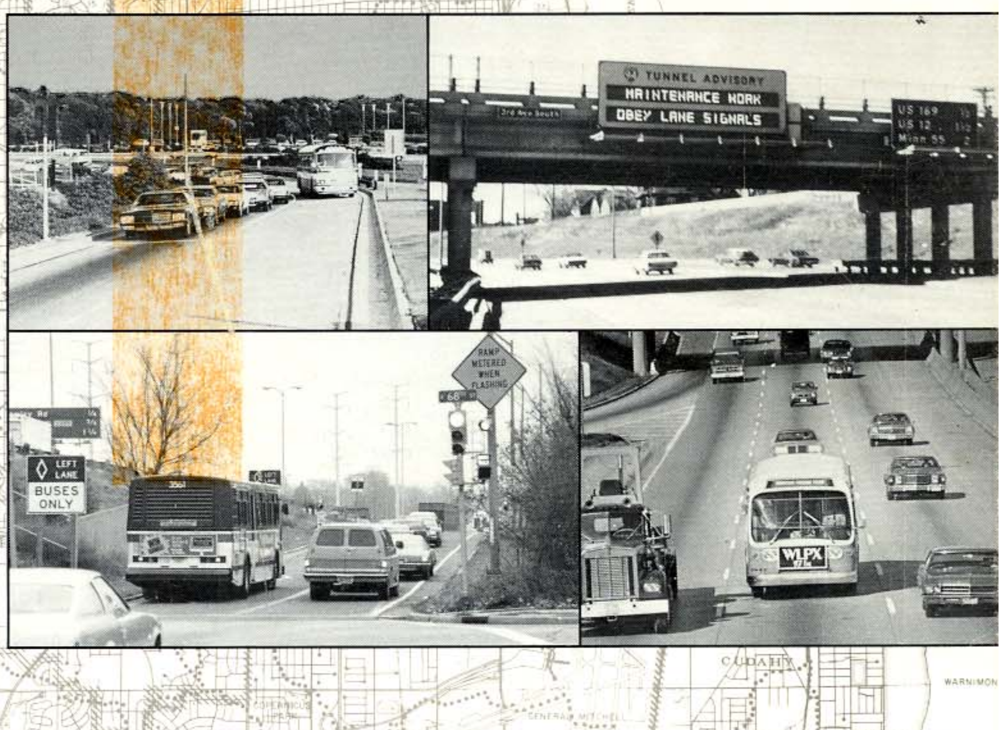
PLANNING REPORT NO. 39

A FREEWAY TRAFFIC MANAGEMENT SYSTEM PLAN FOR THE MILWAUKEE AREA



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due Mr. Ronald C. Sonntag, District Traffic Supervisor, Wisconsin Department of Transportation, and Mr. Robert E. Beglinger, SEWRPC Principal Engineer, for their contribution to the conduct of this study and the preparation of this report.

Planning Report No. 39

A FREEWAY TRAFFIC MANAGEMENT SYSTEM PLAN FOR THE MILWAUKEE AREA

Prepared by the

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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STATEMENT OF THE CHAIRMAN

On June 1, 1978, the Southeastern Wisconsin Regional Planning Commission adopted a new regional transportation system plan, based upon careful review and reevaluation of the original regional transportation system plan adopted by the Commission in 1966. This new transportation system plan included, among other recommendations, transportation systems management measures intended to improve the operation of the regional arterial street and highway system. One of the transportation systems management measures recommended was a freeway traffic management system which could serve to reduce freeway congestion through better management of freeway traffic flow.

In November 1982 the Commission, in cooperation with the Wisconsin Department of Transportation, initiated a more detailed study of the recommended freeway traffic management system leading to the implementation of the recommendations. This planning report documents the findings and recommendations of this more detailed study of a freeway traffic management system for the greater Milwaukee area. The report recommends, among other actions, the creation of a traffic management center and staff to be responsible for improved freeway operation; the development of an electronic system for monitoring freeway traffic flow and operation; the creation of a new freeway emergency service patrol; the creation of a system of permanent changeable message signs; and the development of an integrated system of freeway ramp meters which will provide preferential treatment to buses and carpools by permitting those high-occupancy vehicles to bypass the ramp meters and maintain freeway operating speeds in the 30- to 40-mile-per-hour range. Implementation of the recommended traffic management system may be expected to improve freeway operation by reducing the impact of freeway incidents, providing better control of freeway traffic flow, and encouraging the use of more efficient buses and carpools.

Respectfully submitted,

Anthony F. Balestrieri
Chairman

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Chapter I

INTRODUCTION

The plan presented in this report recommends the improvement and expansion of the Milwaukee area freeway traffic management system. The plan provides recommendations concerning the number, type, and location of freeway ramp meters required to provide an integrated, centrally controlled, freeway traffic management system in the greater Milwaukee area; the degree of freeway access constraint to be exercised at each ramp meter; and the level of operational control to be provided on the freeway system. Recommendations are also made with respect to the means for administering the freeway traffic management system, including the computer and related support equipment to be used to monitor and control the freeway ramp meters, and the facilities and services required to manage freeway traffic incidents and provide advisory information concerning unusual freeway operating conditions. The plan recommendations are based on thorough inventories and analyses of the existing capacity and use of the freeway and related surface arterial facilities in the greater Milwaukee area, and on a careful evaluation of alternative freeway traffic management systems. The findings of the inventories, analyses, and evaluations, and the recommended plan, are summarized herein. The study area, as shown on Map 1, generally encompassed the Milwaukee urbanized area.

The preparation of this Milwaukee area freeway traffic management system plan was a joint effort of the staffs of the Southeastern Wisconsin Regional Planning Commission and the Wisconsin Department of Transportation. The Regional Planning Commission had responsibility for the study organization and design; the formulation of objectives, principles, and standards; the conduct of certain inventories and traffic surveys, including a special origin-destination survey; the analyses of Milwaukee area arterial facility capacity; and the identification of freeway corridor congestion problems and freeway segments warranting freeway traffic management. In addition, the Commission was responsible for alternative plan preparation, testing, and evaluation, and report preparation. The Wisconsin Department of Transportation had responsibility for the inventory of existing freeway traffic management systems in other major urban areas of North America.

To ensure that the recommended freeway traffic management system plan was technically sound and could be supported by the technical staffs of the various units and agencies of government concerned, a special Technical Coordinating and Advisory Committee on Freeway Traffic Management was formed to provide guidance to the technical staff during the study. The membership of this Committee is set forth in the inside front cover of this report.

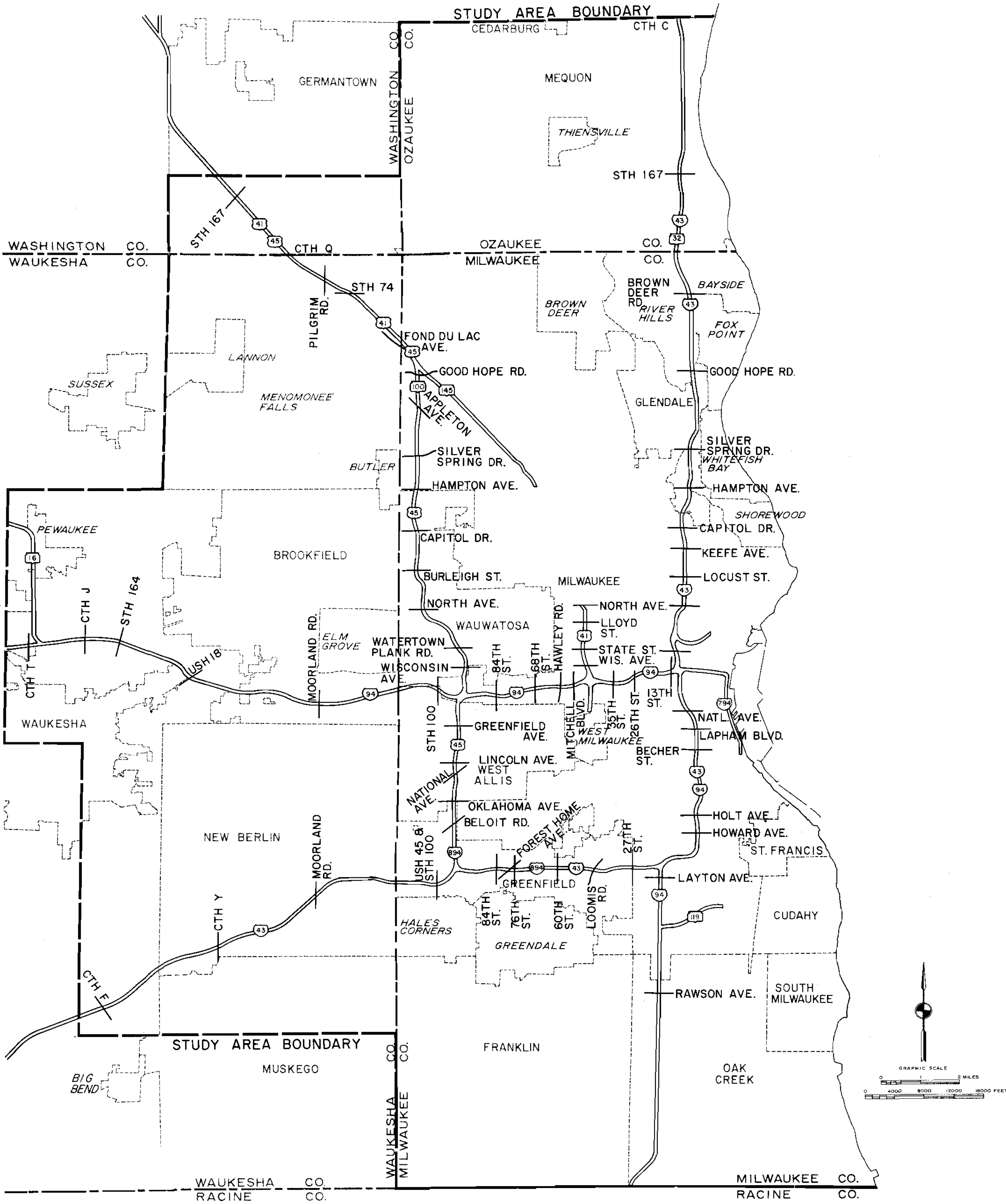
FREEWAY TRAFFIC CONGESTION

Freeway traffic congestion is a result of an imbalance between demand and capacity—that is, congestion occurs when a greater number of vehicles attempt to utilize a segment of freeway than the physical capacity of the facility can accommodate. This congestion is evidenced by reduced travel speeds, increased and unpredictable travel times, and stop-and-go driving which result in increased operating costs, accidents, energy consumption, and air pollutant emissions. A particular freeway location or segment which operates under congested conditions during the same time period on a routine basis is said to experience recurring congestion. If, however, the congestion is a result of an infrequent incident such as an accident, stalled vehicle, or inclement weather, it is said to be nonrecurring congestion. The incident dramatically reduces freeway capacity at the location where the incident occurs—for example, by blocking a freeway lane—but only for a limited time.

Freeway operating conditions, including congested conditions, are governed by fundamental relationships between speed, volume, and capacity. These relationships are graphically summarized in Figure 1. This figure indicates that as the volume of vehicles on a freeway segment increases, the average operating speed of those vehicles decreases until the maximum capacity of about 2,000 vehicles per hour per lane is reached at about 30 miles per hour (mph). A freeway segment experiencing traffic volume demand in excess of capacity is a "bottleneck"

Map 1

STUDY AREA



The geographic area for the freeway traffic management systems study included all of Milwaukee County, and portions of Waukesha, Washington, and Ozaukee Counties, and generally encompassed the Milwaukee urbanized area.

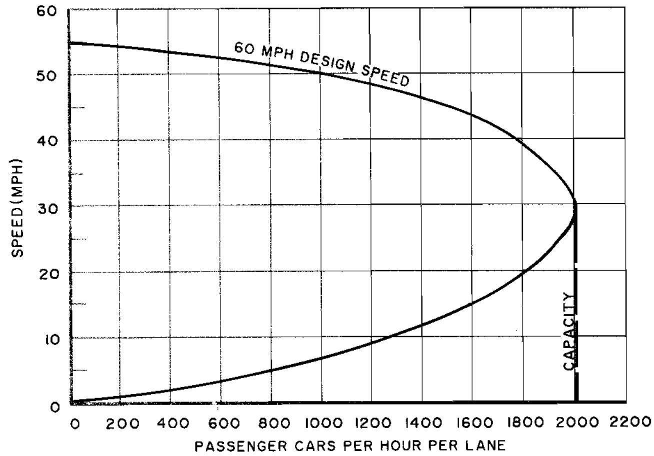
Source: SEWRPC.

on the freeway system. If the segment has less capacity than the segments of freeway "upstream," traffic conditions upstream of the bottleneck can significantly deteriorate to over-capacity operation, as represented by the dashed line in Figure 1. The upstream segment becomes, essentially, a temporary storage area for vehicles which must wait to proceed through the bottleneck. Average speeds may range from less than 10 mph to 30 mph upstream of the bottleneck, and traffic may experience stop-and-go operating conditions. Operating conditions downstream of the bottleneck, however, are independent of the operating conditions of the bottleneck, but are dependent upon the downstream capacity available and the traffic volume demand. Flow in the downstream segment may be stable, and operating speeds may increase significantly over the bottleneck speed of 30 mph if available capacity is in excess of the traffic volume demand.

Capacity bottlenecks are sites which typically experience recurrent congestion. Some examples of capacity bottlenecks of the westbound lanes of the East-West Freeway (IH 94) are the "S" curve between N. 24th Street and N. 31st Street, and the weaving areas east of the Stadium and Zoo Interchanges, as shown in Map 2.

Figure 1

RELATIONSHIPS BETWEEN FREEWAY VOLUME, SPEED, AND CAPACITY[a]



[a]The speed-flow relationships shown are under ideal conditions, which are defined as 12-foot-side minimum lane widths; 6-foot-wide minimum clear shoulders between the edge of travel lanes and the nearest object; no trucks, buses, or recreational vehicles in the traffic stream; and driver characteristics typical of weekday commuter traffic streams.

Source: Highway Capacity Manual, Special Report 109, Transportation Research Board, 1985; and SEWRPC.

