of day on a peak attendance day when the estimated number of vehicles in the parking area exceeds the primary parking capacity, then running time is incrementally increased by an amount that accounts for driving time to the overflow lot, plus any additional delays associated this movement.

SECTION VIII

RESULTS

METHODOLOGY

In general terms, the methodology proceeds as described in the next two paragraphs which follow. It should be emphasized that this description is of the technique, shown schematically in Figure 1, in its most general form, which provides the starting for each of the seven types of complexes investigated. Differences in implementation from this general approach arose for each of the other six complexes, but the methodology for recreational areas follows the general approach closely with few exceptions.

Starting from the physical, geographic, and demographic characteristics of the complex, relationships are established for estimating typical and peak traffic volumes. The concept of operational traffic modes is used to generate best estimates of average running times for cars. The typical traffic volumes and base running times provide the description of typical conditions.

The parameters of the complex which significantly and adversely impact traffic behavior are also defined. Quantitative relationships are proposed or estimated for the controlling parameters of the complex with respect to excess running times in critical traffic operating modes. These, in turn, are superimposed on the base running times to generate peak running times. The peak running times are then associated with peak traffic volumes to create the required information on peak traffic conditions.

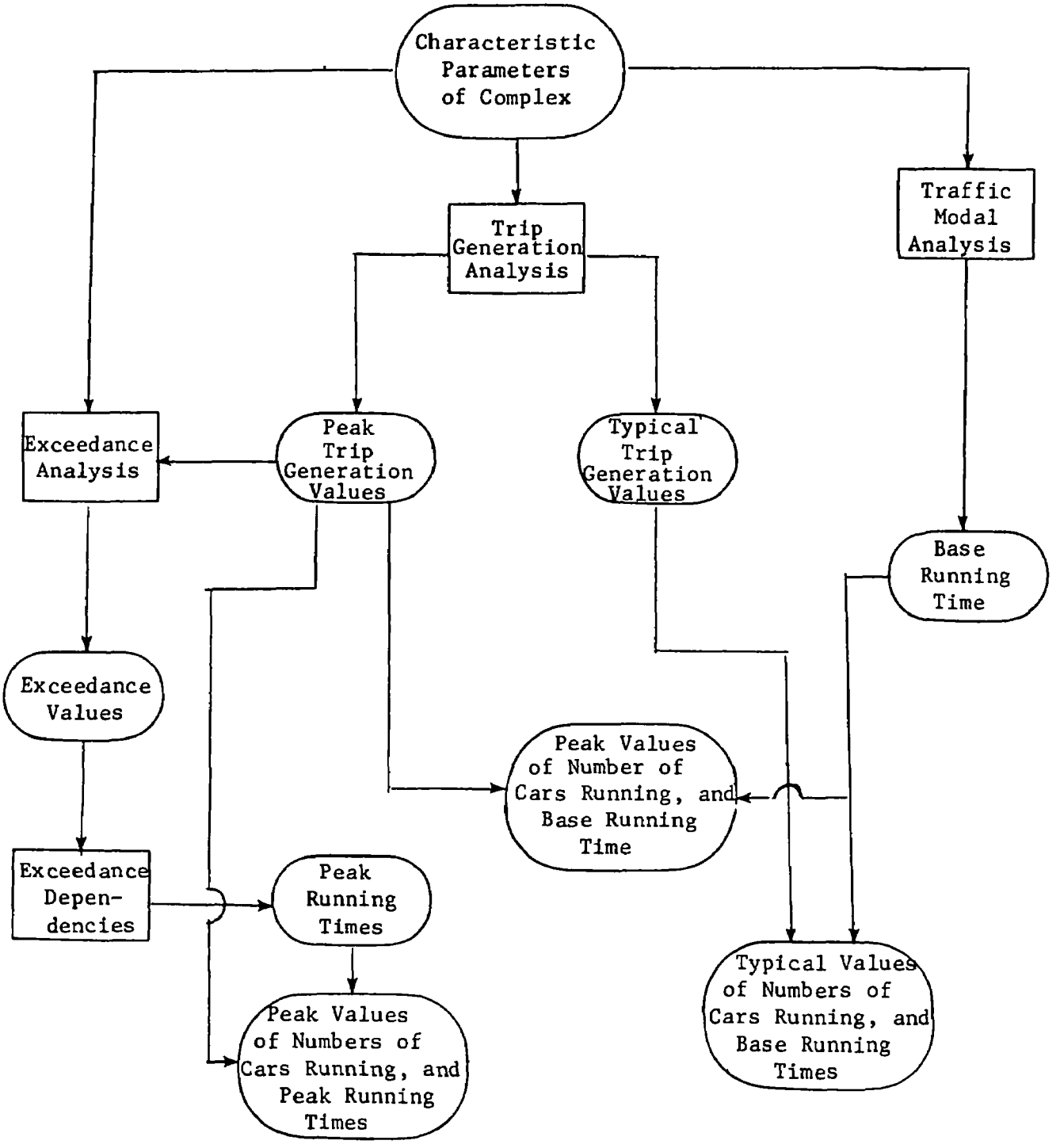

Figure 1. GENERALIZED METHODOLOGY

In the case of recreational areas, as shown in Figure 2, the methodology proceeds from basic information about a given area (see Section V), via traffic behavior data and traffic volume projections (see Section VI), to generate estimates of peak and typical numbers of vehicles and associated running times by hour of the day. Typical and peak one-hour and eight-hour periods, required end products, can then be extracted from this information.

The specifics of the procedure are presented below. First, the attendance patterns associated with typical and peak days at the area are delineated. These may be provided, or derived using an annual total estimate and the seasonal, daily and hourly average data of Section V and the Appendixes. These are converted into number of vehicles entering and leaving the park per hour by dividing numbers of visitors by their respective average vehicle occupancies. Running times in the eight operating modes are then determined. A schematic diagram similar to those in Section V may be helpful in analyzing the operating modes at the area under different traffic volume situations. If the schematic is approximately to scale for the parking area and access roads, it enables estimates of the base running times in each mode to be made.*

The access roads to most large recreation areas are on park property, so running times in the approach and departure modes are influenced only by traffic to and from the area and by the configuration of the access road. Running times in the stop and the start modes are probably always very low--the value of 0.1 minute used in the first task report is still appropriate here. Running times in the entrance and exit modes are estimated by the procedures presented in Section VII, as functions of the traffic volume and entrance and exit gate capacities. Movement into a parking space is primarily related to the size of the facility until the lot becomes filled. Thus the traffic volume estimates must be used in conjunction with parking lot capacity to determine whether capacity is exceeded during peak periods, and hence the number of vehicles that will have an additional running time to an overflow parking area. Time for movement out appears to be primarily a function of parking lot size, and relatively constant for all attendance rates.

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* If a large recreational area is served by widely scattered parking lots (i.e., is divided into major sections), and served by separated access roads, then the sections may be analyzed separately, depending on sizes and distances.

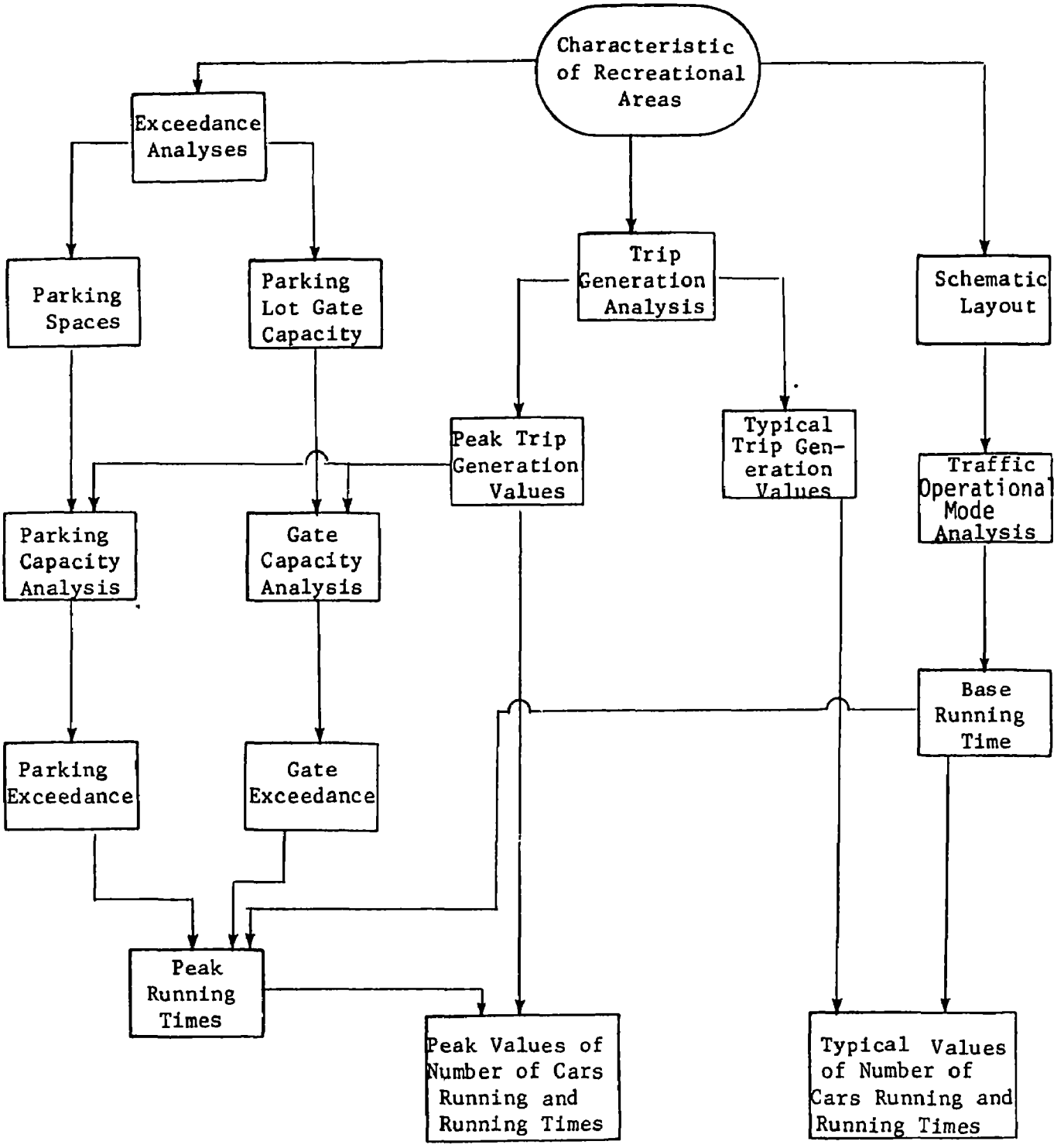

Figure 2. GENERALIZED METHODOLOGY APPLIED TO RECREATIONAL AREAS

The base running time is combined with the typical traffic volume to provide the required values of total vehicles running and base running times. For the peak case, diurnal variations of traffic must be examined to select the peak hour and eight hours.

In summary, the two main concerns for a recreation area are for adequate parking lot entrance capacity and adequate parking spaces, or an efficient menas of directing and moving incoming traffic to an overflow parking area.

GEOGRAPHIC DISTRIBUTION

Most of the running times, and hence emissions, from a recreational area can usually be considered as being distributed fairly uniformly over the parking areas during typical operating periods (base running times). Some concentration of vehicles may occur in the vicinity of the parking lot entrance line. The added emissions attributed to this particular line may be determined from the breakdown of running times by mode for a typical period. It may also be desirable to simulate access road traffic as a separate line source, depending on the orientation of the road (especially if straight away from the area) and the distance of expected effect.

Under peak traffic conditions, the running time in the entrance mode may be increased, and the need to consider the entrance line as a special source is accentuated. The area over which the other running times are distributed may also increase, due to the utilization of secondary parking areas.

METEOROLOGICAL ASPECTS

The meteorological characteristics which most importantly affect atmospheric dilutive capacity are mixing height, wind speed and atmospheric stability. A convenient summary of mixing height and wind speed characteristics which affect air pollution potential is given in the Office of Air Programs Publication No. AP-101 (Holzworth 1972). Atmospheric stability may be determined in terms of cloud cover, solar radiation and wind speed by a method proposed by Pasquill and shown in Table 10. For ground level sources, such as automobiles at recreational areas, the ground level concentrations, both in the vicinity and downwind of the sources will be

Table 10. KEY TO STABILITY CATEGORIES (after Turner 1970)

Surface Wind Speed (at 10 m), m sec^{-1}	Day			Night	
	Incoming Solar Radiation			Thinly Overcast or $\geq$ 4/8 Low Cloud	$\leq$ 3/8 Cloud
	Strong	Moderate	Slight		
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	C	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

NOTE: Class A is the most unstable, class F the most stable class. Night refers to the period from 1-hour before sunset to 1-hour after sunrise. Note that the neutral class, D, can be assumed for overcast conditions during day or night, regardless of wind speed.

"Strong" incoming solar radiation corresponds to a solar altitude greater than 60° with clear skies; "slight" insolation corresponds to a solar altitude from 15° to 35° with clear skies. Table 170, Solar Altitude and Azimuth, in the Smithsonian Meteorological Tables (List 1951) can be used in determining the solar altitude. Cloudiness will decrease incoming solar radiation and should be considered along with solar altitude in determining solar radiation. Incoming radiation that would be strong with clear skies can be expected to be reduced to moderate with broken (5/8 to 7/8 cloud cover) middle clouds and to slight with broken low clouds.

inversely proportional to wind speed and mixing height and directly proportional to atmospheric stability (i.e., the more stable the atmosphere, the higher the concentration).

Peak use of most recreational areas occurs during summer, with the highest days of the week usually being on the weekend. The peak hour use generally occurs during the early afternoon (somewhere from noon to 2p.m.). The peak eight-hour period is generally 11a.m. to 7p.m. Holzworth (1972) has mixing height and wind speed figures which are directly applicable to summer afternoon conditions for locations in the contiguous United States, and these may be used directly (Figures 3 and 4). For the weekend midday peak, atmospheric stability classes B, C, and D may occur with classes C and D being the most prevalent.

The period when meteorological conditions are least favorable for diluting pollutants is the period when recreational areas are essentially not in use, or at least have very little traffic. This would be from very late in the evening until a few hours after sunrise. It is most often during this period that mixing heights are lowest, wind speeds are lowest, and atmospheric stability is greatest.

QUALITATIVE GUIDELINES

In addition to the quantitative guidelines developed above, the review of recreational areas as complex emission sources should also include the following considerations which are not presently reducible to quantitative terms:

1. Since the layouts of recreational areas can frequently be modified comparatively easily, to accommodate larger crowds or to alleviate traffic problems, the amount of space available for expansion or modifications should be defined. Specifically, the ease with which parking capacity and access roads can be expanded and improved should be established.

2. The appropriate and adequate use of signs and markers to direct motorists throughout the vehicular areas is important, since many of the guests are tourists visiting the recreational area for the first time.