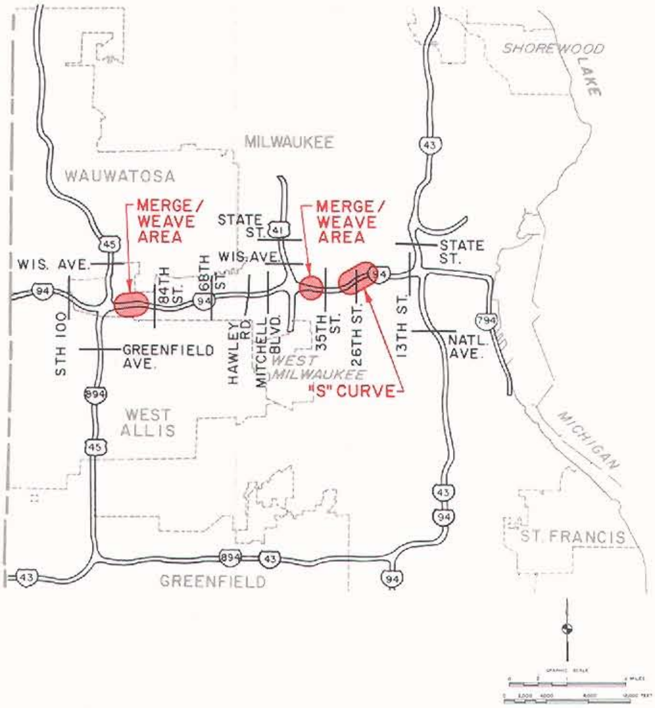
PRINCIPLES OF FREEWAY TRAFFIC MANAGEMENT

The primary function of a freeway traffic management system is to eliminate over-capacity operating conditions and to minimize at-capacity operating conditions, i.e., to achieve a balanced demand-capacity relationship. This is accomplished by controlling volume demand through the use of meters at freeway on-ramps, which operate to control the volume of traffic entering the freeway system during peak travel periods such that available capacity is not exceeded. Exclusive on-ramps or bypass lanes may be provided for buses, carpools, and vanpools at the metered freeway entrances to allow the high-occupancy vehicles to bypass metered traffic. The freeway traffic management system should thus decrease peak-period travel times for transit riders and car- and vanpoolers, who receive the benefits of the improved freeway traffic conditions with no freeway ramp delays. The system should, accordingly, promote and likely increase bus and pool vehicle use. Some improvement of automobile and truck peak-period travel may also be expected, as the benefits of the improved freeway operating conditions should outweigh any delays at metered on-ramps, particularly if some traffic shifts to more efficient bus and car- and vanpool use.

Thus, there are several objectives to be achieved through the development of a freeway traffic management system. The first objective is to improve traffic operating conditions so that traffic volumes do not exceed freeway capacity. A freeway traffic management system should significantly decrease bus and car- and vanpool travel times, and should improve travel conditions for automobiles and trucks. A second objective is to aid in the provision of high-quality bus rapid transit service, and to promote bus and carpool use with minimal capital investment. By ensuring stable flow conditions and adequate freeway operating speeds, and by providing preferential access to the freeway system for high-occupancy vehicles by way of exclusive, nonmetered on-ramps or bypass lanes at metered ramps, a freeway traffic management system improves the level of service compared to uncontrolled conditions, and allows buses to operate in mixed traffic on the freeways at speeds similar to those on an exclusive busway.

Map 2

LOCATIONS OF FREEWAY CAPACITY BOTTLENECKS WESTBOUND ON THE EAST-WEST FREEWAY (IH 94)[a]



[a]*Capacity and operating restrictions at freeway bottlenecks govern the level of service and attainable service volumes that can be achieved in upstream segments, irrespective of the geometric conditions of the upstream segment itself.*

Source: SEWRPC.

The third objective is to promote the most efficient use of the existing transportation system by making better use of nonfreeway arterial street capacity. By controlling the volume entering the freeway system as system capacity is approached, a freeway traffic management system may provide an incentive for freeway traffic to use the arterial street system. Thus, more efficient use may be made of both freeway capacity and existing capacity on the arterial street system.

FREEWAY TRAFFIC MANAGEMENT SYSTEM ELEMENTS

A freeway traffic management system may be considered to be composed of a number of elements. The first element is the freeway on-ramp meters, which provide the means for regulating access to the freeway system. A second element is the freeway operational control strategy, which defines the desired level of operation of the freeway system—that is, the degree of congestion, if any, to exist on the freeway system and the minimum operating speeds to be maintained. A third element is the freeway on-ramp meter control strategy. It defines the rates of entry at the various metered freeway on-ramps in such a manner so as to distribute the required reduction in freeway volumes over the contributing ramps.

A fourth element is the monitoring and control system of the freeway traffic management system. The monitoring and control system should be designed to implement the freeway operational control and ramp-meter control strategies by monitoring freeway operating conditions on a systemwide basis, and modifying, as necessary, the metered freeway ramp entry rates in response to the operating conditions. The fifth element of the freeway traffic management system is the provision of high-occupancy vehicle (HOV) preferential access at metered freeway on-ramps by means of either an exclusive unmetered on-ramp or a bypass lane. This element will encourage a shift from low-occupancy vehicles to high-occupancy vehicles, reducing total demand on the freeway system, and helping to abate congestion. The sixth and seventh elements of a freeway traffic management system are the freeway incident management and motorist advisory information elements. The freeway incident management element identifies and minimizes the effects of freeway incidents such as accidents which restrict traffic flow. The freeway motorist advisory information element provides information about current traffic conditions, emphasizing incidents that reduce available capacity, resulting in poor operating conditions.

THE SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) was created upon the unanimous petition of the seven constituent county boards in August 1960, under the provisions of Section 66.945 of the Wisconsin Statutes. The seven counties are Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha. These counties have a combined area of about 2,689 square miles, or approximately 5 percent of the total area of the State (see Map

3). There were 154 general-purpose local units of government in the seven-county Region in 1987, serving a resident population of 1.74 million persons, or about 36 percent of the total population of the State; and providing 910,000 jobs, or about 40 percent of the jobs in the State.

The Commission exists to serve and assist the local, state, and federal units of government in finding practical solutions to developmental and environmental problems that transcend the geographic boundaries and fiscal limitations of individual municipalities and counties. The planning for the more orderly physical and economic development of the seven-county Southeastern Wisconsin Region by the Commission is entirely advisory, and participation by local units of government in the work of the Commission is on a voluntary, cooperative basis. The organizational structure of the Commission and its relationship to the constituent units and agencies of government making up, or operating within, the Region is shown in Figure 2.

Regional planning as conducted by the Commission has three principal functions: 1) the collection, analysis, and dissemination of basic planning and engineering data on a uniform, areawide basis in order that sound development decisions can be made in both the public and private sectors; 2) the preparation of a framework of long-range, areawide plans for the physical development of the Region; and 3) the provision of a center for the coordination of the day-to-day planning and plan implementation activities of all of the units and levels of government operating within the Region. The Commission in its work has placed great emphasis upon the preparation of plans for land use and supporting transportation, utility, and community facilities.

The work of the Commission is seen as a continuing effort to provide the information necessary for public and private agencies to better make development decisions, and the areawide plans and plan implementation programs required to promote the sound, coordinated development of the Region over time. It emphasizes close cooperation among the public and private agencies responsible for land use development within the Region, and for the design, construction, operation, and maintenance of the supporting public works facilities. More detailed information concerning the Commission and its current work program may be obtained from the annual reports of the Commission.

REGIONAL TRANSPORTATION PLANNING IN SOUTHEASTERN WISCONSIN

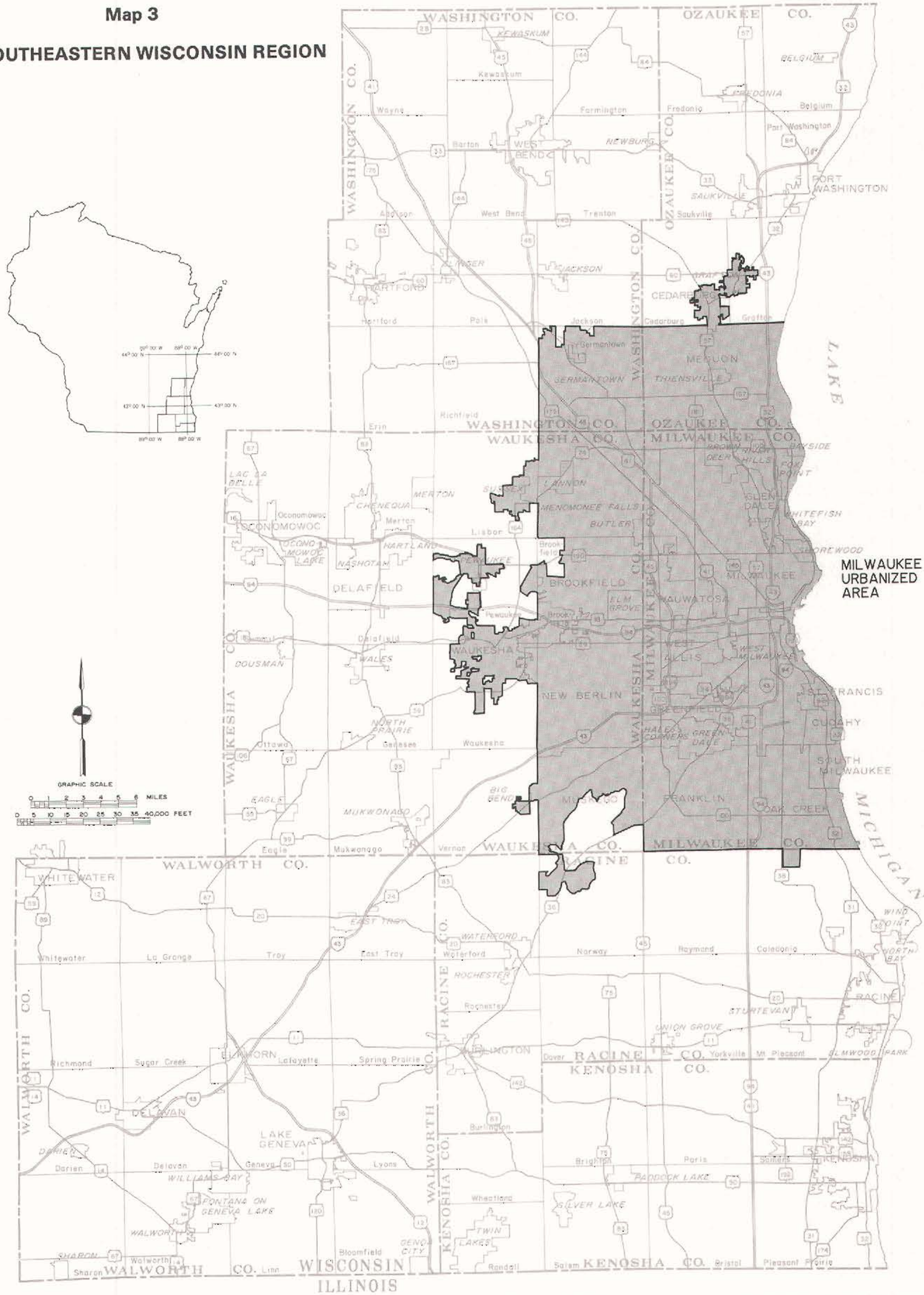
The Commission initiated its important plan design function in 1963 when it embarked upon a major program to prepare a regional land use plan and a supporting regional surface transportation system plan. Since that time, a number of additional individual plan elements have been prepared. By the end of 1987 the adopted regional plan consisted of 22 individual plan elements which can be grouped into four functional categories: 1) land use, housing, and community facility plans; 2) environmental protection plans; 3) community assistance plans; and 4) transportation system plans. The regional plan elements which have direct implications for the Milwaukee area freeway traffic management system plan include the regional transportation system plan, the regional primary transit system plan, and the transportation systems management plans for the Kenosha, Milwaukee, and Racine urbanized areas.

The regional transportation system plan recommends that an expanded freeway traffic management system with preferential treatment for public transit and other high-occupancy vehicles be developed in the greater Milwaukee area. This was one of a number of recommendations intended to ensure that maximum use was made of existing transportation facilities before commitments were made to new capital investment, and to encourage the use of high-occupancy vehicles, including buses and car- and vanpools. The regional transportation system plan recommended that an areawide freeway traffic management system be instituted to control access to the freeway system during peak travel hours in order to ensure high rates of traffic flow at reasonable operating speeds on the existing freeway system.[1] The initial transportation

[1] *For a more detailed discussion of the regional transportation system plan, see Chapters VIII and IX of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans, May 1978. The plan and a summary of the important inventory findings are fully documented in these two volumes.*

Map 3

THE SOUTHEASTERN WISCONSIN REGION

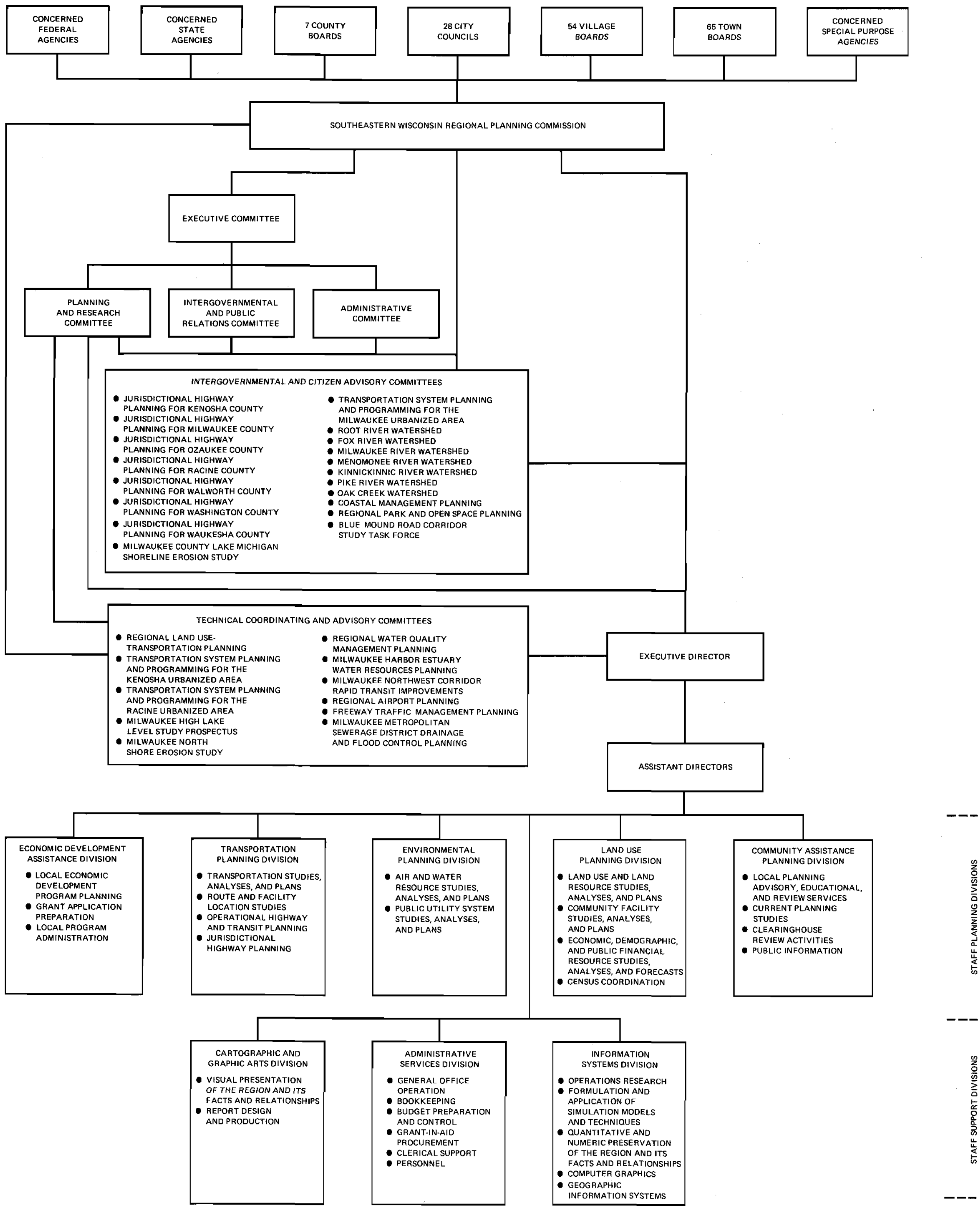


The seven-county Southeastern Wisconsin Region comprises a total area of about 2,689 square miles, or 5 percent of the total land and inland water area of Wisconsin, but contains 36 percent of the total population and provides 40 percent of the total jobs in the State. The Milwaukee urbanized area as shown on this map comprises a total area of about 468 square miles, or about 17 percent of the total land area of southeastern Wisconsin, and contains 71 percent of the total population of the Region and 77 percent of the total jobs in the Region.