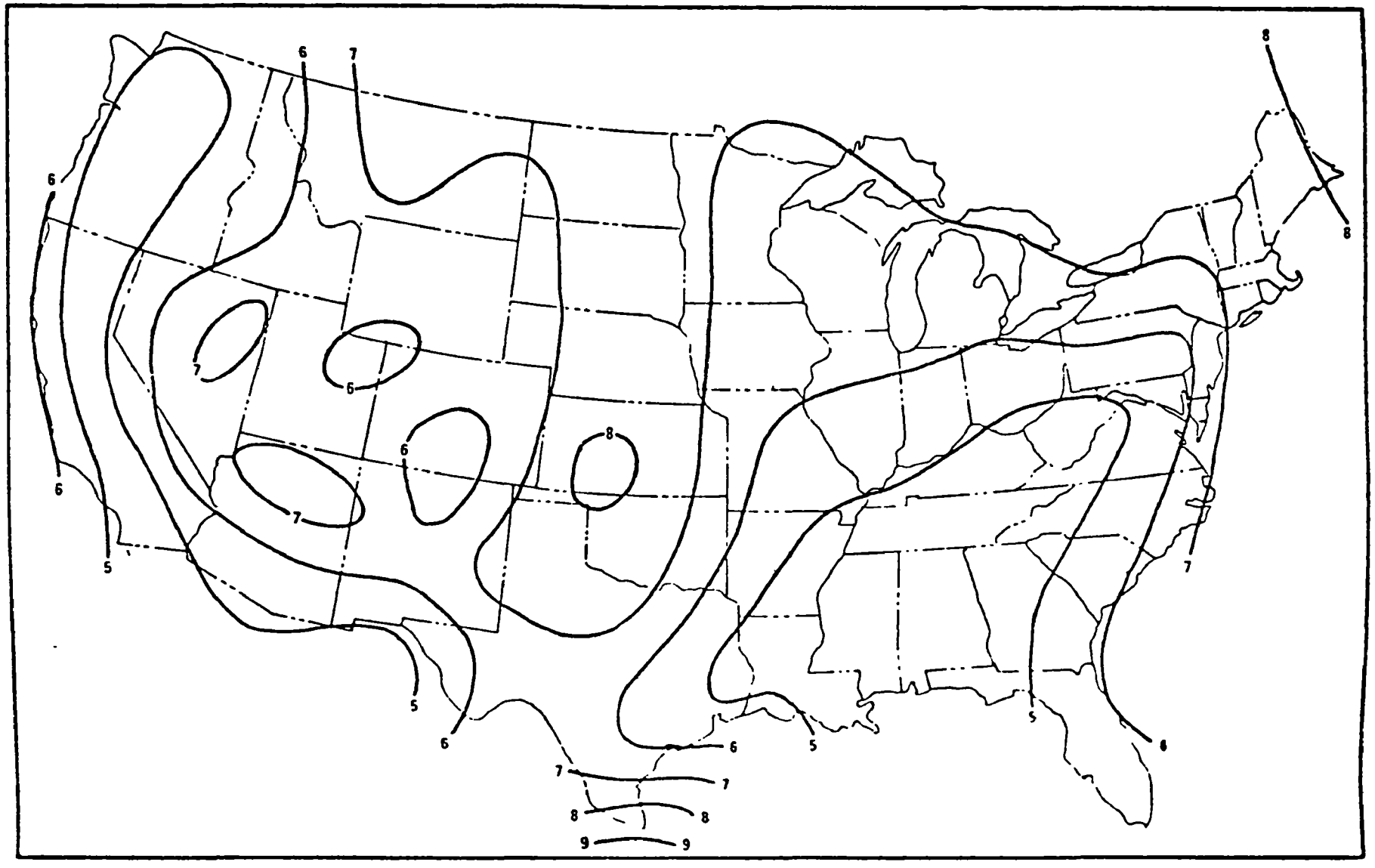

Figure 3. ISOPLETHS (m sec^{-1}) OF MEAN SUMMER WIND SPEED AVERAGED THROUGH AFTERNOON MIXING LAYER

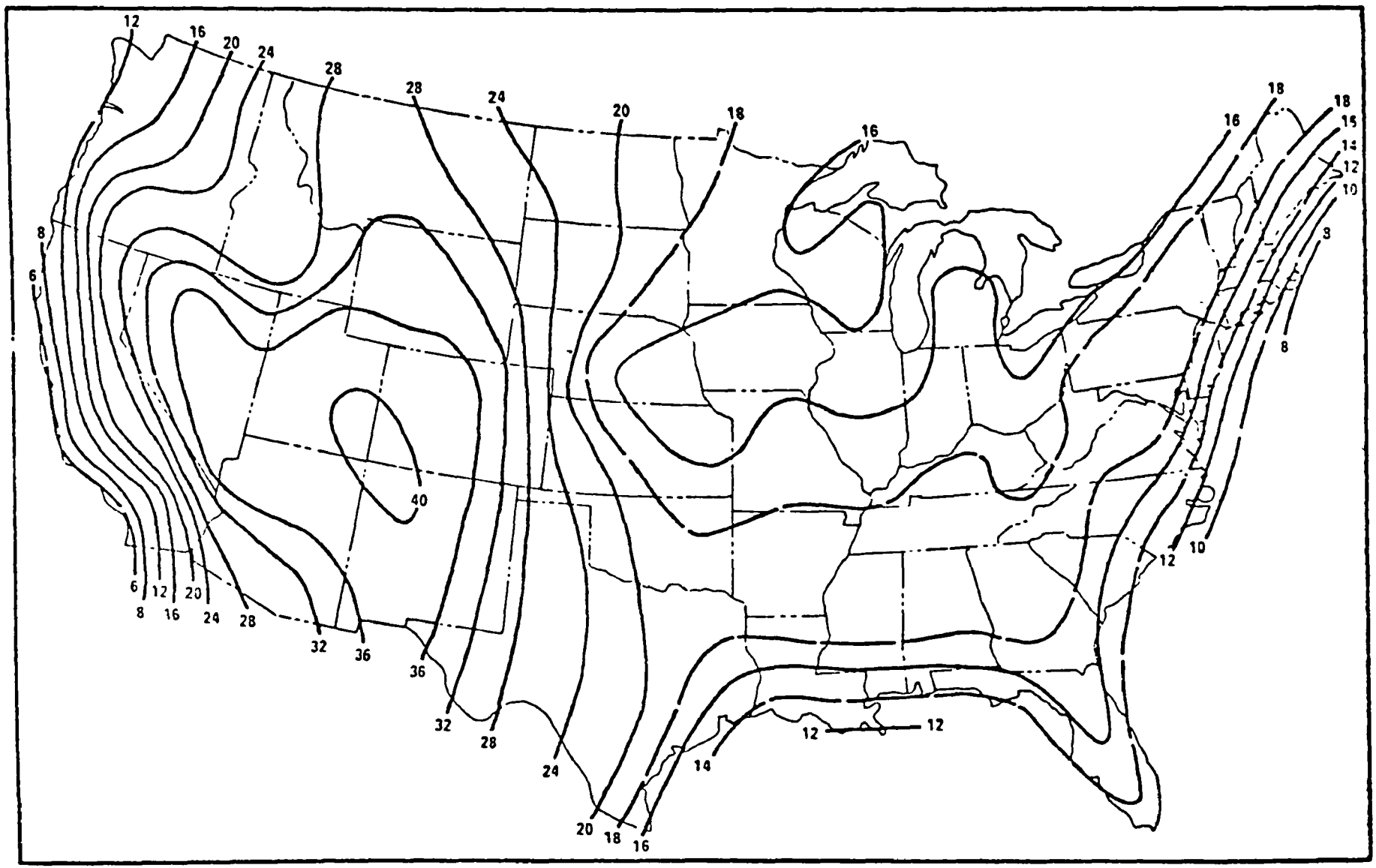

Figure 4. ISOPLETHS ($mx10^2$) OF MEAN SUMMER AFTERNOON MIXING HEIGHTS

3. The developer should demonstrate an effort to optimize traffic circulation patterns in the park by such methods as:

- No left turn movements across the main access roads
- Maximum use of one-way and divided streets
- Markings that separate parking lot entrance lanes from through traffic lanes, where appropriate
- Prohibition of on-street parking within the area.

4. In addition to the employees normally assigned to parking and traffic control, the area's security personnel should be available to assist in these areas during peak periods.

THE NINE QUESTIONS

While the specific information called for by the task work statement has been provided in Sections V through VIII, the nine questions spelled out as part of the work statement warrant specific response. This is given here, with the questions abbreviated.

1. Area alloted to or occupied by a single vehicle? 110 to 150 vehicles per acre of parking lot.

2. Percentage of land and parking spaces potentially occupied by vehicles? The usual percentage? Varies widely depending on area size, use rate, and nature of recreation.

3. Typical and peak values (absolute or fractional) of vehicles running for one- and eight-hour periods? See Section V and Appendixes.

4. Typical and worst case (slowest) vehicle speeds? In the context of our approach, this question is only relevant to analysis of the "Major Highway" complex source task. It is dealt with in that task report.

5. Vehicle distribution within the complex? See subheading entitled Geographic Distribution in Section VIII.

6. Design parameters of the complex likely to be known beforehand? See Section V, Recreational Area Parameters.

7. Design parameters in question (6) which can be most successfully related to traffic, and hence emissions? See Sections V through VII.

8. Relationships of parking lot design to parking densities and vehicle circulation? What is typical design? Design with highest parking densities, lowest vehicle speeds, longest vehicle operating times? To the extent to which these questions are relevant to our methodology, they are answered in Section V.

9. Methodological conditions likely to occur during peak use? Use level during periods of worst meteorology? See the subheading entitled Meteorological Aspects in Section VIII.

SECTION IX

REFERENCES

and General Information Sources

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A Logical and Systematic Design Technique for Park Planning. B.J. Niemann, Jr., and W.H. Tishler, Parks and Recreation (the Official Publication of the National Recreation and Park Association). May 1968.

Alternative Transportation Systems Program. National Park Service. October 1973.

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Personal Communication with the State Park Departments of New York, California, Ohio, Pennsylvania and Illinois. November 1973.

Table A-1. CLASSES OF AREAS IN THE NATIONAL PARK SYSTEM

Code	Class of Area	No. of Areas Administered	
		Dec. 1970	Dec. 1960
NB	National Battlefields	5	1
NBP	National Battlefield Parks	4	3
NBS	National Battlefield Sites	3	5
NC	National Cemeteries	10	10
NHS	National Historic Sites	52	28
NHP	National Historical Parks	13	9
NL	National Lakeshores	4	-
NMem	National Memorials	19	17
NMemP	National Memorial Park	1	1
NMP	National Military Parks	11	11
NM	National Monuments	85	80
NP	National Parks	35	30
	National Parkways	5	5
NRA	National Recreation Areas	13	4
NS	National Seashores	7	1
NSR	National Scenic Riverways	3	-
NST	National Scenic Trails	1	-
	National Scientific Reserve	1	-
	Historic Area	1	-
	International Park	1	-
	National Capital Parks	1	1
	White House	1	1
	Parks - Other	5	2
	Total	281	209