Source: SEWRPC.

Figure 2

SEWRPC ORGANIZATIONAL STRUCTURE



Source: SEWRPC.

systems management plan for the Milwaukee urbanized area, completed in 1978, refined the long-range transportation system plan recommendations for the proposed freeway traffic management system.[2] The transportation systems management plan recommended that the proposed freeway traffic management system include monitoring equipment for early incident detection and clearance; changeable message signs and other driver information aids; and preferential treatment for high-occupancy vehicles, including buses, vanpools, and carpools. The primary transit system plan for the Milwaukee area, completed in June 1982, determined the best way to provide rapid transit service in the greater Milwaukee area, and recommended the provision of such service primarily by motor buses operating over the freeway system which would be operationally controlled during peak travel periods. This plan recommended that a central control system be utilized to control automobile and motor truck access to the freeways during peak travel periods to ensure uninterrupted freeway traffic flow and operating speeds of at least 40 mph on all freeway segments. The buses would have priority access to the system by way of preferential ramps or bypass lanes, and would thereby be able to bypass vehicle queues at the on-ramps and take advantage of the improved freeway operation achieved with the control system.[3]

NEED FOR A FREEWAY TRAFFIC MANAGEMENT SYSTEM PLAN FOR THE GREATER MILWAUKEE AREA

The preparation of a freeway traffic management system plan for the greater Milwaukee area is warranted at this time for a number of reasons. One reason is to abate existing and probable future transportation system congestion. Traffic congestion within the greater Milwaukee area is the most severe on the freeway system during the morning and evening peak travel periods. A freeway traffic management system is specifically directed toward abatement of severe peak-period freeway traffic congestion, and such a system would encourage the more efficient use of the existing transportation facilities. A freeway traffic management system may redirect some freeway traffic to surface streets and highways, and should encourage transit ridership and carpool and vanpool use through the provision of preferential access to the freeway system by high-occupancy vehicles.

Another reason is the need to consider the potential of a freeway traffic management system to aid in the provision of high-quality public transit service in the Milwaukee area by ensuring reasonable operating speeds on the freeway system, thus obviating the need for capital-intensive, exclusive rapid transit rights-of-way. A third reason is the need to consider the potential of a freeway traffic management system to improve air quality and reduce motor fuel consumption by reducing peak-period traffic congestion. Undertaking the necessary measures to improve air quality is essential in order to protect the public health and welfare. Decreases in traffic congestion can also effect reductions in motor fuel consumption because motor fuel consumption increases substantially under the low-speed, speed-change, and stop-and-go cycles present under congested traffic conditions.

A final reason for preparing a freeway traffic system management plan is the need to consider carefully the equity of the impacts of a freeway traffic management system in the greater Milwaukee area. Accordingly, consideration must be given to not only the costs and benefits to the greater Milwaukee area as a whole, but to who will receive the benefits and who will experience the disbenefits. A clear understanding of the impacts of a freeway traffic management system—particularly the increased efficiency of the transportation system relative to anticipated disincentives imposed by the control system, and who will benefit and who will not—not only will be useful to the design and implementation of the best overall system, but will be essential to the support of the concept of freeway traffic

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[2]*For a more detailed discussion of the freeway control system proposed in the transportation systems management plan for the Milwaukee area, see Chapter VII of SEWRPC Community Assistance Planning Report No. 21, A Transportation Systems Management Plan for the Kenosha, Milwaukee, and Racine Urbanized Areas in Southeastern Wisconsin: 1978, December 1977.*

[3]*For a more detailed discussion of the bus-on-freeway primary transit service, see Chapter VII of SEWRPC Planning Report No. 33, A Primary Transit System Plan for the Milwaukee Area, June 1982.*

management by public officials and by the general public of the greater Milwaukee area.

STUDY PROCESS

The greater Milwaukee area freeway traffic management system planning program employed a six-step process. These six steps were: 1) study organization; 2) the formulation of freeway traffic management objectives and supporting standards; 3) inventory; 4) analysis of existing conditions; 5) design, test, and evaluation of alternative system plans; and 6) plan selection and adoption.

Study Organization

Before beginning actual technical work on the study, the study effort was designed in sufficient detail so as to assure coordination among the various participants and the efficient use of funds and personnel. To accomplish this, consideration was given to the methods, procedures, staff assignments, and time schedules proposed to be followed in accomplishing each work element. Finally, an advisory committee structure was created to provide technical coordination and direction to the study.

Formulation of Objectives and Standards

The formulation of objectives and standards was the second step in the planning process. The objectives constitute a formal definition of the desired characteristics of the freeway traffic management system plan which is to be designed by articulating the needs which the system should satisfy. The objectives were translated into quantifiable standards to provide a basis for problem identification, alternative plan design, test, and and evaluation, and plan selection.

The standards included evaluation and design standards. The evaluation standards are intended to be used in the assessment of the performance of alternative freeway traffic management systems. These standards were developed within the overall structure provided by the objectives and standards formulated under the regional transportation system plan, the transportation systems management plan for the Milwaukee urbanized area, and the primary transit system plan for the Milwaukee urbanized area. These standards relate to delay and queue lengths at freeway on-ramps, and to passenger miles and vehicle miles of travel on the freeway system. The design standards provide the necessary guidelines for the design of the physical improvements recommended in the freeway traffic management system plan.

Inventories

The third step of the planning process was the conduct of the necessary inventories. Much of the data required to complete the inventories was collated from existing Commission data files or from the data files of other agencies. Some of the inventories, however, required survey efforts to acquire new data. Four categories of data were found to be necessary: 1) planning base maps and engineering plans and profiles; 2) physical and operational characteristics of existing transportation facilities and services; 3) traffic volume and pattern data for existing transportation facilities and services; and 4) information on the state-of-the-art of freeway traffic management technology.

The planning base maps and engineering plans and profiles were collated from existing sources. The Commission has prepared general planning base maps and aerial photographs, and the Wisconsin Department of Transportation and Milwaukee County have prepared engineering plans for the Milwaukee area freeway system. The physical and operational characteristics of the Milwaukee area freeways and surface arterial streets to which freeway traffic may be diverted under the range of freeway traffic management alternatives were collated from inventories conducted under the Commission's continuing transportation planning program.

Unlike the first two inventory categories which relied primarily on the collation of available data, the two remaining categories required extensive data collection efforts. To obtain the detailed information on the greater Milwaukee area freeway system travel patterns, license plate surveys were conducted on all of the greater Milwaukee area freeway corridors for a three-hour morning and evening peak travel period. Concurrent with the license plate surveys, the Wisconsin Department of Transportation conducted travel time runs from which average freeway operating speeds were determined. An inventory of hourly traffic volume during the peak period for the surface arterial streets was also conducted.

The final inventory category consisted of a survey of proven and tested freeway traffic management technology that has been, and is now being, applied in the Milwaukee area and in other parts of the United States. This inventory, conducted by the Wisconsin Department of Transportation, collected a broad range of data, including the areal extent of ramp meters for each freeway traffic management system surveyed, the type of freeway operational control strategy, and the type of ramp meter control strategy. The inventory also determined the type and technology of monitoring and control systems, including the information needs for freeway traffic management system operation and updating, the use of freeway advisory information systems, the use of freeway incident management techniques, and facility requirements.

Analyses

The fourth step of the planning process was the analysis of existing conditions. The peak-period capacity of freeways and alternative surface arterial street routes within the Milwaukee area was determined. The capacity of a freeway facility is primarily a function of the number of lanes, lane width, lateral clearance, horizontal and vertical alignment, proportion of trucks in the traffic stream, and degree of traffic flow peaking. The capacity of a surface arterial facility is primarily a function of pavement width, intersection approach gradient, provision for parking or turn lanes, traffic signal timings, type and proportion of turning movements, and the degree of traffic flow peaking. Using the estimates of peak-period freeway and surface arterial capacity and the inventories of traffic volumes and patterns, existing traffic congestion problems within Milwaukee area freeway corridors were identified. The problems identified were then used to guide the design of alternative freeway traffic management systems, and to indicate freeway locations where capacity improvements should be considered. Travel patterns on the greater Milwaukee area freeway corridors were analyzed to identify, by time period, those freeway entrance ramps which contributed substantial traffic volumes to segments of the freeway system warranting a traffic management system.

Finally, a travel simulation model was adapted, calibrated, and validated to estimate freeway traffic management system travel behavior impacts. This model was used to estimate impacts such as diverted freeway traffic and increased public transit or carpool and vanpool utilization. Energy consumption and air pollutant emissions were also estimated.

Preparation, Test, and
Evaluation of Alternatives

The fifth step in the planning process was the preparation, test, and evaluation of a range of feasible alternatives for managing the greater Milwaukee area freeway traffic. Two basic alternatives were developed. The first represented the existing freeway traffic management system within Milwaukee County with modest improvements, and the second represented a major expansion of the existing system into an areawide system.

The objective of the existing freeway traffic management system is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. In order to accomplish this objective, 21 freeway on-ramps in central Milwaukee County are currently metered. In addition, the existing freeway traffic management system provides preferential access for buses at six locations, four of which are metered and have bus bypass lanes. Entry rates at each ramp meter are responsive to the traffic volumes on immediately adjacent freeway lanes.

The objective of the second freeway traffic management system alternative is to eliminate freeway congestion and provide an average operating speed of 40 mph by preventing traffic demand from exceeding available freeway capacity. In order to accomplish this objective, freeway on-ramps would be metered throughout Milwaukee County, as well as at selected on-ramps in Ozaukee, Washington, and Waukesha Counties. Preferential access would be provided for all high-occupancy vehicles—buses, carpools, and vanpools—at an increased number of sites. An extensive monitoring and control system with a centralized computer would provide the necessary data to: 1) adjust ramp-meter entry rates based on systemwide operating conditions; 2) provide motorists with timely information about unusual operating conditions and other pertinent information; and 3) provide early incident detection.

The evaluation of the alternatives was based upon estimated costs, an assessment of the ability of each alternative to attain the freeway traffic management objectives, and an assessment of the potential of the alternative systems to alleviate congestion problems.

Plan Selection and Adoption

The sixth step in the planning process was plan selection and adoption. Following the conduct of public hearings, a freeway traffic management system plan was chosen for adoption from among the alternatives considered. The recommended plan, along with the requisite preliminary engineering designs, was intended to provide a sound guide to the completion of the freeway traffic management system in the greater Milwaukee area through the cooperative action of all of the levels, units, and agencies of government concerned.

The recommended plan clearly identifies all freeway traffic management improvements required, and addresses such issues as the geographic area to be covered by the ramp meters and the strategy for governing their operation; the locations at which preferential access for high-occupancy vehicles is to be provided; system control hardware; a motorist advisory information system; and an incident management system.

FORMAT OF PRESENTATION

The major findings and recommendations of the Milwaukee area freeway traffic management system preliminary engineering study are documented and presented in this report. Following this introductory chapter, Chapter II of this report presents the freeway traffic management system plan objectives, principles, and standards. Chapter III describes other freeway traffic management systems in operation in the United States. Included is a discussion of the operational objectives of each system, the impacts experienced by the motorists, the costs to implement the systems, and the benefits associated with each system. Chapter IV presents a summary of the important findings of the inventories of traffic volumes and patterns. Included are the findings and conclusions of the peak-period capacity analysis for the freeways and alternative surface arterial street routes within the greater Milwaukee area; identification of existing freeway traffic congestion problems; and identification of portions of the greater Milwaukee area freeway system that may warrant freeway traffic management. Chapter V presents the results of the design, test, and evaluation of the alternative freeway traffic management systems considered. Chapter VI describes the recommended freeway traffic management plan and summarizes the actions for implementation. Chapter VII provides a summary of the findings and recommendations of the entire study.

SUMMARY

This report presents a recommended plan for freeway traffic management in the greater Milwaukee area. Implementation of the recommended plan would provide for the more efficient movement of traffic on the Milwaukee area freeway system and the Milwaukee area arterial street and highway system as a whole. Traffic congestion on the freeways and on the related surface arterials would be reduced, including traffic congestion resulting from freeway demand exceeding capacity during weekday peak traffic periods, and congestion resulting from incidents and special events on weekday nonpeak periods and on weekends. Importantly, utilization of the system by high-occupancy vehicles—buses and car- and vanpools—would be encouraged.

The greater Milwaukee area freeway traffic management system plan was developed through the application of a six-step planning process: 1) study organization; 2) the formulation of objectives and standards; 3) inventories; 4) analyses of existing capacities versus demand; 5) the preparation, test, and evaluation of alternative system plans; and 6) plan selection and adoption.

Technical work for the greater Milwaukee area freeway traffic management system preliminary engineering plan was performed by the staffs of the Regional Planning Commission and the Wisconsin Department of Transportation. The work of the study was guided by a technical coordinating committee made up of representatives from public agencies concerned with, and knowledgeable about, freeway traffic management system development.

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Chapter II

OBJECTIVES, PRINCIPLES, AND STANDARDS

INTRODUCTION

The formulation of objectives is an essential part of any sound planning effort. Objectives guide the preparation of alternative plans and, when converted to specific measures of plan effectiveness—termed standards—provide the structure for comparatively evaluating the alternatives. Because planning objectives provide this basis for plan preparation and selection, the formulation of objectives is a particularly critical, as well as necessary, step in the planning process. One of the major tasks of the advisory committees established by the Commission to guide its various system planning efforts is to assist in the formulation of the necessary development objectives and supporting planning principles and standards. The freeway traffic management system objectives set forth herein were formulated by the advisory committee concerned and are similar to the long-range transportation system development objectives previously adopted by the Commission and the advisory committees concerned.[1] The similarities between the Milwaukee area freeway traffic management system objectives and standards set forth herein and the previously adopted transportation system development objectives and standards are to be expected, since the objectives—not only for the transportation system as a whole, but for the various elements of that system—essentially serve to formally define the basic needs which transportation facilities and services should satisfy, such as personal mobility, economic efficiency, environmental quality, and public safety.

BASIC CONCEPTS AND DEFINITIONS

The term "objective" is subject to a wide range of interpretation and application, and is closely linked to other terms often used in planning work which are also subject to a wide range of interpretation and application. Therefore, in order to provide a common frame of reference, the following definitions have been adopted for use in Commission planning efforts:

1. Objective: A goal or end toward attainment of which plans and policies are directed.
2. Principle: A fundamental, primary, or generally accepted tenet used to support objectives and prepare standards and plans.
3. Standard: A criterion used as a basis of comparison to determine the adequacy of plan proposals to attain objectives.
4. Plan: A design which seeks to achieve agreed-upon objectives.
5. Policy: A rule or course of action used to ensure plan implementation.
6. Program: A coordinated series of policies and actions to carry out a plan.

Although this chapter deals only with the first four of these terms, an understanding of the interrelationship between the foregoing definitions and the basic concepts which they represent is essential to the following discussion of objectives, principles, and standards.

OBJECTIVES

The following freeway traffic management system objectives have been adopted by the Commission after careful review by, and upon the recommendation of, the Advisory Committee:

1. A freeway traffic management system which facilitates quick and convenient travel between component parts of the Milwaukee area.

[1] *See Chapter II of SEWRPC Planning Report No. 25, A Regional Land Use and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans, May 1978; and Chapter II of SEWRPC Planning Report No. 33, A Primary Transit System Plan for the Milwaukee Area, June 1982.*

2. A freeway traffic management system which minimizes the disruption of existing neighborhood and community development, including adverse effects upon the property tax base, and which minimizes the deterioration and/or destruction of the natural resource base.

3. A freeway traffic management system which reduces freeway and standard arterial accident exposure and provides for increased travel safety.

4. A freeway traffic management system which facilitates the provision of effective and attractive travel by transit and other high-occupancy vehicles.

5. A freeway traffic management system which provides for an equitable distribution of any freeway traffic management benefits and costs, and an equitable distribution of any freeway ramp meter delays and of any improvements in the speed of freeway travel.

6. A freeway traffic management system which is economical and efficient, satisfying all other objectives at the lowest possible cost.

It must be recognized that equitable distribution of delays or other disbenefits may not be practicable in all situations. Specifically, as part of the response of the incident management system, it may be desirable to minimize ramp-meter entry rates at selected ramps upstream of an incident, while simultaneously increasing downstream ramp-meter entry rates in order to fully utilize the freeway system downstream of the incident. This strategy may divert vehicles to the arterial system upstream of the incident, thereby increasing travel time. Coordinated response of the freeway traffic management system in dealing with incidents may therefore result in periods of inequitable distribution of delays and other disbenefits. However, the incident management system should be designed to minimize both the impact and the duration of an incident, and therefore minimize the period of any inequitably distributed delay or other disbenefits.

PRINCIPLES AND STANDARDS

Complementing each of the foregoing freeway traffic management system objectives is a planning principle and a set of planning standards. Each set of standards is directly relatable to the planning principle, as well as to the objective, and serves to facilitate quantitative application of the objectives in plan design, test, and evaluation. The planning principle, moreover, supports each specific objective by asserting its validity.

The planning standards adopted herein fall into two groups: comparative and absolute. The comparative standards, by virtue of their nature, are applied in the comparison and evaluation of alternative plan proposals. The absolute standards are applied individually to each alternative plan proposal, and are expressed in terms of minimum or desirable values. Table 1 sets forth the objectives, the supporting planning principles, and the associated comparative and absolute standards.

OVERRIDING CONSIDERATIONS

In the application of the planning standards and in the preparation of the alternative freeway traffic management system plans, several overriding considerations must be recognized. First, it must be recognized that an overall evaluation of the alternative freeway traffic management system plans must be made on the basis of cost. Such analysis may show that the benefits derived from attainment of one or more of the objectives or supporting standards do not justify the expenditure of capital required to achieve the objective or objectives, and, therefore, that the objectives or standards cannot be met practically and must be either reduced or eliminated. Second, it must be recognized that it is unlikely that any one alternative plan proposal will meet all of the objectives and standards completely, and that the extent to which each objective and standard is met, exceeded, or violated must serve as a measure of the ability of each alternative plan to achieve the objective. Third, it must be recognized that certain objectives and standards may conflict, requiring resolution through compromise, and that meaningful plan evaluation may take place only through the comprehensive assessment of each of the alternative plans against all of the objectives and standards. Fourth, one of the prime considerations in the planning and design of the freeway traffic management system is the need to maximize the flexibility of the resulting system.

Three types of flexibility can be considered with respect to a freeway traffic management system: operational flexibility, or the ability of the system to operate under a variety of operational and system administration strategies and environments; technological flexibility, or the ability of the system to accommodate significant changes in technology; and configurational flexibility, or the ability of the system configuration to be altered to respond to unanticipated changes in urban development and/or travel demand.

SUMMARY

This chapter has presented a set of freeway traffic management system development objectives, principles, and standards developed and adopted by the study advisory committee and the Commission staff itself to guide the alternatives through plan preparation, test, and evaluation. The six objectives have been developed within the context of the regional transportation system plan objectives, principles, and standards previously adopted by the Regional Planning Commission.

The standards which support the six specific objectives provide important guidelines for subsequent freeway traffic management planning efforts, facility design efforts, and related plan implementation efforts. This chapter thus documents the guiding objectives and supporting standards which the recommended freeway traffic management plan is intended to meet, and the criteria by which implementation policies and programs can be designed to carry out the plan recommendations and ensure compatibility and consistency between freeway traffic management improvements and the regional transportation system plan.

Table 1

FREEWAY TRAFFIC MANAGEMENT SYSTEM
EVALUATIVE OBJECTIVES, PRINCIPLES, AND STANDARDS

OBJECTIVE NO. 1

A freeway traffic management system which facilitates quick and convenient travel between component parts of the greater Milwaukee area.

PRINCIPLE

To support the existing travel demand generated by the everyday activities of business, shopping, and social intercourse within a large urban region, a transportation system which provides for reasonably fast, convenient travel is essential. Traffic delays increase the operating costs of business and industry and impair the quality of life of the area's residents.

STANDARDS

1. Total travel time should be minimized.[a]

2. The freeway system access control provided by the on-ramp meters should be sufficient to achieve a balance between freeway traffic volumes and freeway capacity, thereby ensuring that a minimum operating speed of 40 miles per hour is maintained on each segment of the freeway system during the peak hour on an average weekday.

3. The access control provided by the freeway on-ramp meters at any given site should not result in delay in excess of five minutes during the peak hour, nor should the queue extend onto the adjacent surface arterial street system if it would adversely impact the operation of the surface arterials.

OBJECTIVE NO. 2

A freeway traffic management system which minimizes the disruption of existing neighborhood and community development, including adverse effects upon the property tax base, and minimizes the deterioration and/or destruction of the natural resource base.

PRINCIPLE

The social and economic costs attendant to the disruption and dislocation of homes, businesses, industries, and communication and utility facilities, as well as the adverse effects on the natural resource base, can be minimized through the proper location, design, and operation of transportation facilities.

STANDARDS

1. The dislocation of homes, businesses, industries, and public and institutional facilities, and the acquisition of right-of-way should be minimized.
2. The freeway traffic management system should be located, designed, and operated so as to minimize the amount of air pollutants generated by the transportation system.
3. The total amount of energy consumed in operating the freeway traffic management system, particularly petroleum-based fuels, should be minimized.
4. The freeway traffic management system should be designed and operated to minimize the level of noise pollution generated by the transportation system.

OBJECTIVE NO. 3

A freeway traffic management system which reduces freeway and standard arterial accident exposure and provides for increased travel safety.

PRINCIPLE

Accidents take a heavy toll in life, property damage, and human suffering; contribute substantially to overall transportation cost; and increase public costs for police and welfare services. Therefore, every attempt should be made to reduce both the incidence and severity of accidents.

STANDARD

1. The total number of freeway and standard arterial vehicular accidents should be minimized.

OBJECTIVE NO. 4

A freeway traffic management system which facilitates the provision of effective and attractive travel by transit and other high-occupancy vehicles.

PRINCIPLE

Increased transit, carpool, and vanpool use can greatly benefit the greater Milwaukee area. Increasing the number of persons per vehicle can reduce the need for additional highway and parking facility construction, and the annual operating costs for highway maintenance and support services such as traffic control and law enforcement.

STANDARDS

1. The total number of passenger miles of travel by transit, carpools, and vanpools should be maximized within the greater Milwaukee area.
2. Preferential access for high-occupancy vehicles (HOV) should be provided at metered on-ramps, particularly those that are utilized for regularly scheduled transit service, those where the potential time savings attendant to avoiding ramp-meter delay is substantial, and those where a concentration of trips is conducive to carpool/vanpool formation. High-occupancy vehicles shall be defined as buses that are providing regularly scheduled service and other vehicles with two or more occupants.

OBJECTIVE NO. 5

A freeway traffic management system which provides for an equitable distribution of any freeway traffic management benefits and costs, and an equitable distribution of any freeway ramp-meter delays and of any improvements in the speed of freeway travel.

PRINCIPLE

A freeway traffic management system has the potential to increase the level of service to some users of the transportation system by facilitating access to facilities operating safely and reliably at or near design speeds, as well as the potential to reduce the level of service to others by delaying autos and trucks at freeway on-ramps and by inducing some freeway traffic to divert to adjacent surface streets. The benefits and disbenefits of a freeway traffic management system should be distributed in an equitable manner among all users of the system.

STANDARDS

1. The benefits of improved freeway operating speeds resulting from the implementation of a freeway traffic management system should be equitably shared by area freeway system users, as measured by travel time.

2. The disbenefits of delay incurred at freeway on-ramps resulting from the implementation of a freeway traffic management system should be equitably shared by area freeway system users, as measured by ramp delay.

3. The net benefits resulting from the implementation of a freeway traffic management system should be equitably shared, as measured by the difference between reduced freeway travel time and increased ramp delays.

OBJECTIVE NO. 6

A freeway traffic management system which is economical and efficient, satisfying all other objectives at the lowest possible cost.

PRINCIPLE

Total financial resources are limited, and any undue investment in transportation facilities and services must occur at the expense of other public and private investments. Therefore, the freeway traffic management system capital investment and operating costs necessary to attain the desired objectives should be minimized.

STANDARDS

1. The sum of the total capital investment required to implement the freeway traffic management system and the annual cost of its operation should be minimized.

2. The direct public and user benefits accrued from implementing and operating the freeway traffic management system should outweigh the direct costs of the improvements.[b]

[a]The overall travel time is traditionally defined as the total door-to-door time of travel from origin to destination, including the time required to arrive at the vehicle and leave the vehicle, as well as over-the-road travel time. Travel time, as considered under this study, will include only that part of the overall travel time directly related to freeway travel. Specifically, the travel time components include the delay incurred at a freeway on-ramp meter, and the ramp-to-ramp freeway travel time. For mass transit vehicles, it may also include travel time between the boarding site and the freeway—for example, the time required to traverse the surface streets to reach the freeway from the park-ride lots would be included.

[b]Direct benefits include travel time savings for freeway users, reduced accidents, reduced operating costs for transit, and reduced fuel consumption and operating costs.

Source: SEWRPC.

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Chapter III

INVENTORY OF EXISTING FREEWAY TRAFFIC MANAGEMENT SYSTEMS

INTRODUCTION

During the 1950's and early 1960's when freeway systems were being constructed and opened to traffic, and becoming more and more extensive, it became apparent that urban freeways did not operate freely by themselves. Congestion occurred due to regular overloading of the freeway during normal peak commuting periods, and as the result of unplanned events such as accidents, disabled vehicles, spilled loads, and changes in climatic conditions such as rain and snow which temporarily reduce roadway capacity. Some traffic engineers, charged with maintaining safe and efficient movement of traffic on the transportation network, including the freeway and local arterial street system, believed that ways and means of improving the operation of freeway facilities experiencing congestion problems ought to be explored. This concern resulted in several pioneering efforts undertaken in the late 1950's and the early 1960's to identify the causes of freeway congestion and to develop possible solutions to the problem.

HISTORY OF FREEWAY TRAFFIC MANAGEMENT—NATIONWIDE PERSPECTIVE

In the City of Detroit in the late 1950's, the City Traffic Engineer became concerned that the freeways were becoming overloaded and unable to handle the traffic volumes originally intended. This concern led to a brief test of a single television camera as a possible means of observing freeway traffic conditions in order to analyze the problems and develop solutions. This initial effort began one of the longest and most comprehensive research projects of freeway operations that has been undertaken. The project, popularly known as the Lodge National Proving Ground, was conducted in four stages. The first stage, beginning in 1955 and lasting until 1963, was under the direction of the Michigan State Highway Department in cooperation with the City of Detroit, Wayne County, and the Bureau of Public Roads (predecessor of the Federal Highway Administration). During this period, the initial effort of a single television camera was expanded into a system of 14 television cameras located over a 3.2-mile section of the John C. Lodge Freeway in the City of Detroit. The television pictures of the freeway were displayed on a battery of 15 monitors in a control room. During this stage, closed circuit television (CCTV) was found to be an effective means of detecting incidents. A system of lane control signals, along with changeable advisory speed signing, was developed and installed, and found to be effective in improving freeway flow when incidents, congestion, and other events such as lane closures for freeway maintenance caused temporary lane blockages. The system was initially operated manually in response to observations of the television picture.

Stage two of the research effort began in 1963 and lasted until 1966. This effort was jointly funded, with 15 states contributing to the project identified as the "National Proving Ground for Freeway Surveillance Control and Electronic Aids." The project was under the direction of the Michigan State Highway Department and guided by a Project Policy Committee made up of representatives of contributing organizations. During this stage, reliable control and detection equipment was developed, along with an on-line computerized surveillance and control system utilizing a central computer and vehicle sensors on the freeway. Also, it was observed during this stage that freeway breakdowns were caused more by incidents than by traffic volume overloading. The beneficial effects of ramp closure by automatic signals during critical periods were also determined.

Stages three and four of the study lasted from 1966 until 1971, when the project was terminated and the television and control system removed. During these stages, funding was provided by the National Cooperative Highway Research Program (NCHRP) of the Highway Research Board (now the Transportation Research Board). Research contracts were established with the Texas Transportation Institute and the University of Michigan to perform numerous research studies. The main studies included: an evaluation of the effectiveness and benefits of ramp metering, concluding that ramp metering was effective in reducing travel time; an evaluation of CCTV in detecting incidents, concluding that it was a useful tool in reducing response times; an evaluation of electronic incident detection by means of electronic detectors, concluding that the system had a high probability of detecting incidents; an evaluation of the effectiveness of citizen band radio as a means of detecting and verifying incidents, concluding that citizen band radio provided a reliable means of incident detection and verification; an evaluation of the effect of climatic changes on freeway capacity, concluding that in some instances wet pavements reduce capacity by 8 percent; and many other research activities involving variable message signing, sign legibility, route diversion techniques and effectiveness, and other techniques and applications now being utilized as part of ongoing freeway traffic management systems.