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Abraham Lincoln Birthplace NHS	1.1	1.6	2.5	6.0	7.1	15.7	24.5	25.2	6.9	5.5	2.1	1.8
Acadia NP	.6	.6	.9	5.4	6.9	11.3	23.2	23.5	12.1	7.9	6.0	1.1
Adams NHS	.1	.1	.1	3.5	8.4	15.3	20.4	22.9	13.7	14.2	.9	.1
Andrew Johnson NHS	3.4	4.3	7.1	8.7	11.8	11.4	13.4	12.0	7.1	9.3	6.0	5.4
Antietam NBS	2.0	2.6	6.7	10.2	18.4	11.2	12.2	11.1	8.1	9.0	6.1	2.5
Appomattox NHP	1.4	1.6	4.3	8.5	9.4	13.8	19.2	20.8	8.0	7.7	4.0	1.3
Arches NP	1.4	1.3	2.4	8.1	12.1	17.1	19.5	18.0	9.9	5.6	2.3	1.0
Arkansas Post NMem	34.3	6.6	8.8	6.6	6.6	11.2	8.4	5.0	3.2	3.1	3.0	3.3
Aztec Ruins NM	1.5	1.6	2.8	5.0	6.6	16.0	23.4	24.8	8.2	5.4	3.0	1.6
Badlands NM	1.0	1.1	1.5	2.1	4.8	15.7	29.6	28.0	8.6	4.5	1.9	1.3
Bandelier NM	.8	2.1	4.3	7.8	11.2	15.2	17.5	21.8	7.7	6.6	3.3	1.6
Battleground NC	4.1	4.1	8.1	8.1	13.2	14.2	9.5	11.5	7.5	6.8	4.1	8.8
Bent's Old Fort NHS	2.1	3.6	7.7	7.3	12.3	12.3	18.4	19.4	6.6	3.5	3.6	3.4
Big Bend NP	6.4	5.6	6.8	11.1	7.6	11.8	12.8	12.3	7.9	5.4	7.1	5.1
Big Hole Battlefield NB					7.0	19.0	29.5	30.4	13.9			
Black Canyon NM	.5	.4	1.3	2.1	5.7	14.5	29.7	29.0	12.9	4.6	.9	.2
Blue Ridge Parkway	1.6	.6	4.0	6.3	9.0	13.2	18.9	16.6	9.5	13.7	4.7	2.0
Booker T Washington NM	4.0	5.0	7.2	6.3	12.6	11.3	15.3	14.3	8.3	8.5	4.3	3.0
Brices Crossroads NBS	.4	4.0	8.5	9.6	12.0	12.0	10.7	13.4	8.0	8.0	8.0	5.3
Bryce Canyon NP	.3	.3	.9	2.8	6.7	20.7	27.3	25.8	9.8	4.2	1.0	.3
Buck Island Reef NM	7.8	9.1	11.6	9.9	6.8	7.8	8.6	8.8	5.9	6.1	8.1	9.5
Cabrillo NM	10.1	7.9	6.6	7.1	7.4	7.4	11.7	11.6	7.8	7.0	6.5	8.9
Canyon de Chelly NM	3.0	2.5	3.2	8.1	10.1	13.5	15.8	16.5	10.3	6.9	5.4	2.9
Canyonlands NP	.4	.2	1.8	6.6	24.0	15.5	14.9	13.6	12.3	8.1	2.1	.4

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cape Cod NS	1.3	1.6	2.2	2.9	3.9	10.7	25.1	29.9	11.3	5.2	1.8	1.3
Cape Hatteras NS	2.0	2.4	3.9	4.7	7.9	15.4	22.7	22.1	8.4	5.3	3.2	1.9
Capitol Reef NM	1.2	1.3	3.5	5.7	8.1	24.2	16.8	15.9	10.5	8.3	2.4	1.9
Capulin Mountain NM	1.8	1.2	2.4	4.6	7.5	15.8	23.6	23.7	7.7	5.5	3.8	2.3
Carlsbad Caverns NP	2.4	2.5	3.1	5.0	6.0	18.9	24.9	20.9	6.0	3.8	3.2	3.3
Casa Grande Ruins NM	8.1	11.2	9.8	11.3	5.9	6.9	7.5	8.8	6.3	7.6	8.4	6.2
Castillo de San Marcos NM	4.2	5.4	7.8	9.8	6.1	12.7	19.0	16.9	4.0	3.6	4.0	6.5
Cedar Breaks NM	1.1	1.1	.8	.4	2.8	15.1	26.7	25.2	15.4	10.2	.6	.2
Chaco Canyon NM	4.4	4.3	6.6	9.5	11.0	9.7	12.2	10.0	8.3	7.5	6.0	4.7
Chalmette NHP	8.8	5.7	6.3	8.9	7.9	9.0	18.9	10.2	6.4	3.8	7.8	5.6
Chickamauga - Chattanooga NMP	4.0	4.0	5.6	7.2	8.5	12.9	15.6	14.9	8.4	7.3	6.0	5.6
Chiricahua NM	3.8	4.6	7.9	10.7	10.0	10.7	14.0	13.9	7.7	6.4	6.3	4.1
Christiansted NHS	4.4	6.0	12.0	11.3	9.5	7.1	9.4	9.6	3.7	6.5	11.3	9.3
City of Refuge NHP	5.6	6.6	7.2	4.4	7.7	8.6	12.9	14.1	8.0	8.1	7.6	8.2
Colonial NHP	3.9	5.0	8.2	8.7	9.6	10.2	10.4	12.1	8.9	9.4	7.8	5.8
Colorado NM	3.8	3.7	3.8	6.5	7.8	12.1	13.1	15.2	12.0	11.2	4.9	5.7
Coronado NMem	6.0	5.9	7.5	10.1	10.3	8.9	9.6	9.8	8.4	9.1	7.0	7.3
Coulee Dam NRA	.5	.8	2.4	3.2	6.6	16.1	30.3	23.7	10.1	3.8	1.7	.8
Cowpens NBS	4.2	4.2	4.2	4.2	8.5	8.5	12.8	12.8	12.8	12.8	7.7	6.4
Crater Lake NP	.5	.8	1.0	2.2	4.8	14.3	27.1	29.9	12.9	3.7	1.3	.9
Craters of the Moon NM	.1	.5	1.1	2.4	5.7	17.8	28.0	28.1	11.3	3.4	1.2	.4
Cumberland Gap NHP	1.4	2.3	3.0	5.4	8.5	15.2	15.2	22.2	9.7	10.1	4.1	2.8
Custer Battlefield NM	.7	1.0	1.5	2.3	6.9	18.7	24.8	25.7	10.7	4.2	2.6	.3
Custis-Lee Mansion	2.2	2.8	5.2	15.2	11.2	11.7	15.2	18.3	5.9	6.1	3.9	1.6

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Death Valley NM	8.1	9.7	10.6	15.5	5.4	4.9	3.4	3.8	4.8	8.2	14.1	11.1
DeSoto NMem	8.9	9.3	22.3	9.0	5.1	7.2	6.8	5.9	4.8	5.2	7.2	8.2
Devils Postpile NM						12.5	30.4	39.2	17.7			
Devils Tower NM	.6	.2	.9	1.0	5.6	18.5	28.7	29.5	9.3	4.2	1.2	.3
Dinosaur NM	.6	.4	1.0	2.9	7.1	18.4	24.8	27.1	10.4	4.8	1.6	.9
Edison NHS	3.0	7.9	9.3	11.1	10.4	9.5	11.8	11.2	5.0	7.7	8.5	4.0
Effigy Mounds NM	2.1	2.9	4.2	3.0	9.2	11.2	16.6	19.0	10.7	18.7	1.4	1.0
El Morro NM	1.1	1.6	3.2	8.6	10.8	14.2	17.5	19.7	7.2	8.4	4.8	2.4
Everglades NP	10.2	12.0	12.9	12.7	7.6	6.4	6.8	6.3	4.9	4.7	6.7	9.0
Federal Hall NMem	2.8	7.0	9.1	9.1	9.6	8.4	9.1	12.5	8.9	8.1	8.4	7.0
Flaming Gorge NRA	1.4	1.7	3.0	6.3	14.4	12.9	23.0	15.2	11.7	5.9	3.1	1.3
Fort Caroline NMem	6.6	8.8	11.2	10.4	7.8	8.4	12.8	7.9	5.8	7.7	6.9	5.8
Fort Clatsop NMem	1.5	2.3	3.8	5.9	8.5	14.5	22.8	25.6	7.0	3.5	3.0	1.5
Fort Davis NHS	4.0	3.7	5.9	7.3	8.7	13.1	16.2	16.4	8.0	5.9	6.2	5.0
Fort Donelson NC	4.9	5.3	7.3	8.8	9.8	10.7	11.3	9.3	8.8	9.0	7.6	7.2
Fort Frederica NM	3.9	3.8	6.2	8.0	7.4	12.9	17.2	15.4	7.2	6.5	5.0	5.9
Fort Jefferson NM	13.8	17.8	14.0	7.3	6.1	5.0	2.8	3.4	2.9	3.3	10.5	13.1
Fort Laramie NHS	1.3	1.2	2.2	3.1	7.2	16.1	23.6	29.8	7.4	4.3	2.4	1.2
Fort Matanzas NM	5.4	5.9	7.6	8.4	7.5	11.8	16.6	14.3	5.9	5.9	5.3	5.5
Fort McHenry NM	4.6	5.1	7.0	9.6	13.5	8.7	12.7	15.2	9.5	5.7	5.1	2.7
Fort Necessity NB	.1	.1	.4	3.2	9.6	12.1	25.5	25.9	10.1	10.7	2.4	.1
ort Pulaski NM	4.7	4.8	7.4	9.2	8.5	11.6	13.6	12.2	8.0	7.0	7.5	5.5
ort Raleigh NHS	1.1	1.1	1.1	3.9	4.9	21.9	27.7	22.0	10.7	3.2	1.8	.7
ort Smith NHS	5.0	3.4	5.2	5.2	8.0	16.1	15.4	17.8	8.0	6.8	5.3	3.8