During the same period of time, similar concerns about freeway operation and congestion were occurring in other areas, particularly Chicago, Illinois; Houston, Texas; and Los Angeles, California, where developed freeway systems were becoming more extensive and experiencing the problems of recurrent and nonrecurrent congestion.

In Chicago, the Chicago Area Expressway Surveillance and Control project was initiated in 1961 in response to the fact that it was demonstrated that continuous maintenance and operational responsibility on the freeway system was required in an effort to maintain and improve operation. The project was established to investigate ways and means to provide more efficient and safe operations. The initial effort in the project was to install instrumentation as a means of gathering data to identify the causes of congestion. In 1962, a total of 25 ultrasonic detectors were installed to monitor the outbound flow on five miles of the Eisenhower Expressway. Each detector was connected via leased telephone lines back to a central control center, where analog computers were used to accumulate and analyze the freeway operational data. This early effort found that there were three general causes of freeway congestion:

1. Numerous incidents such as accidents, disabled vehicles, debris on the pavement, maintenance operation, and weather conditions adversely affected traffic flow at random times and locations.
2. During peak periods, there was a distinct problem of overloading, where traffic volume demands on the freeway exceeded the capacities available.
3. There were physical, geometric problems built into the system that caused reduced flows under certain conditions, such as long grades in conjunction with heavy truck use during high-volume traffic periods, and other geometric features such as lane reductions or lane drops at freeway interchanges where the capacity reduction caused a bottleneck situation.

The solution to the problem of freeway overloading was directed at bringing the freeway demand and capacity relationship into balance by controlling entering ramp volumes. Initial experiments with ramp metering began in 1963. These efforts proved successful and were gradually expanded to the present system of 70 meter-controlled ramps. The problem of random freeway incident detection was approached with the electronic surveillance of freeway flow by vehicle detection and service patrols. The initial detection system has expanded to the present system of 1,650 vehicle detectors.

On the Gulf Freeway in Houston, Texas, the initial efforts again involved instrumentation of the freeway in order to identify the sources and causes of congestion. After several years of study, ramp control was initiated in 1965, with eight entrance ramps controlled with ramp meters. In 1966, prototype analog computers were installed to evaluate the demand-capacity and gap acceptance theories of ramp metering. In 1967, a completely automatic analog ramp control system was installed. At the same time, a system of closed circuit television, including 14 cameras located on a six-and-one-half-mile length of the Gulf Freeway, was also installed, with monitors in a central control room. The television cameras were installed primarily for research and evaluation of the ramp control project; however, the Houston Police Department was invited by the Research Group to observe the television monitors for incident detection, and they were found to be an effective and useful tool for incident management.

In Los Angeles, which had long been considered a leader in the construction and operation of extensive freeway systems incorporating high standards of geometric design and capacity, the need to manage traffic was also very evident. The Freeway Operations Unit of the Los Angeles District Office was formally created in 1965, and by 1969 was using many of the control techniques in use today. From this initial effort, the District proposed as a demonstration project a comprehensive freeway surveillance and control project on a 42-mile loop in the Los Angeles area which contained freeway segments representative of the entire 470-mile freeway system in the area. This demonstration project, undertaken in 1971, incorporated many of the now proven techniques of freeway traffic management—including complete electronic detector surveillance of the system utilizing induction loops in the pavement, expansion of ramp-metering projects already in place, incident management strategies including electronic detection and roving service patrols, aerial surveillance, and the provision of motorist information through advisory signing and commercial radio.

Each of these initial efforts has evolved into major comprehensive freeway traffic management projects now in place or in advanced stages of planning. The Chicago and Los Angeles efforts have evolved into extensive and comprehensive traffic management systems incorporating state-of-the-art techniques. The Detroit project has evolved into a comprehensive project implemented in 1981 and incorporating many of the techniques and actions originally studied in the Detroit area but utilizing more advanced and state-of-the-art techniques and technology. The Houston area has undergone considerable reconstruction of freeway facilities, and is presently utilizing an extensive system of isolated freeway ramp control, and installing surveillance and control as part of an overall program of constructing reversible flow-authorized vehicle lanes (AVL—more commonly referred to as high-occupancy-vehicle, or HOV, lanes) in the freeway medians. This program is intended to be part of a comprehensive control system.

HISTORY OF FREEWAY TRAFFIC MANAGEMENT—MILWAUKEE PERSPECTIVE

The intense research activity occurring at the national level generated considerable interest in the potential for solving freeway congestion problems at many and varied local levels. The pioneering work was successful in demonstrating that numerous traffic management elements were effective and could be utilized individually or as part of a comprehensive freeway management system. In 1968, the Wisconsin Department of Transportation created the Freeway Operations Unit in the Milwaukee District for the purpose of analyzing and identifying potential solutions to congestion problems that were beginning to develop after the completion and opening of the Marquette Interchange in December 1968. The Marquette Interchange and the connecting roadways provided the final link in establishing freeway continuity between IH 43 (the North-South Freeway) to the north, IH 94 (the East-West Freeway) to the west, and IH 94 (the North-South Freeway) to the south. During 1969, extensive and comprehensive traffic data were collected on the East-West Freeway, including traffic volume input and output counts between the Zoo and Marquette Interchanges; travel time data over the same segment and parallel local streets; and aerial photography for the purpose of computing and plotting freeway densities to identify bottleneck locations and the duration and extent of congestion. These data were collected during both the morning and evening peak periods.

As a result of the information obtained during the operational studies, the first ramp-metering system was installed on an experimental basis on the East-West Freeway at three locations to control traffic entering the freeway in the westbound direction during the evening peak period. The ramp meters were installed on the westbound entrance ramps from 17th Street, 28th Street, and Hawley Road. The initial equipment was installed as a temporary traffic signal and operated for a two-week trial period in a traffic-responsive mode based upon data collected at an existing freeway traffic counter located at 26th Street. Freeway lane occupancy was measured and was transmitted to operators at each ramp-metering signal by means of the Milwaukee County radio system, where the operators manually selected predetermined metering rates. The results of this experimental installation resulted in substantial improvements in freeway flow, with little impact on the surface street system, and the decision was made to retain the ramp-metering signals on a permanent basis.

From this initial effort, the ramp control program was expanded to include the present total of 21 metered ramps. The ramp-metering controls were designed to operate in a traffic-responsive mode in which metering rates are selected based upon freeway conditions measured at the local entrance ramp by means of induction loop detectors on the freeway main line near the ramp entrance. The control equipment was initially designed to provide three different metering rates of 6-, 9-, and 12-second intervals, based upon lane occupancy measured by the freeway detector. Sixteen of the ramp control units were replaced with microprocessor-based controllers that provide an expanded range of six metering rates based upon volume flow and lane-occupancy conditions measured in the vicinity of the entrance ramp. In addition, the local controllers obtained the flexibility to respond to preemption by high-occupancy vehicles, and the capability to be interconnected and coordinated as a local system with one controller serving as the master, or to serve as a local controller under the supervision of a central master computer.

In conjunction with the ramp-metering program, a number of HOV priority treatments were incorporated at metered ramp locations to accommodate and provide preferential access for freeway flyer transit buses. The first priority treatment was an exclusive bus entry ramp constructed in 1975 at the westbound entrance ramp to the East-West Freeway from N. 13th Street at W. Clybourn Street. The ramp allowed buses only to enter the freeway from Clybourn Street and to completely bypass the metering operation to have free access to the freeway. Additional bus bypass lanes have been provided at the following metered ramps as freeway flyer service was expanded or as the ramp meters were installed:

1. Northbound entrance ramp to IH 43 from 7th and North Avenues.

2. Northbound entrance ramp to IH 94 from Holt Avenue.

3. Eastbound entrance ramp to IH 94 from 68th Street.

In addition to the four bus bypass lanes at metered ramps, two exclusive entry ramps at uncontrolled ramp locations were provided from park-ride lots developed immediately adjacent to the freeway entrances. These ramps were located at the Watertown Plank Road park-ride lot adjacent to southbound USH 45, and at the College Avenue park-ride lot adjacent to northbound IH 94. The ramps initially operated for buses only, but now can also be used by carpools of two or more persons.

INVENTORY

The early pioneering efforts to bring ordered operation and management to freeway systems have resulted in the development of numerous traffic management activities that may be utilized in developing solutions to the peak-hour congestion problem, a recurrent type of congestion problem. In addition, much attention has been focused on the management of the unplanned occurrence of congestion generally resulting from an incident such as an accident, disabled vehicle, spilled load, or maintenance or construction activity. In order to determine the full scope of traffic management activities that operating agencies are incorporating in their day-to-day function of managing or "operating" the freeway system under their jurisdiction, a total of 17 agencies were contacted to determine to what extent they have incorporated freeway traffic management elements within their day-to-day activities, and to what extent they have committed resources—both financial and manpower—to carrying out these activities. All the projects selected incorporated some degree of ramp-metering control within their scope of traffic management activities.

Freeway Traffic Management Elements

A comprehensive traffic management system may include a number of elements in order to obtain optimum operation under normal day-to-day conditions, and to minimize the effects of the unplanned or incident-induced congestion. Traffic management elements that are being applied in the management of the recurring congestion problem include ramp metering, closed circuit television, preferential treatment for high-occupancy vehicles, and motorist information systems utilizing variable message signs, commercial radio, and highway advisory radio systems. Management of the nonrecurrent congestion problem requires additional traffic management elements directed to freeway incident management, including early incident detection and confirmation; coordination with law enforcement, fire, emergency medical, and towing services for early response to an incident; and additional traffic management activities to mitigate the effects of congestion that may develop as a result of reduced capacity situations. The additional activities may include incident response teams to manage traffic and route diversion at the scene. Some of the traffic management elements may be used to manage both recurrent and nonrecurrent congestion.

The specific traffic management elements and their scope and potential applications are described below.

<u>Ramp Metering</u>: Ramp meters are traffic signals located on freeway entrance ramps from the local street system or, in some cases, freeway-to-freeway entrance ramps, and are used to control the rate of entry of vehicles onto a freeway segment. One objective of ramp metering is to control the traffic volume entering the freeway to maintain free-flowing conditions within the available capacity of the freeway lanes. As noted earlier, one cause of freeway congestion is overloading of the system, or traffic demand in excess of the available capacity, which causes the freeway system to break down and experience stop-and-go operation, with fewer vehicles able to move past a point than under more free-flowing conditions. Another objective of ramp metering is to smooth the flow of traffic on the freeway main line by eliminating or reducing traffic conflicts in the ramp merge areas. Most ramp metering is operated so as to allow one vehicle at a time to enter the freeway. This type of operation allows motorists on the freeway main line and motorists entering the freeway from the ramp to adjust their speeds in order to merge more smoothly than when groups of vehicles released from a surface street traffic signal attempt to enter the freeway at one time.

A variety of ramp-metering techniques may be utilized, depending upon freeway geometric conditions and traffic volume demand. Ramp metering may be operated in a pre-timed mode or traffic-responsive mode. In the pre-timed mode, vehicles are allowed to enter at a prescribed rate based upon historical traffic volume conditions on the entrance ramp as well as on the freeway. In the traffic-responsive mode, the rate of entry through the ramp meter is adjusted on a real-time basis, based upon conditions on the freeway measured locally as with an independent controller, or under the control of a master controller, which may be a central computer, whereby the responsive metering rates are determined on the basis of system as well as local considerations.

The actual method of operation of the ramp meter at a particular ramp may take on a variety of forms, depending upon the objectives of the ramp control, and local geometric and traffic conditions. The following alternatives are possible:

1. Single lane, one vehicle at a time entry.
2. Single lane, multiple vehicle at a time entry.
3. Multiple lane, with vehicles released one at a time from each lane either simultaneously or alternately.
4. Multiple lane, with more than one vehicle at a time released from each lane.

<u>Motorist Information Systems</u>: It is essential that the motorist be provided with adequate information to make the proper decisions and judgments in traveling a freeway system. The basic motorist information system consists simply of the standard guide signs found on any freeway segment providing the motorist with destination and exit ramp information. Motorist information as a traffic management element may be provided in a dynamic fashion, and may include timely information regarding the route and regarding the traffic conditions likely to be encountered.

<u>*Commercial Radio*</u>: The information may be conveyed to the motorist by means of commercial radio broadcasts, with the information on freeway conditions being gathered independently by the radio reporter by means of direct observation, usually in aircraft, by traveling by vehicle in the traffic stream, or by monitoring radio broadcasts of the enforcement agencies responsible for managing freeway traffic flow. Information on the performance of the freeway system may also be furnished to the commercial radio broadcasting system by the transportation agency responsible for operating the freeway system and in a position to provide real time, pertinent information.

<u>*Changeable Message Signing*</u>: Information may also be presented to the motorist by means of changeable message signing located along the freeway system. The signs may utilize a light bulb matrix, a disc matrix, or rotating drums. Such signing can be used to provide information about traffic conditions or congestion ahead, recommended diversion from the freeway

because of congestion and incidents, special event routing, or special road conditions or restricted lanes due to weather conditions, an accident, or road work activity.

Highway Advisory Radio (HAR): Highway advisory radio systems use special frequencies at the low or high end of the AM radio band to transmit pertinent information to motorists. The systems are operated by the transportation agency responsible for operation of the roadway system. Highway advisory radio systems are generally very localized and directed to motorists using a particular route. Motorists are advised by means of actuated or static signing to tune to the appropriate frequency and receive information regarding roadway conditions immediately downstream that may be influenced by congestion, restricted roadway conditions because of accidents, or road work. Advisory route diversion and detour information may also be provided.

High-Occupancy-Vehicle (HOV) Priority Treatments: A number of traffic management actions have been developed that provide priority or preferential access for high-occupancy vehicles—buses, carpools, and vanpools—with the objective of encouraging greater use of transit facilities and encouraging more ridesharing to reduce the total number of vehicles on the road. These actions may include separate or priority lanes for buses and carpools to bypass traffic waiting at a ramp-metering signal, thereby eliminating the delay experienced by single-occupancy vehicles waiting at the signal. Other preferential treatments include the provision of park-ride facilities for use by motorists to change modes to transit vehicles or to form carpools. These facilities may have preferential and sometimes exclusive access provisions for quick and easy entry to the freeway. Where conditions permit, and adequate demand exists, a separate freeway lane or roadway may be designated for the exclusive use of high-occupancy vehicles to provide a higher level of service and quicker travel times, thereby further encouraging use of transit and ridesharing arrangements.

Motorist Aid System: A motorist involved in an accident or who experiences mechanical difficulty or failure of his automobile may become stranded on the freeway and present a hazard not only to himself but to other motorists. By its very nature, the freeway does not provide a stranded motorist with easy access to a telephone or other source of help. To address this need, motorist aid call boxes have been installed in some areas of the United States. These systems are similar to a police call box and may provide for either voice or signal communication to identify the problem. Another means of serving this need is through courtesy or service patrols furnished by the state transportation agency. On many urban area freeway systems, this function is performed by the enforcement agency responsible for patrolling the facility.

Interface Capability and Coordination with Arterial Streets Through Traffic Systems: The operation of the local street intersection in the immediate vicinity of entrance ramps may be affected by congestion on the freeway because of overloading, or by congestion at metered ramps, where traffic queues may extend to the local street system. Current technology provides the opportunity for the interconnect of local street traffic controls with freeway control systems so that adjustments in the local street signal timing may be made responsively to conditions affecting the operation of the streets. This interconnection and coordination may be accomplished on a limited, isolated basis, or on a system basis.

Freeway Incident Management: Nonrecurrent congestion, or the unexpected development of congestion, largely results from the occurrence of incidents such as accidents, disabled vehicles blocking lanes, or spilled loads. The management of nonrecurrent congestion may be accomplished through the development of a system of early detection, incident confirmation, and rapid response and removal of the incident.

Early Detection: Early detection of an incident may be accomplished through the use of roving patrols, closed circuit television, or simply reports to the public. The use of closed circuit TV requires constant visual observations by trained observers, and experience has shown that the occurrence of an incident may not be readily apparent on a TV monitor. A more effective means of detecting an incident that affects the normal flow of traffic is electronic surveillance using detectors located on the freeway at regular intervals. The induction loop detector, commonly used in many traffic applications such as traffic signal operation and traffic stream data collection, is installed along the freeway at regular intervals to measure the presence and movement of vehicles. The disruption to flow is indicated when the measured freeway flow is significantly different from one station to the next.

Incident Confirmation: Once the incident is detected, it is essential that the nature of the incident be identified in order to provide for rapid response and early removal. Incident confirmation may be accomplished in a number of ways, including dispatching police or emergency vehicles or dispatching a routine service or maintenance patrol, or by means of closed circuit TV. In addition, some agencies are using citizen band (CB) radios to monitor the conversations of motorists in the area of an incident to determine the nature of an incident. CB base stations located in the field are dialed up and monitored when the electronic detection system identifies the occurrence of an incident.

Rapid Response and Removal: Upon confirmation of the occurrence and nature of the incident, appropriate police, fire, and emergency medical service, as well as tow trucks and heavy equipment to remove the incident, may be dispatched to provide aid to victims, and to remove vehicles and loads. Additional actions that may be taken involve the active management of traffic on the roadway being affected by the occurrence of the incident. For example, incident response teams can be established to control traffic and warn motorists of lane closures and the possible diversion of traffic off the freeway, including the marking of appropriate detour routes.

Conclusion: It is apparent that many of the traffic management elements that may be employed in the management of freeway operations may be used for both recurrent and non-recurrent congestion problems. There are many levels of technique and sophistication that may be employed in bringing the above traffic management elements into useful application, depending upon the financial resources and manpower available. A crucial element in the development of a freeway traffic management system is the instrumentation of the freeway with traffic detectors at regular intervals. Such instrumentation is connected to a central data gathering controller or computer in order to collect traffic operational data which may be used to obtain a qualitative and quantitative indication of the operation of the freeway. This information may be used to determine appropriate or warranted traffic control device applications or necessary geometric improvements, as well as serving as the basis for the operation of traffic control devices. Real time electronic surveillance capability, to various degrees, is essential to the operation of traffic-responsive control devices such as ramp metering, to the operation of motorist information systems, and to the acquisition of data to evaluate overall performance.

Overview of Systems Inventoried

A total of 17 operating systems in the United States and Canada were contacted in 1984 by means of a questionnaire and interviews in an effort to identify the full range and extent of freeway traffic management efforts being utilized. The projects to be contacted were screened from a summary of freeway operations projects contained in Informational Report No. 15, October 1982, published by the Transportation Research Board and prepared by the Freeway Operations Committee. The projects selected for review were those that included ramp metering as a traffic management element. The surveyed systems can generally be grouped into one of the following three categories:

1. Systems with central computer control and a freeway operational surveillance capability utilizing a continuous system of electronic vehicle detection.

2. Systems with central computer control of ramp metering, but no continuous freeway surveillance and electronic vehicle detection capability.

3. Systems with ramp metering operating as local independent control without central supervision.

The projects contacted and reviewed in Category 1 above included the following:

1. Semi-Automatic Traffic
   Management Systems (SATMS)
   California Department of Transportation
   Los Angeles, California

2. Chicago Area Freeway Traffic
   Management System
   Illinois Department of Transportation
   District 1, Traffic Systems Center
   Chicago Metropolitan Area

3. Twin Cities Freeway Traffic
   Management System
   Minnesota Department of Transportation
   Minneapolis-St. Paul Area

4. Surveillance Control and Driver Information (SCANDI)
   Michigan Department of Transportation
   Detroit, Michigan

5. Seattle Freeway System
   Washington State Department of Transportation
   Seattle, Washington

6. QEW Mississauga Freeway Traffic Management System
   Ministry of Transportation and Communications, Ontario
   Toronto, Ontario, Canada

7. Routes IH 66/IH 35
   Virginia Department of Highways and Transportation
   Fairfax and Arlington County, Virginia

8. Integrated Motorist Information System (IMIS)
   New York State Department of Transportation
   Long Island, New York

The projects contacted and reviewed in Category 2 included the following:

1. Ramp Metering Project
   California Department of Transportation
   San Diego County, California

2. Ramp Metering Computer System
   Colorado Department of Highways
   Denver, Colorado

3. Ramp Metering Project, IH 17
   Arizona Department of Transportation, Highway Division
   Phoenix, Arizona

Projects contacted and reviewed in Category 3 above included the following:

1. Texas Department of Highways and Public Transportation
   Houston, Texas

2. Texas Department of Highways and Public Transportation
   Fort Worth, Texas

3. Texas Department of Highways and Public Transportation
   San Antonio, Texas

4. California Department of Transportation
   San Francisco Bay Area, California

5. California Department of Transportation
   Sacramento, California

6. IH 5 North, Banfield (IH 894) Freeway
   Oregon State Highway Division
   Portland Area

Table 2 summarizes each of the projects in its respective category, along with the major traffic management elements and activities incorporated in each of the projects.

As indicated in Table 2, the projects in Category 1 were generally broader in scope than the projects in the other categories, and incorporated more traffic management elements and activities. All eight of the projects in Category 1 contained electronic incident detection capability and motorist information systems utilizing changeable message signs, while six of the projects included closed circuit TV for incident verification. Four of the projects in Category 1 monitored CB radio as a means of incident verification, and three of the projects incorporated highway advisory radio systems.

As previously mentioned, each of the projects reviewed contained ramp-metering control devices. In the projects reviewed and summarized in Table 2, a total of 988 metered local street entrance ramps were in operation, with an additional 129 ramps to be placed in operation in the near future. The majority of the metered ramps, 610, were located in the Los Angeles area, where 25 additional ramp meters were planned for 1985. In addition, there were 19 freeway-to-freeway metered ramps in the reviewed projects, with 12 of these located in Minneapolis. San Diego reported four metered freeway-to-freeway ramps.

The scope of the projects indicated above is described in more detail below.

Systems with Central Computer Control and a Continuous System of Electronic Vehicle Detection and Freeway Surveillance

Los Angeles, California: Los Angeles, one of the nation's largest urban centers, with a population in excess of 10 million people and with one of

Table 2

FREEWAY TRAFFIC MANAGEMENT PROJECTS: 1984

Traffic Management Element	Category A Central Control and Electronic Surveillance System							
	Los Angeles, California	Chicago, Illinois	Minneapolis, St. Paul, Minnesota	Detroit, Michigan	Seattle, Washington	QEW Freeway Toronto, Canada	IH 66-IH 395 Virginia	IMIS Long Island, New York
Surveillance and Control System	X	X	X	X	X	X	X	X
Central Computer Control	X	X	X	X	X	X	X	X
Control System Cost (millions)[a]	16.5	9.0	3.6	16	4.5	2	17	30
Miles of Controlled Highways	475	110	27.3	32.5	17	8	20	92.7
Metered Freeway Entrance Ramps	610	70	53	25	18	10	25	68[c]
Metered Freeway to Freeway Ramps	0	0	12	0	0	0	0	0
Areawide Areal Extent of Metering	X	X	--	--	--	--	--	--
Corridor Specific	--	--	--	X	X	X	X	X
Central City Only	--	--	--	--	--	--	--	--
Extends to Suburbs	--	--	X	--	X	--	X	X
Adjacent Only to Congested Segments	--	--	--	--	--	--	--	--
Upstream of Congested Segments	--	--	--	--	X	--	--	--
Electronic Incident Detection	X	X	X	X	X	X	X	X
Incident Verify/Confirm	X	--	X	X	X	X	X	--
CCTV (citizen band radio)	--	X	X	X	--	--	--	X
Agency-Owned Service Patrols	--	X	--	--	--	--	X	--
HOV Bypass Bus or Bus and Carpool	X	--	X	X	X	--	--	--
Exclusive Mainline HOV Lanes	X	--	--	--	--	--	X	--
Motorist Information								
Changeable Message Signs	X	X	X	X	X	X	X	X
Highway Advisory Radio	--	X	X	--	X	--	--	--

Traffic Management Element	Category B Central Control Only			Category C Ramp Metering Local Control					
	San Diego, California	Denver, Colorado	Phoenix, Arizona	Houston, Texas	Fort Worth, Texas	San Antonio, Texas	San Francisco, California	Sacramento, California	Portland, Oregon
Surveillance and Control System	--	--	--	--	--	--	--	--	--
Central Computer Control	X	X	X	--	--	--	--	--	--
Control System Cost (millions)[a]	--	--	0.8	0.58	0.3	0.13	--	--	--
Miles of Controlled Highways	36[b]	--	9.8	19	5	4.1	35[b]	5[b]	11
Metered Freeway Entrance Ramps	50	10	16	40	12	8	41	9	16
Metered Freeway to Freeway Ramps	4	0	0	0	0	1	2	0	0
Areawide Areal Extent of Metering	--	--	--	--	--	--	--	--	--
Corridor Specific	X	--	--	--	--	--	--	--	--
Central City Only	--	X	X	--	--	--	--	--	--
Extends to Suburbs	X	--	--	--	--	--	--	--	--
Adjacent Only to Congested Segments	--	--	--	X	--	X	--	--	--
Upstream of Congested Segments	--	--	--	--	--	--	--	--	--
Electronic Incident Detection	--	--	--	--	--	--	--	--	--
Incident Verify/Confirm	--	--	--	--	--	--	--	--	--
CCTV (citizen band radio)	--	--	--	--	--	--	--	--	--
Agency-Owned Service Patrols	--	--	--	--	X	X	--	--	--
HOV Bypass Bus or Bus and Carpool	X	X	--	X	--	--	X	X	X
Exclusive Mainline HOV Lanes	--	--	--	--	--	--	X	--	--
Motorist Information									
Changeable Message Signs	X	--	--	--	X	X	--	--	--
Highway Advisory Radio	--	--	--	--	--	--	--	--	--

[a]Data from Transportation Research Board, Informational Report No. 15, October 1982, prepared by the Freeway Operations Committee.

[b]California Department of Transportation, Project Status Reports, January 1985.

[c]As of 1984, 68 metered freeway entrance ramps had been committed but not implemented in the IMIS system.

Source: Wisconsin Department of Transportation.

the most extensive and completely developed freeway systems, totaling approximately 475 miles within the metropolitan area, has one of the most extensive traffic management systems in place and operation. Because of the traffic demands placed on the system, and the public dependence on the automobile, many traffic management elements have been applied in the Los Angeles area both on a systematic and on an isolated basis to improve the operating efficiency of the freeway system and the mobility of the traveling public. While many traffic management techniques were already in operation, major traffic management efforts began in 1970 with the development of the freeway surveillance and control project on the 42-mile loop. The project included a continuous system of mainline freeway detection for surveillance and operational purposes, numerous additional ramp-metering signals, changeable message signs, and HOV priority treatments. The project objectives were directed to the management of the recurring peak-period congestion problems, as well as the management of incidents occurring regularly throughout the system.

There were approximately 1,260 freeway entrance ramps in the metropolitan area in 1984, with an additional 200 freeway-to-freeway ramp connections. Approximately 525 directional miles of freeway were controlled by 610 entrance ramp meters, generally utilizing 170 type microprocessor-based local controllers. The ramp-metering signals in Los Angeles were installed to operate in a local control mode, and many were initially operated as simple, pre-timed metering with a program of metering rates based upon historical traffic patterns on the ramp as well as the freeway main line. Approximately half of the ramp meters continued to operate in a pre-timed mode in 1984, while the remaining half operated in a traffic-responsive mode based upon local detection. A program was well underway to automate the entire Los Angeles metropolitan system, with the local microprocessor ramp-metering controllers reporting to mini-computers at a central location. It was anticipated that 160 existing ramp meters and 20 new locations would be tied into the central system during 1985. The ramp-metering control utilized ramp detection, including queue, demand, and passage detectors in the vicinity of the ramp entrance. Because of the wide variety of traffic demands on the entry ramps, as well as the freeway main lines, the system included a wide variety of single-lane and multiple-lane metering, as well as single- and multiple-vehicle release.

The California Department of Transportation (Caltrans) was one of the pioneers in providing preferential treatment for high-occupancy vehicles, and has included preferential treatment for buses and carpools within its control scheme since the early stages of its development. In 1984, 194 of the 610 metered entrance ramps provided HOV bypass lanes for buses and for carpools with two or more persons. In addition, 10 exclusive HOV freeway entrance ramps were provided, nine of which were for buses only. The exclusive entry ramp permitting carpools as well as buses required a carpool occupancy of three or more persons. There were 11 miles of dedicated freeway or HOV lanes provided on the San Bernadino Freeway (LA-10) in 1984, of which seven miles were contiguous lanes adjacent to the normal freeway lanes, and four miles were separate bus and carpool roadways outside the freeway right-of-way. Originally known as the San Bernadino Busway, the exclusive lanes were opened to carpools of three or more for their entire length in June 1977 with outstanding success. Originally, the busway usage was confined to peak periods only, but in September 1979 the busway was opened for use by carpools 24 hours per day.

In 1984, motorist information in the Los Angeles area was provided by a system of 48 changeable message signs located on the freeway and controlled through the central traffic management center. Thirty of the signs used light bulb matrix technology, while the remaining 18 were disc matrix changeable message signs. Plans were underway to increase the number of changeable message signs to a total of 80 to 100. The signs were used for motorist advisory information regarding unusual conditions and congestion ahead, as well as route diversion messages. In addition, information was provided from the traffic management center to a number of commercial radio broadcast stations. The information was provided by the Traffic Management Center via teletype to the radio stations, the Southern California Auto Club, and the California Highway Patrol every half hour during peak periods, and immediately when unusual traffic conditions such as incidents occurred. Under the agreement with the local broadcast stations, the California Department of

Transportation provided the necessary hardware for the transmission of information, provided the radio station agreed to broadcast the information within five minutes of receiving it.