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fort Sumter NM	1.7	2.1	4.6	11.8	9.7	21.4	15.4	18.9	5.4	3.9	3.2	1.9
Fort Union NM	2.7	2.9	4.6	7.5	9.0	14.0	18.4	18.3	8.0	7.2	4.6	2.1
Fort Vancouver NHS	3.1	3.2	4.3	9.0	11.1	7.8	30.4	8.4	4.4	6.8	6.3	4.6
Fredericksburg & Spotsylvania NMP	5.9	4.0	7.7	9.8	9.8	9.9	10.6	12.6	8.0	7.9	6.8	6.4
General Grant NMem	1.9	5.0	5.9	11.3	10.8	12.6	13.3	13.3	7.7	8.2	6.0	3.3
George Washington Birthplace NM	2.5	2.7	5.7	9.8	9.6	13.4	14.0	14.4	8.2	8.8	7.8	3.2
George Washington Carver NM	2.4	2.8	5.5	8.1	12.9	12.4	12.5	12.7	7.4	16.3	4.3	2.0
George Washington Parkway	.8	1.8	3.5	11.7	11.1	10.9	11.4	20.2	11.2	11.8	3.7	1.4
Gettysburg NMP	.8	1.7	3.6	10.4	13.5	11.8	15.9	19.4	8.3	8.5	3.7	1.7
Gila Cliff Dwellings NM	.1	.6	.2	2.9	5.3	20.8	29.5	19.3	10.3	4.4	4.3	1.8
Glacier NP		.1	.2	.4	4.2	12.8	38.1	34.1	9.1	.8	.1	
Glacier Bay NM	1.7	1.4	1.2	1.9	6.3	20.9	28.9	26.0	7.1	.4	2.0	1.6
Glen Canyon NRA	2.3	1.7	3.4	7.3	11.9	16.8	15.7	15.6	10.0	8.1	4.9	2.2
Gran Quivira NM	2.2	3.8	8.0	9.8	8.6	13.1	15.4	13.1	11.4	6.8	5.5	2.2
Grand Canyon NM	.1	.3	9.8	9.0	13.2	14.6	11.6	16.3	9.0	9.6	3.2	3.2
Grand Canyon NP	1.8	1.3	2.9	5.4	6.9	18.0	20.8	21.3	11.1	6.0	2.8	1.8
Grand Portage NM	.1	.1	.1	1.4	5.0	11.0	23.7	30.4	18.4	4.3	.4	.1
Grand Teton NP	.1	.2	.3	1.5	4.9	17.5	30.9	28.1	10.2	3.7	2.4	.2
Great Sand Dunes NM	.4	.4	1.5	2.8	11.6	16.2	23.3	28.7	9.0	3.7	1.5	.8
Great Smoky Mountains NP	1.8	1.4	2.8	5.0	7.1	14.5	22.6	20.3	8.6	10.7	3.3	1.9
Guilford Courthouse NMP	4.6	4.6	8.3	8.2	12.5	11.8	11.9	12.8	6.3	7.0	6.8	4.6
Haleakala NP	10.3	6.4	6.7	7.5	5.3	10.7	10.5	12.5	8.6	7.2	7.2	7.0
Hampton NHS	2.4	4.3	6.7	12.8	15.0	12.3	7.6	9.5	7.0	9.3	7.1	5.3
Harpers Ferry NHP	3.4	4.0	5.7	7.9	11.0	10.5	13.1	12.6	9.3	12.6	5.7	3.5

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hawaii Volcanoes NP	6.5	6.3	6.6	8.3	8.3	8.9	10.6	12.0	8.8	8.1	7.1	8.0
Home of Franklin D. Roosevelt NHS	.9	1.3	2.2	6.8	10.2	11.7	19.7	21.6	10.5	9.7	2.6	1.0
Homestead NM	3.5	3.5	4.7	5.2	11.6	12.5	14.0	18.5	10.2	9.4	3.2	3.0
Hopewell Village NHS	.8	.7	2.4	5.1	10.7	8.6	23.3	21.3	9.5	11.0	5.0	1.1
Horseshoe Bend NMP	2.9	4.8	8.3	8.4	10.5	13.5	12.7	13.9	8.6	8.5	5.6	2.4
Hot Springs NP	4.2	5.0	7.6	8.5	8.4	11.8	13.9	11.8	8.7	8.4	7.0	4.3
House where Lincoln Died	1.7	3.8	4.1	12.5	7.5	10.2	13.7	19.4	7.5	7.1	6.9	5.6
Hovenweep NM	1.0	.4	1.6	8.1	11.4	15.6	20.2	20.3	10.0	7.0	2.9	.8
Independence NHP	2.3	4.5	5.0	9.0	11.1	11.7	13.5	16.2	7.2	7.9	6.8	4.3
Isle Royal NP					1.6	12.2	38.2	44.1	3.7			
Jefferson National Expansion Memorial NHS	9.7	6.4	6.9	7.0	11.5	16.1	15.5	10.3	6.3	5.1	3.1	1.6
Jewel Cave NM						20.6	37.5	38.0	3.8			
Joshua Tree NM	8.4	7.3	11.1	21.8	8.6	8.0	4.4	3.7	4.2	5.7	10.2	6.0
Katmai NM					4.0	23.3	32.0	29.1	7.8	3.4		
Kennesaw Mountain NBP	4.6	5.6	9.4	9.7	10.2	14.3	14.1	9.7	4.8	8.2	5.5	4.0
Kings Canyon NP	1.5	1.3	1.6	3.5	8.3	13.8	22.1	21.5	12.8	5.9	3.1	4.7
Kings Mountain NMP	2.9	3.5	6.3	9.7	11.1	12.1	15.2	13.2	7.5	9.0	5.4	4.2
Lake Mead NRA	5.0	5.7	7.9	13.6	10.4	12.4	9.9	8.1	7.8	7.2	7.2	4.8
Lassen Volcanic NP	2.1	1.5	1.3	1.7	4.9	14.0	23.8	28.9	13.3	4.8	1.2	2.4
Lava Beds NM	1.4	2.0	2.8	4.2	6.4	11.1	17.4	20.0	15.0	11.4	4.5	3.0
Lehman Caves NM	.3	.4	1.1	7.1	8.5	14.2	28.5	22.0	10.3	5.1	1.9	.5
Lemon NRA	.1	.7	.8	5.5	9.0	21.6	24.0	23.7	7.8	5.3	1.3	.2
Lincoln Boyhood NMem	.4	.6	1.3	3.3	8.5	10.9	22.1	30.2	8.3	8.9	3.1	2.5
Lincoln Memorial	1.0	2.7	4.3	14.7	11.5	12.4	16.5	16.5	6.9	5.3	5.2	3.0