Incident management is a high priority of the Los Angeles Traffic Management System, and in 1984, the system incorporated a number of features directed to the detection, verification, and early removal of incidents. The original 42-mile loop, which provided continuous detection capability for incident detection, had been expanded to include an additional 280 directional miles away from the loop, for a total of 365 directional miles of the 475-mile system under continuous surveillance detection. The continuous surveillance instrumentation was supplemented with 12 closed circuit television cameras located on the Santa Monica Freeway and additional cameras at three isolated locations. The primary function of the CCTV was to verify incidents detected by means of the surveillance loops placed at about half-mile intervals as part of the original 42-mile loop project. Further incident detection capability was provided by means of a continuous call box system located along the right-hand shoulder of all freeways in Los Angeles County. The call boxes were spaced at approximately one-quarter-mile intervals. Since the California Highway Patrol was totally responsible for incident management at the scene, all calls received from the call box system went directly to the Highway Patrol office, and the Highway Patrol was notified by the Traffic Management Center when freeway incidents were detected by means of the electronic detection system.

While the California Highway Patrol had full responsibility for incident management, the responsibility for traffic management at the scene of an incident was shared jointly by the California Highway Patrol and the California Department of Transportation. Unique to the Los Angeles area in 1984 was the use of incident response teams. These teams are mobilized in the event of a major incident requiring traffic management at the scene. Traffic management is considered warranted if two freeway lanes will be closed for two hours or more. Incident management teams are made up of numerous traffic engineers and technicians with other daily responsibilities. When a traffic management effort is required, these individuals are dispatched to the scene, often from their offices or homes. These individuals are all equipped with their own traffic control devices, including advance signing and detour markings. Alternate route detour plans have been developed for every segment of the Los Angeles freeway system should a freeway closure and detour be required. As of 1984, the incident response teams had available 10 changeable message sign trucks, four command vehicles, and five signing vehicles. In addition to managing traffic at the locations of major freeway incidents, these response teams have been invaluable in the handling of traffic for special events such as the Super Bowl and Rose Bowl, and are proving to be very cost- effective.

The freeway operational control strategy generally employed in the Los Angeles area is to minimize the duration and severity of congestion, although the total elimination of congestion is frequently not possible to attain, even where geometric capacity improvements have been made. Regarding metering strategy and the metering rate selection, approximately half the controllers operated in a pre-timed mode in 1984, based upon historical traffic patterns. The remaining half of the ramp controllers automatically selected metering rates responsive to local mainline conditions based upon critical volume and lane occupancy measurements in the vicinity of the metered entrance ramp. In 1984, the central control system was capable of monitoring only about half the metered locations. The status of the freeway, as determined from the information from the continuous surveillance detectors and that provided by those local controllers connected to the Traffic Management Center, was displayed on a system map within the control center for use by the operators in evaluating performance and identifying incidents. Control software was prepared by a consultant; however, operational revisions and maintenance were performed by in-house staff. The control center was located in an area of approximately 720 square feet. There was no interconnection or coordinated operation of the freeway control system with the surface arterial system, although periodic reviews of travel time and speed were made on the parallel facilities. The measures of effectiveness routinely gathered in evaluating system performance included the freeway vehicular flow, person volume flow, freeway travel times, freeway operating speeds, accidents, ramp meter delay, ramp meter queue lengths, and ramp meter violation rates.

Chicago, Illinois: One of the earliest and most comprehensive freeway traffic management systems was developed in Chicago under the direction of the Illinois Department of Transportation. In the very early stages of the management and operation of the freeway system, the Department placed a high priority on the problem of incident detection and removal. This effort began in 1958 with the acquisition of a fleet of vehicles for the purpose of locating and removing stranded motorists and incidents along the freeway system. The effort to improve traffic flow on the urban freeway system by means of automatic surveillance and control techniques began in 1961 with the creation of the Chicago Area Expressway Surveillance Project. The project began as a research-oriented and funded program, utilizing highway planning and research (HPR) funds in the initial effort, and has evolved into a totally operational program extending surveillance and control over 110 miles of the Chicago area freeway system. The general approach has been electronic surveillance consisting of vehicle detection at approximately half-mile intervals on the freeway main line and all entrance, exit, and freeway-to-freeway ramps for data gathering and evaluation purposes, and the incorporation of controls, including ramp control and highway advisory elements, as warranted.

As of 1984, there were approximately 280 freeway entrance ramps located within the limits of the control system, and approximately 11 freeway-to-freeway interchanges. Seventy of the freeway entrance ramps were under what is considered an areawide application of ramp control. The ramp meters were under the total control of the central computer control, with the appropriate meter rate determined at the central location. A typical meter installation included queue, demand, and passage detectors for the operation of the metering signal, and mainline detection at one-half-mile intervals for the determination of local metering rates, as well as rates selected on a system basis. There were no special accommodations for buses or carpools on the Chicago area freeway system as of 1984. Rail rapid transit, located in the median areas of three major freeways, is intended to serve the demand for public transit, and reduces the need for HOV facilities.

Motorist information elements also receive a high priority in the Chicago system. In 1984 there were two highway advisory radio systems in operation, with three additional systems under construction. One changeable message sign using a disc matrix type of technology was in place, and was used to provide information to the motorist on travel and trip conditions, unusual congestion, and route diversion. The highway advisory radio applications were site-specific, with consideration for system application in the future. Highway advisory radio was used to provide information on travel conditions, route diversion, and lane closures due to maintenance and construction work. The motorist information element also included the provision of computerized traffic reports from the central surveillance computer to commercial radio stations requesting and providing for the necessary hardware hookup. In 1984, six media users received the traffic reports on a regular basis. The traffic reports available from the central computer were updated every five minutes, and it was estimated that the commercial broadcasts reached 75 percent of the listening public.

The freeway incident management element of the system utilized the continuous electronic surveillance capability of the freeway detectors. The detectors were used to identify incidents, as well as to provide data necessary to support the elements of ramp-metering control and motorist information. Operator evaluation of all surveillance inputs was used in determining the occurrence of a detected incident. Citizen band radio transmissions were monitored to confirm the occurrence and nature of incidents. Several CB radio base stations were located in the field at strategic locations and were dialed up from the control center when the electronic detection system or other source, such as a citizen or enforcement report, indicated the occurrence of an incident. Appropriate enforcement, fire, and rescue agencies were notified and dispatched through the control center. A significant incident management activity operated by the Illinois Department of Highways is its fleet of expressway patrol vehicles, which in 1984 provided regular service patrols over 79 miles of the urban freeway system for the purpose of servicing disabled vehicles, as well as assisting in the removal of damaged vehicles and spilled loads. The fleet consisted of 38 patrol trucks with towing capability and four heavy-duty wreckers.

The service patrol operated on a 24-hour-a-day, seven-day-a-week basis.

The major objective of the control strategy employed is to minimize the duration and severity of congestion. In 1984, the metering strategy involved the selection of metering rates based upon local traffic conditions, upon freeway corridor traffic conditions, and upon consideration of the freeway system beyond the immediate corridor. The capability existed to provide pre-timed control on the basis of historical traffic patterns as a backup operation in the relatively rare event of computer control interruption. At the time of the questionnaire, the Traffic Management Center had been recently relocated to a new facility, providing the opportunity for the Department of Transportation to replace the control equipment and upgrade some procedures to state-of-the-art standards. In 1984, the system used color graphic cathode ray tube (CRT) displays for both system and local area condition displays, and various black and white CRT's with data displays for information evaluation. The control facility was located in a new building specifically constructed for the control center. The 16,000-square-foot building was constructed in 1981 and 1982 at a cost of $2.1 million . The control software was developed primarily by project staff, with the staff also preparing any program revisions on an operational basis. In 1984, the daily system evaluation included the gathering of information regarding freeway volume flow and freeway travel times, freeway operating speeds, and a measure of system performance and condition developed in Chicago and termed Minute Miles of Congestion, where congestion is measured in terms of critical occupancy extending over time and length on a freeway segment. In addition, special studies were undertaken to evaluate freeway vehicular volume flow, travel times, operating speeds, and accidents, as well as ramp-meter queue lengths and violation rates.

Minneapolis-St. Paul: Formal freeway traffic management activity began in the Twin Cities area in 1970 with the installation by the State Department of Transportation of six ramp meters on IH 35E in the St. Paul area that operate in an independent local control mode. The Department's activity was greatly expanded both in area and in scope in 1974, when the major traffic management system on IH 35W became operational and provided continuous vehicle detection and closed circuit television surveillance capability, central control, ramp metering, and HOV priority treatments. The Department's activity has continued to expand in scope of activity, as well as geographic area. The system is described as a comprehensive traffic surveillance and control system, and in 1984 included a total of 35 freeway miles extending into suburban areas within the control system. Within the area included in the traffic management service area, there were 55 freeway entrance ramps, of which 43 were metered. In addition, there were 16 freeway-to-freeway ramps within the control limits, of which 12 were metered on a daily basis. Nineteen of the 65 metered ramps were located in the central cities of Minneapolis and St. Paul, and the remainder were located in suburban areas. The Minnesota Department of Transportation has had unique success in metering freeway-to-freeway entrance ramps. Nationally, there were approximately 19 situations in which freeway-to-freeway connecting ramps were metered in 1984; 12 of these were located in the Twin Cities area. Of the 65 metered ramps, 38 in the IH 35W project were under the direct control of the central location. Nineteen of the ramp meters operated with 170 type microprocessor-based local controllers that were under the complete direction of the central controller, but able to operate independently upon loss of communication with the central controller. Eight ramp meters operated in a totally independent local control mode, utilizing fixed-time metering programs. The Department intended to convert the 38 ramp meters under full control of the central controller to a local control condition. The meters were operated with a simple demand detector calling for the green light. Preferential HOV treatments were provided at numerous locations at metered ramps. There were 12 exclusive HOV entry ramps where the meter could be bypassed by appropriate vehicles, of which five were for buses only and seven were also for carpools with two or more persons. In addition, at two locations, HOV bypass lanes were provided on a metered ramp, which were for use by buses only.

Motorist information was provided by means of light bulb matrix, disc matrix, and fiber optic-type changeable message signs. The Department also had in place changeable message signs utilizing rotating drums to provide the appropriate message selection The changeable message signs were used to provide daily travel condition information, as well as information on unusual conditions, congestion, and route diversion. Highway advisory radio was used to provide information regarding congestion and unusual conditions, and route diversion to vehicles in a particular 6,000-foot zone. Regular traffic reports were provided to commercial radio stations each 20 minutes during the peak period, and special reports were issued as necessary. The information was provided via a multi-drop communication link using the commercial telephone system; thus, only one call was necessary to contact all of the radio stations transmitting the information.

Incident detection capability is a feature of the surveillance system, with freeway detectors being installed continuously at half-mile intervals. The detection system was installed primarily for the purpose of ramp control; however, incident detection and management were major considerations. Thirty-one closed circuit television cameras were used for the purpose of incident verification and operational evaluations. The use of the CCTV was perceived by the Department of Transportation as being extremely beneficial, and thus expansion of the system to provide continuous coverage has been envisioned; as of 1984, however, the Department was limited by the capacity of the central control hardware. The State Patrol was directly responsible for managing the incident scene, and direct communication from the traffic management center to the patrol dispatcher was provided.

Regarding the system operation and operational control strategy, the primary objectives are to minimize the duration and severity of congestion and to maximize the volume flow on the freeway. The operational objective is to maintain a minimum operating speed of 40 mph. One of the original objectives of the IH 35W project was to establish desirable operating speeds and priority HOV treatment to encourage greater use of bus transit on the freeway system. The metering strategy employed selected metering rates based upon the freeway corridor traffic conditions, with the exception of the eight locally controlled ramps which operated in a local-responsive mode. A unique metering selection strategy is employed in the Minneapolis project in that several metering programs have been established reflecting normal conditions, as well as rain or snow conditions. While no public resistance to the extension of ramp metering to new areas has been encountered, system expansion has been affected by funding problems.

In 1984, the system control and monitoring were provided by means of a central computer processor and color graphic displays utilizing CRT hardware. The freeway instrumentation included detectors typically at half-mile spacing in all lanes in which entrance, exit, and freeway-to-freeway ramps were counted. The metering control algorithm was based upon the traffic volume flow rates downstream at critical bottleneck locations, traffic volume entering the segment, and local lane occupancy measurements. The initial software development and subsequent revisions to the software have been done by in-house staff. The Traffic Management Center is located in a specially constructed facility built in 1972 that contains 10,000 square feet of floor space on two floors.

In 1984 this system was evaluated on a weekly basis, consisting of a review of actual conditions in the field to update the system operations. Summary reports are prepared on an annual basis. Traffic conditions measured on a regular basis in 1984 included freeway vehicular flows, operating speeds, accidents, ramp-meter delay, and ramp-meter queue length. Also, special studies were conducted of person volume flow, of travel times and modal shift occurrences, and of ramp-meter violation rates.

Seattle, Washington: The Seattle Traffic Management System, which is located primarily on IH 5, was initiated by the Washington State Highway Department and placed in operation in 1981. The system was originally designated the "FLOW System," and was intended to provide a unified traffic management approach utilizing ramp control, HOV priority treatments, continuous surveillance capability by means of electronic vehicle detection and CCTV, and incident detection and management features. In 1984, the traffic management and freeway instrumentation was being expanded and coordinated in conjunction with the freeway reconstruction effort and provision of HOV priority treatments and lanes. The system contained a total of 18 "corridor specific" metered ramps, extending into suburbs, and located upstream of congested freeway segments. The ramps were operated with 170 local type microprocessor-based controllers that were under the full control of a central computer and able to operate independently with the loss of communication or control from the central computer. A typical ramp-meter installation contained queue, demand, and passage detectors, and mainline detectors which were utilized for system as well as local determination of metering rates.

The traffic management system included a variety of high-occupancy-vehicle priority treatments. HOV bypass lanes on metered ramps were provided at 10 locations for use by buses and for carpools with at least three persons. In addition, two exclusive HOV entrance ramps were provided, one for buses only to bypass a ramp meter, and the one for buses and for carpools with two or more persons. Dedicated freeway lanes were provided for buses only on three different freeway segments, ranging in length from three to six miles for a total of 11 miles. The exclusive lanes were developed as part of the reconstruction projects and were constructed using the median shoulder.

The motorist information elements of the project included changeable message signs and highway advisory radio. Two light bulb matrix signs were in place in 1984, and six additional disc matrix type signs were to be added in 1985. Highway advisory radio was used to provide information to the motorist about unusual congestion and route diversion, and to inform the motorist about construction traffic control. Five highway advisory radio signs had been installed, primarily as a part of a freeway reconstruction project on IH 90.

Continuous electronic detection was provided within the limits of the original "FLOW" project, located at approximately one-half-mile intervals in all lanes. The system was installed primarily to provide ramp-metering system control, but was also used in the detection of incidents. A total of 17 closed circuit television cameras had been installed and were used primarily for incident confirmation, as well as system performance evaluation. The occurrence of incidents was also confirmed by means of dispatched patrol vehicles.

The control objective of the freeway operational control system is to minimize the duration and severity of congestion and to maximize the volume flow on the freeway. The selection of metering rates is based upon local traffic conditions adjacent to the freeway ramp, as well as freeway corridor conditions. No public resistance to the extension of the metering system has been encountered, and in 1984 future projects were being planned in conjunction with the freeway upgrading and the HOV program.