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mammoth Cave NP	3.3	3.3	4.5	7.8	7.7	10.2	14.9	21.4	9.9	6.7	6.1	3.5
Manassas NBP	3.0	3.2	5.8	8.0	10.7	11.8	15.7	16.2	8.2	9.0	6.4	1.2
Mesa Verde NP	.3	.3	.9	2.3	6.3	18.7	26.5	28.7	10.4	3.3	1.1	.5
Minute Man NHP	1.5	1.6	3.2	13.7	8.5	11.4	15.1	19.5	8.6	10.4	4.7	1.8
Montezuma Castle NM	3.5	4.0	6.5	10.8	7.7	9.9	13.7	13.6	8.9	9.9	6.7	4.0
Moore House				8.6	9.5	10.2	10.4	12.1	8.8			
Moores Creek NMP	3.3	5.4	7.5	11.6	15.1	10.6	11.7	8.2	6.8	10.5	5.8	3.6
Morristown NHP	3.6	4.7	5.3	7.4	10.3	10.5	11.7	12.4	8.9	10.3	9.9	4.1
Mound City Group NM	1.3	1.5	4.1	6.4	13.4	11.8	15.7	17.8	10.5	11.2	3.4	2.2
Mount McKinley NP	.1	.1	.2	.1	1.3	14.9	51.1	27.0	5.0	.2	.1	.1
Mount Rainier NP	1.2	2.0	1.5	2.9	5.7	11.4	22.1	22.8	15.1	7.7	5.5	2.0
Mount Rushmore NMem	.3	.3	.6	1.1	4.8	18.1	30.7	31.0	8.7	2.7	.8	.4
Muir Woods NM	5.1	5.0	6.0	7.7	6.9	9.7	14.4	15.3	9.9	9.3	5.4	4.6
Natchez Trace Parkway	6.0	5.7	7.3	8.1	9.0	7.3	9.9	9.5	8.8	9.0	8.7	8.1
National Capital Parks	1.0	1.2	3.0	13.6	10.3	13.6	17.9	15.3	7.9	7.2	3.5	5.5
Natural Bridges NM	.1	.3	1.5	4.9	13.6	19.4	15.4	18.1	13.8	10.2	1.9	.9
Navajo NM	2.0	1.3	5.1	9.5	12.6	17.1	12.9	14.1	7.9	7.7	6.2	3.0
Ocmulgee NM	6.1	7.2	9.1	13.1	10.7	10.5	10.1	8.5	6.6	6.8	6.5	4.3
Olympic NP	2.3	3.2	4.2	6.7	6.2	10.9	17.6	28.2	11.1	3.6	3.7	2.3
Oregon Caves NM	.1	.3	.4	1.4	2.8	13.6	29.1	33.6	10.7	2.4	.5	.1
Organ Pipe Cactus NM	9.4	9.3	8.1	7.3	9.4	8.9	8.5	6.7	6.2	7.3	9.4	8.9
Padre Island NS	4.0	4.6	5.2	6.2	9.0	16.5	14.6	13.1	10.8	5.4	5.4	4.5
Pea Ridge NMP	2.0	2.3	3.4	6.3	8.6	16.1	14.4	17.6	8.1	13.3	5.2	2.3
Pecos NM	1.0	1.3	2.7	2.5	6.2	14.3	24.4	24.5	9.0	7.7	2.7	3.6

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Perry's Victory NM				.2	4.1	15.8	30.7	36.9	11.1	1.2		
Petersburg NB	4.1	4.9	5.4	8.0	8.6	12.5	12.0	11.5	11.9	11.8	2.9	5.7
Petrified Forest NP	2.4	2.2	3.5	4.8	6.0	20.0	22.9	21.4	7.0	5.0	2.7	2.0
Pinnacles NM	5.5	14.7	10.6	10.8	13.1	9.7	7.6	7.1	6.3	5.7	5.6	2.9
Pipe Spring NM	1.7	1.9	3.9	13.2	13.7	13.8	14.5	17.2	10.0	6.1	2.2	1.1
Pipestone NM	.3	.3	.9	2.5	7.5	22.4	25.5	20.2	10.1	4.7	3.4	1.7
Platt NP	2.9	3.2	5.4	6.7	13.3	17.4	18.4	14.2	7.7	4.7	3.6	2.5
Point Reyes NS	4.5	6.1	6.1	8.4	9.7	8.2	12.8	9.8	11.1	11.0	6.9	4.9
Rainbow Bridge NM	.2	.3	1.3	13.1	18.7	18.9	10.4	11.5	13.6	9.3	2.7	.1
Richmond NBP	4.5	5.0	8.7	10.6	10.3	10.2	11.7	13.9	7.7	7.7	6.1	3.7
Rocky Mountain NP	1.3	1.2	1.1	1.3	3.8	15.5	29.8	29.3	10.5	3.7	1.2	1.4
Russell Cave NM	1.8	2.9	5.3	8.1	10.6	13.9	17.8	19.1	7.8	7.0	3.8	1.8
Sagamore Hill NHS	1.2	3.6	4.1	8.2	10.8	11.8	15.7	16.9	8.1	9.4	7.9	2.3
Saguaro NHS	9.3	12.0	10.9	12.6	6.8	5.7	6.9	7.4	6.5	7.1	7.2	7.6
Salem Maritime NHS	1.5	2.8	3.4	6.8	7.8	9.5	21.1	24.2	9.7	6.2	4.7	1.8
San Juan NHP	8.5	8.8	10.7	10.0	6.8	11.9	9.7	8.1	4.4	6.0	7.2	8.0
Sanford NRA	2.0	2.4	6.3	8.2	14.3	10.8	16.1	10.2	11.4	6.4	6.5	5.5
Saratoga NHP	.3	.5	2.5	5.1	11.4	14.3	21.8	19.6	9.2	8.8	5.4	.5
Scotts Bluff NM	2.2	2.3	5.1	5.0	8.4	14.4	18.1	20.1	9.2	7.8	3.9	2.8
Sequoia NP	2.0	2.0	2.2	3.9	7.7	14.1	21.1	22.4	12.0	5.1	3.1	3.0
Shadow Mountain NRA	.2	.1	.3	1.2	7.3	14.9	25.6	32.5	10.0	3.6	2.8	.7
Shenandoah NP	1.6	1.6	3.0	6.0	8.6	11.9	17.5	17.5	9.9	16.5	3.8	1.5
Shiloh NMP	2.6	3.9	7.0	9.5	13.2	11.6	17.7	13.1	7.1	7.8	4.4	2.1
Sitka NM	3.3	2.8	3.7	10.8	9.6	13.0	15.1	14.1	11.3	8.3	4.1	3.4

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Statue of Liberty NM	.8	1.5	2.9	9.4	9.9	13.7	19.0	21.0	8.0	6.5	5.0	2.3
Stones River NB	3.0	5.5	4.2	6.3	6.3	12.9	14.6	15.1	9.0	11.3	6.2	4.4
Sunset Crater NM	2.0	1.8	4.4	8.7	9.4	16.7	19.0	17.6	8.9	5.2	3.3	2.9
Theodore Roosevelt Memorial NMemP	.7	.8	1.7	3.0	8.4	20.8	30.2	21.2	5.0	3.4	2.8	1.4
Theodore Roosevelt Birthplace NHS	4.3	8.1	13.0	11.7	9.4	8.7	7.8	9.5	4.0	7.6	11.0	4.4
Thomas Jefferson Memorial	1.1	2.0	5.2	23.0	13.0	10.7	11.6	14.7	5.3	6.0	4.7	2.2
Timpanogos Cave NM	1.7	1.9	2.4	3.4	11.1	13.2	20.9	21.1	15.1	6.5	1.2	1.6
Tonto NM	11.4	12.7	16.8	14.4	6.8	6.8	5.9	4.4	4.2	4.8	5.1	6.2
Tumacacori NM	9.2	11.5	10.7	9.8	5.4	7.6	9.5	8.8	4.4	5.3	7.1	10.7
Tupelo NB	2.5	1.0	4.0	8.9	2.8	10.5	12.5	33.0	7.3	9.2	4.9	2.7
Tuzigoot NM	2.3	2.2	3.5	9.6	9.8	12.3	13.6	15.1	9.7	9.4	7.4	4.3
Vanderbilt Mansion NHS	1.1	1.6	2.1	6.2	10.1	12.7	20.0	19.7	11.1	10.1	3.5	1.3
Vicksburg NMP	4.9	5.6	8.1	8.0	8.6	11.9	12.7	16.0	7.2	6.0	5.2	5.3
Virgin Islands NP	7.8	7.7	10.2	8.4	7.0	8.3	8.2	8.4	6.2	9.4	9.4	8.2
Walnut Canyon NM	1.8	1.5	3.4	7.0	7.9	18.4	21.8	18.2	8.1	6.5	3.2	1.6
Whiskeytown NRA	1.7	2.9	2.7	6.5	12.1	21.4	19.6	15.6	9.0	3.8	2.4	1.7
White House	1.7	2.1	4.8	16.7	12.4	11.7	13.7	14.2	6.9	6.8	4.9	3.4
White Sands NM	3.9	4.4	7.6	12.3	9.4	11.9	14.9	14.0	6.8	5.6	4.4	4.2
Whitman Mission NHS	3.1	4.9	5.9	9.3	12.2	12.5	14.9	12.3	8.6	8.1	4.2	3.4
Wind Cave NP	1.4	1.8	3.0	3.3	5.8	13.4	27.5	24.7	9.7	5.0	2.0	2.0
Wright Brothers NM	.4	.9	1.4	3.6	5.2	10.5	22.3	23.8	6.7	3.9	1.8	1.0
Wupatki NM	2.4	1.9	4.7	9.4	10.2	18.7	17.9	17.2	8.1	3.8	3.1	1.8
Yellowstone NP	.1	.0	.1	.4	3.7	17.6	33.4	31.0	10.6	2.2	.2	.0
Yosemite NP	1.4	1.5	1.4	3.7	8.6	14.3	21.2	20.7	10.7	9.0	4.0	2.8

(continued)

Table A-2. NATIONAL PARK SYSTEM - MONTHLY PERCENTAGE OF 1966 VISIT TOTALS -

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yucca House NM	3.0	4.1	12.3	13.8	6.1	7.1	13.3	18.4	15.3	3.0	3.0	.0
Zion NP	1.6	1.7	2.3	5.0	9.0	18.9	21.6	20.4	10.2	5.0	2.0	1.5
National Park System	2.7	2.8	4.4	7.8	8.8	13.0	18.1	17.7	8.8	7.4	4.5	3.3

Note: The sum of monthly percentages may not equal one hundred due to rounding.

(concluded)

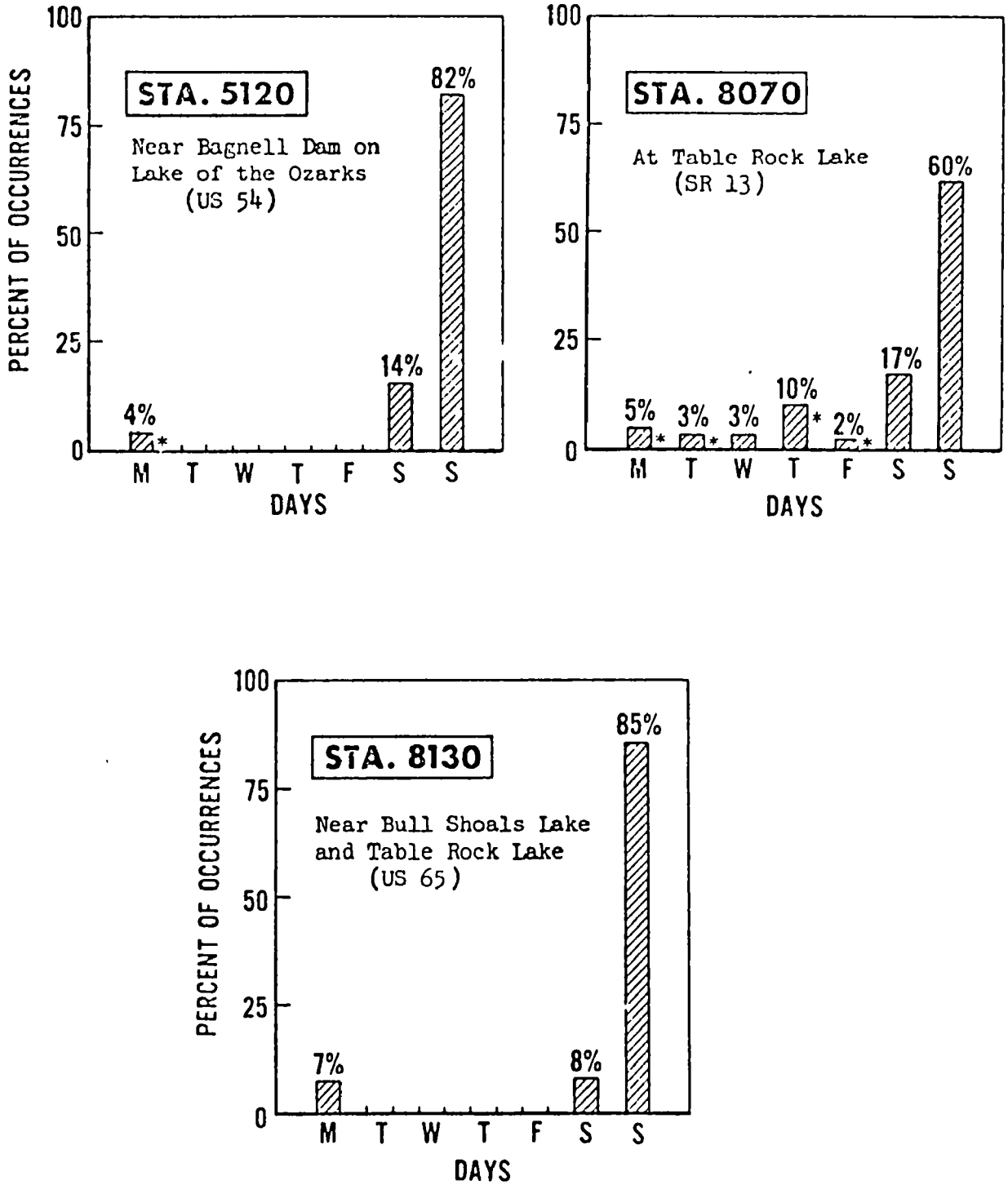

Figure B-1. DAY OF OCCURRENCE OF 100 HIGHEST HOURS OF THE YEAR

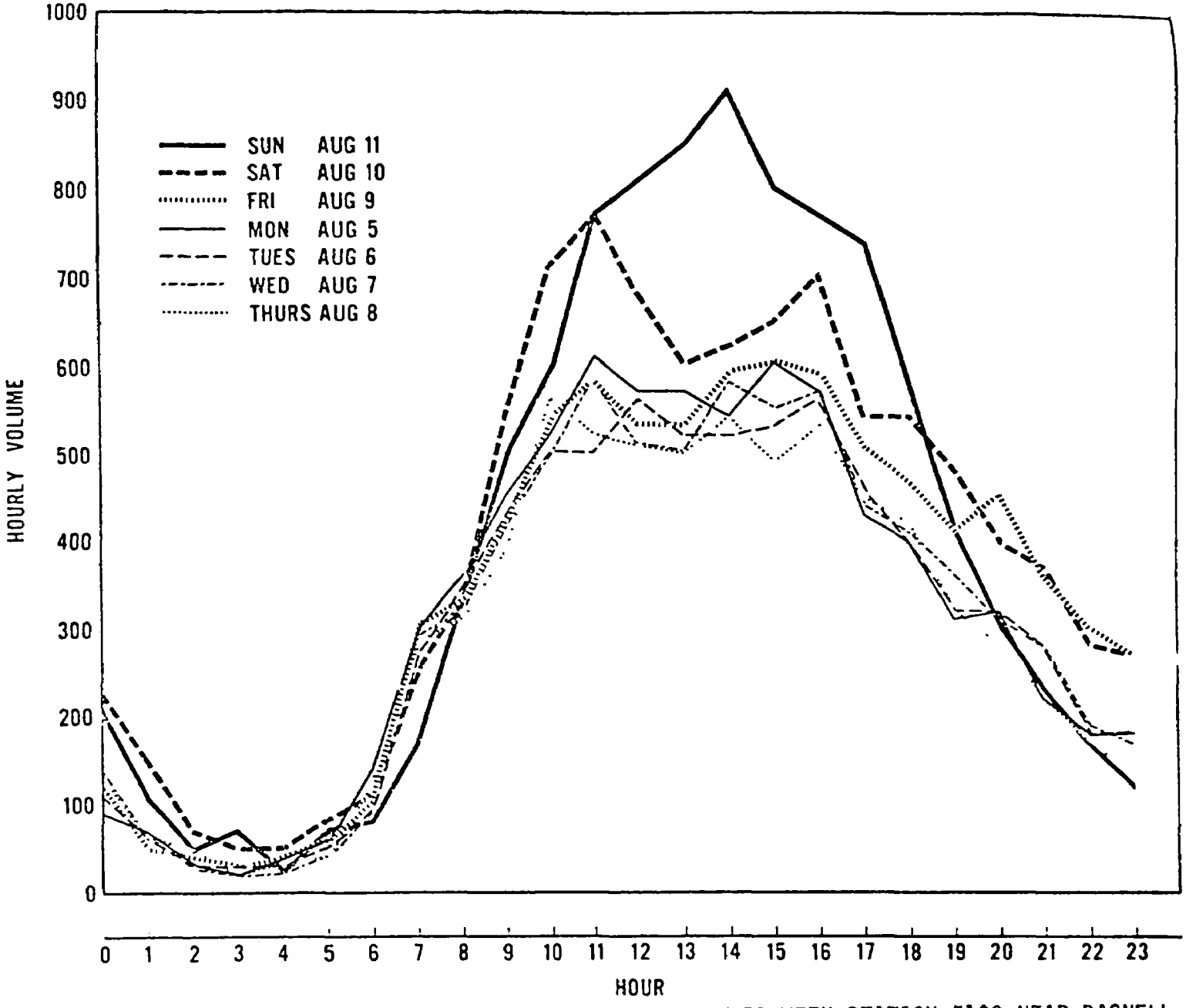

Figure B-2. HOURLY TRAFFIC PATTERN FOR TYPICAL SUMMER WEEK STATION 5120 NEAR BAGNELL DAM (US 54)

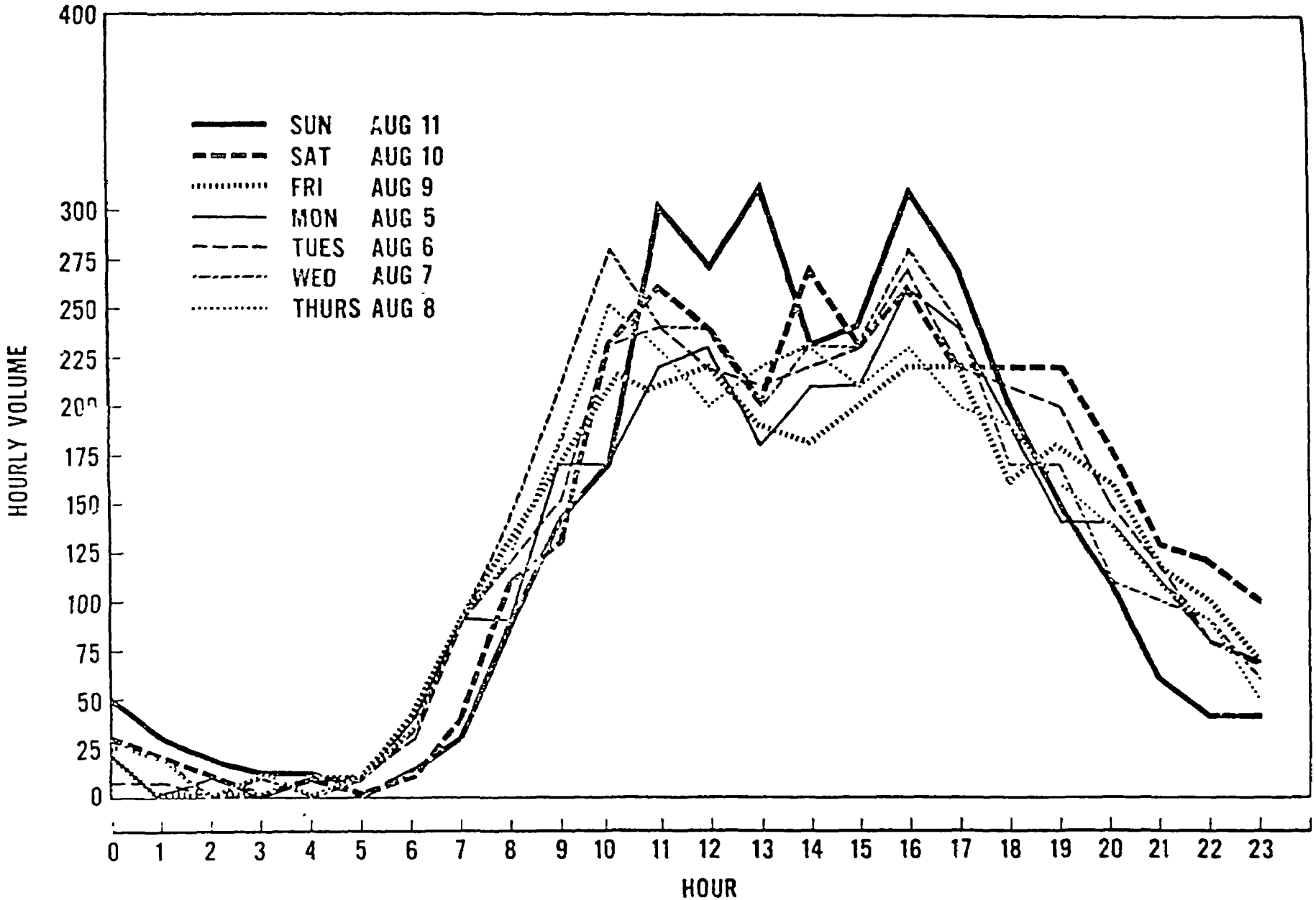

Figure B-3. HOURLY TRAFFIC PATTERN FOR A TYPICAL SUMMER WEEK STA. 8070 AT TABLE ROCK LANE (SR 13)

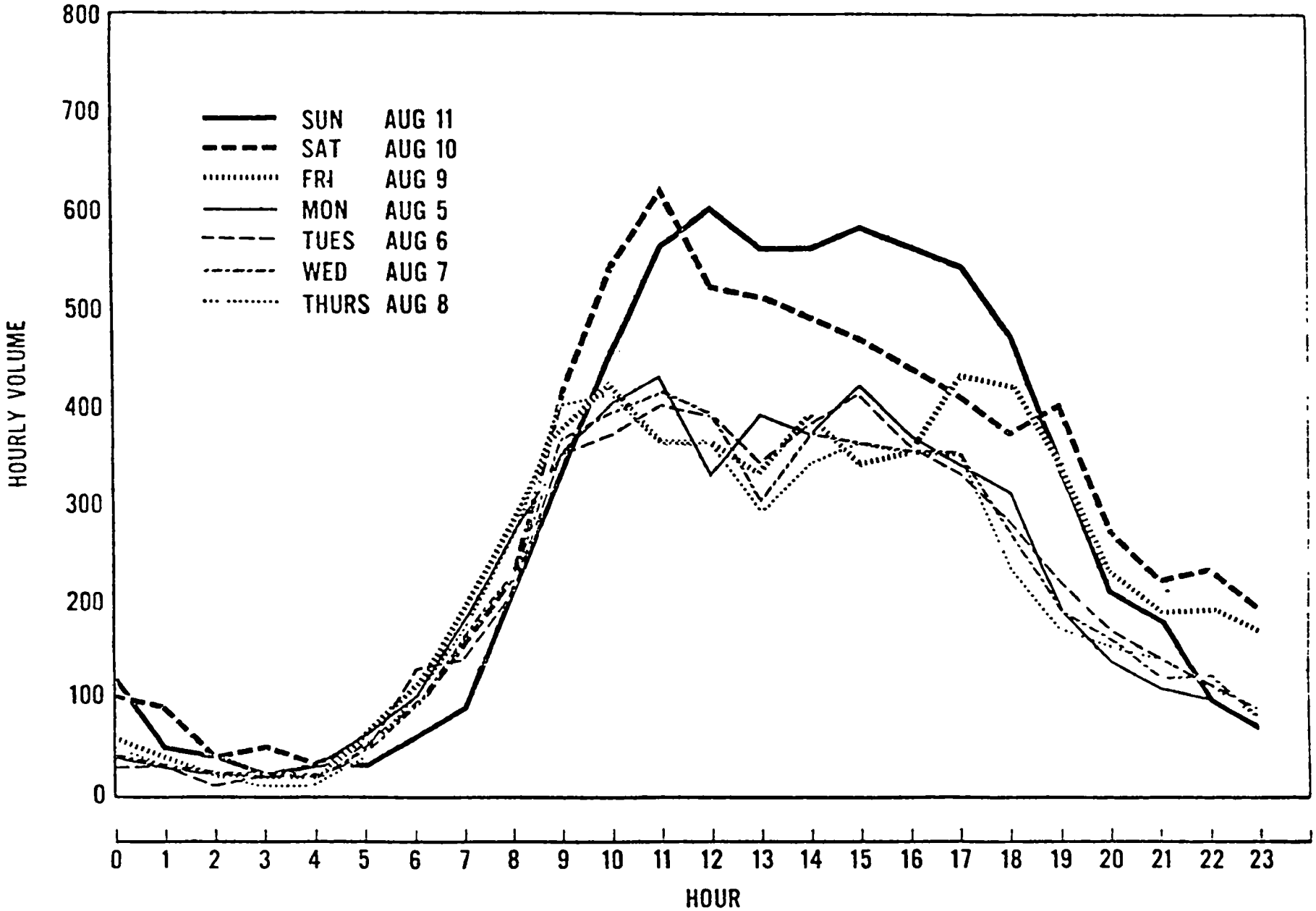

Figure B-4. HOURLY TRAFFIC PATTERN FOR A TYPICAL SUMMER WEEK STA. 8130 SERVES BULL SHOALS AND TABLE ROCK LAKES (US 65)

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4 TITLE AND SUBTITLE Vehicle Behavior In and Around Complex Sources and Related Complex Source Characteristics Volume VII - Recreational Areas		5 REPORT DATE November 1973 (Date of issue) 6 PERFORMING ORGANIZATION CODE
7 AUTHOR(S) Scott D. Thayer		8 PERFORMING ORGANIZATION REPORT NO
9 PERFORMING ORGANIZATION NAME AND ADDRESS Geomet, Inc. 50 Monroe Street Rockville, MD 20850		10 PROGRAM ELEMENT NO 11 CONTRACT/GRANT NO 68-02-1094
12 SPONSORING AGENCY NAME AND ADDRESS Office of Air Quality Planning and Standards Environmental Protection Agency Research Triangle Park, North Carolina 27711		13 TYPE OF REPORT AND PERIOD COVERED Final 14 SPONSORING AGENCY CODE

15 SUPPLEMENTARY NOTES

16 ABSTRACT

A general methodology is presented for relating parameters of traffic behavior in recreational areas, including vehicle running time and traffic volume, to more readily available characteristics of the areas, including attendance rates, temporal variations in attendance and parking capacity and design. Such relationships are to be used to relate recreational area characteristics to air quality.

17. KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
Air pollution, parks, urban planning, urban development, urban transportation, transportation management, transportation models, land use, regional planning, vehicular traffic, traffic engineering, highway planning	Indirect sources Indirect source review	13 B

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