System control is provided by means of a central computer. System status is displayed using color-graphic CRT's. The freeway mainline detector spacing is generally at half-mile intervals, and at interchanges at which all entrance and exit ramps and freeway-to-freeway connecting ramps are counted. The system software was developed by a consultant and upgraded by in-house staff. Operational and maintenance revisions to the software are performed by in-house staff. The freeway control program is not directly integrated or connected with the parallel or intersecting arterial street systems. The control center facility is located in existing agency space that was expanded to accommodate the center. The measures of traffic performance that were routinely evaluated in 1984 included freeway vehicular flow, freeway travel times that were inferred based upon average vehicle length and occupancy times, freeway operating speeds, and ramp-meter violation rates. Also, special studies were conducted of vehicle occupancy, freeway accidents, modal shifts, fuel consumption, air pollution, ramp-meter delay, ramp-meter queue lengths, and HOV violation rates. Also, an annual report summarizing the measures of effectiveness was prepared.

<u>Toronto, Canada</u>: The Ministry of Transportation and Communications, Ontario, Canada, has several projects in various stages of planning and operation. The project reported on herein is the Queen Elizabeth Way (QEW) Mississauga Freeway traffic management system, which is an operational project containing ramp-metering elements as well as surveillance and control features. Project operation began in the late 1970's, primarily as a demonstration project. This project is corridor-specific, and is located near Toronto in the community of Mississauga. In 1984, there were 10 entrance ramps on the system, all of which were metered. The ramp meters were operated with local controllers that were under the full control of the central master computer. In the event of the loss of control or communication from the central computer, the local controller could continue to operate independently. The ramp meter operated with queue detectors at the ramp entrance, with demand and passage detectors at the signal. Mainline

detectors adjacent to the freeway entrance ramps were available for local determination of metering rates. Motorist information was provided by means of two changeable disc matrix message signs. The signs provided information to the motorist regarding unusual conditions or freeway congestion. A limited amount of route diversion information was also provided. Incident detection capability was provided by means of detectors on the freeway main line at approximately one-half-mile intervals. The detection system was installed primarily to provide continuous surveillance for use in conjunction with ramp-metering system control, and for incident detection. Incident verification was by means of continuous CCTV and citizen band radio, which was monitored by the police only. Incident response was provided by the law enforcement agency, which in this case was the Ontario Provincial Police. The control objectives are to minimize the duration and severity of congestion, and to maximize the volume flow on the freeway, as well as to maintain a minimum operating speed of 60 kilometers per hour (37 mph). Metering rates are changed based upon freeway corridor traffic conditions—in particular, volume and lane occupancy, measured locally.

In 1984, system control was provided by means of a central computer, with system status and operation data displayed using color graphics and a CRT terminal. Freeway detectors were located in all freeway lanes at approximately one-half-mile intervals, and all freeway entrance and exit ramps were counted. The metering control algorithm was based upon traffic flow and lane occupancies. The software was developed in-house by staff, and operational revisions to the software package were made by the staff. The freeway control system was not integrated with parallel or exiting arterial street signal systems. The control center was housed in a trailer because of the demonstration nature of the project, and system evaluations were performed on a limited basis because of the shortage of staff. Traffic measurements were routinely taken of vehicular volume flow and freeway accidents. Also, special studies were conducted of ramp meter delay, queue lengths, and meter violation rates.

Systems in Category 1 that Were Not Operational in 1984: The following two projects were not fully operational in 1984, but represent comprehensive freeway traffic management projects incorporating a fully instrumented electronic surveillance system in addition to a variety of traffic management elements.

Arlington and Fairfax Counties, Virginia (IH 66/IH 395): This project, undertaken by the Virginia Department of Highways and Transportation, provides state-of-the-art traffic management systems on 11.5 miles of IH 395 (Shirley Highway) and 10 miles of IH 66. Operationally, IH 66, which operates as an exclusive HOV facility in the peak direction during the peak hour, is unique. The traffic management systems are composed of traffic surveillance and control systems and include variable message signing.

The project is corridor-specific, extending into suburban Washington D. C., with ramp meters at 25 of the 42 freeway entrance ramps within the corridor. In 1984, the ramp-meter control hardware included local controllers under the supervision of, and driven by, the central computer control, with metering rates selected at the central control. In the event of loss of the central computer or communications, the local controllers could operate in an independent, pretimed mode, with the ability to turn on and off at specified times. The local controllers preprocessed the field detector information and furnished processed data to the central computer. The ramp meters operated with queue demand and passage detectors, with mainline detectors available for the local determination of metering rates. Since IH 66 operated as an exclusive HOV facility during peak hours in the peak direction of flow, each entrance ramp functioned as a HOV priority entrance with no need for additional preferential provisions. Carpools carrying three or more persons could also use the facility and the entrance ramps during the peak periods. IH 395 (Shirley Highway) had a reversible roadway in the center median for the exclusive use of buses and carpools carrying four or more passengers.

A total of 70 disc matrix changeable message signs were used to provide systemwide and site-specific information. The signs provided information on travel and trip conditions, and on unusual congestion.

In 1984, freeway incident management was provided by freeway detectors located at half-mile intervals on all lanes of the freeway. The detection was provided primarily to provide information for the ramp-metering control system, as well as for incident detection purposes.

Response to incidents was provided by law enforcement agency patrols, as well as by a continuous patrol operated by the Virginia Department of Highways and Transportation. The freeway patrol consisted of a fleet of four vehicles, two of which patrol continuously, with service provided seven days a week, 24 hours a day.

The objective of the system operation is to maximize the volume flow on the freeway. Ramp-meter installation was based upon the volume-to-capacity within a segment of freeway, and the practicality and need for metering at a specific location. Metering rates were selected based upon freeway corridor conditions, and the metering rates were changed based upon lane occupancy measured both locally and on a system basis. The ramp-metering system is designed for expansion, and will be expanded when funds become available. The City of Alexandria, Virginia, did bring suit against the Virginia Department of Highways and Transportation to prohibit the ramp metering on the basis that the metering would cause large volumes of traffic to be diverted to the local street system. The suit was decided, with the local court finding in favor of the Department of Highways and Transportation.

Freeway traffic is monitored by a central computer, with the system status displayed by fixed map displays, as well as color-graphic CRT's. The freeway is instrumented with mainline detectors in all lanes at half-mile intervals, with each of the entrance and exit ramps counted. A total of 25 CCTV cameras had been installed on IH 395 as of 1984, providing continuous visual coverage of that facility. In addition, 10 cameras were provided on IH 66 in the vicinity of the metered ramps, and nine additional television cameras were to be provided on IH 66 in the near future. A monitor for each of the cameras located in the field was provided in the control center. The cameras were used for incident verification as well as operational and performance analysis. The project specifications, including the operating software, were developed by a consultant. Operational revisions and maintenance will be performed by the consultant until the capability is acquired by in-house staff. As of 1984, the freeway control system was not integrated with the parallel or intersecting arterial street system.

A new control facility has been constructed for the traffic management center, providing 6,500 square feet of floor space on two floors, which may be expanded to three. A quarter of the facility is used by the State Patrol as a headquarters for communications and dispatching purposes.

When the system becomes fully operational, the Department is prepared to monitor and evaluate freeway performance on a regular basis. At such time, traffic measurements will be routinely taken of freeway vehicular flow, freeway travel times, freeway operating speeds, freeway accidents, ramp-meter delay, and ramp-meter queue lengths. Special studies will be conducted of person volume flows, modal shifts, fuel consumption, air pollutants, and ramp-meter violation rates.

Integrated Motorists Information System (IMIS), Long Island, New York: This project was initiated by the New York State Department of Transportation and located on IH 94 (Long Island Expressway), and includes parallel freeway and surface arterials. The project is a traffic surveillance and control system in a corridor approximately 35 miles in length, and includes approximately 93 miles of limited access facilities. This project represents a comprehensive traffic management effort being applied to an entire urban corridor area, and includes state-of-the-art application of hardware as well as traffic management techniques. A unique objective of the project, in addition to the surveillance and control of the freeway facility, is to divert traffic from the freeway to other arterials—both freeway and surface streets—located in the corridor to take advantage of available unused capacity, as necessary. The project was about 70 percent complete in 1984, and was anticipated to be placed in operation near the end of 1985 or in early 1986.

One traffic management element of the project is an extensive ramp-metering program. There were 175 freeway entrance ramps within the control limits in 1984, and four freeway-to-freeway ramps entering the system. It is intended that ramp meters be placed in operation on 68 of the entrance ramps, 34 in the inbound direction and 34 in the outbound direction. There were no plans to meter freeway-to-freeway ramp connections. The ramp metering is defined as corridor-specific and extends into the suburban area. The ramp control system will utilize local controllers of limited ability, with the central master control being provided by the central computer, including the determination of ramp-metering rates. The local controllers will pre-process the data from the detectors in the field and transmit processed information to the central computer. In the event of loss of communication or control by the central control, the local controller will be able to operate in a simple pre-timed mode. The ramp-meter operation will be actuated by means of queue, demand, and passage detectors at the ramp-metering signal.

Extensive motorist information advisory elements are included within the traffic management system. A total of 74 disc matrix changeable message signs will be provided, to be used in a system application basis. The purpose of the changeable message signs will be to provide the motorists with information regarding unusual conditions and congestion on the freeway, and route diversion. In addition, video terminal and telephone "hotline" communication links will be provided to a commercial traffic information network called "SHADOW TRAFFIC" which, in turn, will disseminate the information to approximately 50 local radio stations for broadcast.

As part of the freeway incident management effort, continuous instrumented electronic surveillance will be provided on the freeway system, with freeway detectors located in all lanes at half-mile intervals. In addition, all freeway entrance and exit ramps, as well as freeway-to-freeway connectors, will be counted as part of the surveillance system. The detection system will serve primarily to obtain information for incident detection purposes. However, the system will also perform ramp-metering and system control functions. Incidents will be confirmed by existing law enforcement agency patrols; also, 22 CB radio base stations will located throughout the controlled corridor that may be dialed up and monitored when the electronic detection system signals the occurrence of an incident. In addition, the Department of Transportation will be developing contracts for local towing and wrecking services that will require 20 minutes response time. Police and fire departments will continue to dispatch ambulances as necessary.

The objective of the freeway operational control system operation will be to minimize the duration and severity of congestion, maximize the volume flow on the freeway, and eliminate freeway congestion. Metering rates will be selected based upon corridor traffic conditions.

Central computer control will be used to monitor freeway traffic conditions, with three central computer processors to be provided, two of which will be used for running the system and one of which will serve as a backup. The system status and operational information will be displayed on a fixed map as well as color-graphic CRT's. The software was being developed by a consultant; operational maintenance and revisions of the software were to be performed by in-house staff. Because of the unique objective of this project—that is, to divert traffic from one parallel freeway facility to another, or to the arterial street system—the freeway operational control system was to be integrated with the parallel and intersecting street systems. On the arterial streets that may be used as alternate routes, the signal system was to be under the control of the central computer. The control center was to be located in a renovated building with approximately 4,000 square feet of space.

Overall system evaluation is to be performed by the U. S. Department of Transportation, Federal Highway Administration. A consultant and the State will review system performance and modify operating procedures on a continuing basis, as necessary. The traffic data that will be collected and processed on a routine basis include freeway vehicular volume flow, freeway operating speeds, freeway accidents, and ramp-meter queue lengths. In addition, special studies will be conducted of person volume flows, freeway travel times, freeway accidents, mobile shifts, fuel consumption, air pollution, ramp-meter delays, and ramp-meter violations rates.

<u>Systems with Central Computer Control of Ramp Metering Without Continuous Electronic Vehicle and Freeway Surveillance Capability</u>

<u>San Diego, California</u>: This project, under the direction of the California Department of Transportation, is located in San Diego County and is described primarily as a ramp-metering system. As of 1984, 36 directional miles of freeway were controlled with freeway entrance ramps. The system was corridor-specific, extending into the suburbs, and generally provided control upstream of congested freeway segments. There were 68 freeway entrance ramps within the control system limits, of which 50 were controlled with ramp-meter signals. In addition, there were 10 freeway-to-freeway ramp connections enter-

ing the controlled segments of freeway, with four of these are controlled with ramp-metering signals. The metered ramps were controlled by means of 170 type microprocessor-based local controllers under the supervision of the central master computer, which had the capability to override the local controller, as necessary. The local controllers gathered traffic data from detectors located on the freeway and furnished the central control system with pre-processed information via communication links. The ramp meter operated in a traffic-responsive mode by utilizing demand and passage detectors located at the meter, and mainline detectors in the vicinity of the entrance ramp used for collecting traffic data and determining metering rates. As in other California applications, the provision of preferential treatment for buses and carpools received a high priority. A total of 15 metered entrance ramps had HOV bypass lanes for buses and for carpools with two persons.

The motorist information gathered by the central computer processor was provided to commercial radio broadcast stations by telephone. The California Department of Transportation was in the process of adding hardware for dedicated telephone circuits from the commercial radio stations directly to the central processor for the provision of real time traffic information. Because the system lacked a continuous electronic surveillance system, there was no automatic incident detection capability within the central computer control.

The objective of this freeway operational control system is to minimize the duration and severity of congestion, and to maximize the volume flow on the freeway. Another objective is the maintenance of a minimum operating speed of 50 mph. Ramp meters had been installed where freeway volume flow ranges were in excess of 2,000 vehicles per lane per hour. Metering rates were selected based upon freeway corridor traffic conditions, and upon lane occupancy measurements that were acquired locally at metered entrance ramps. The metering installations were not being extended to those areas where the installation criterion was not satisfied, and where the incremental cost was in excess of the incremental benefits. As in the Minneapolis-St. Paul area, there was a significant amount of freeway-to-freeway ramp metering in the San Diego area. Four freeway-to-freeway ramps were metered in 1984. Central control and monitoring of the system were provided by means of a central computer gathering data transmitted from the local controllers in the field, and system operating and traffic conditions were displayed on CRT's. The vehicle detection on the freeway was not of a continuous nature, but was located on the freeway main line at each metered interchange. In addition to the mainline traffic, each of the entrance ramps was counted, and the exit ramps within the metered interchange were also generally counted, along with those freeway-to-freeway ramps in the immediate vicinity of the control segment. The control system software was developed by the California Department of Transportation staff, as were the maintenance and operational revisions of the software. There was limited integration of the freeway control system with the parallel or intersecting street system, with such integration occurring at three locations, where intersection signal timing was adjusted during peak periods to store part of the queue at the ramp meter on the intersection approach to the ramp.

The central control facility occupied approximately 600 square feet of space. The system was monitored during each peak period for overall system performance, as well as operation of the field equipment to identify any equipment failures. The data collected on a routine basis included freeway vehicular flow and freeway operating speeds. In addition, special studies were conducted of person volume flow, as well as freeway travel times and freeway accidents. Also, special studies were conducted annually of ramp-meter delays, ramp-meter queue lengths, and ramp-meter violation rates. Frequent operational surveillance was performed in the field to determine if any ramp-meter operations were significantly interfering with surface street functions, so that adjustments could be made. Regarding the system evaluations, it was felt that the "before" and "after" evaluations were not too meaningful because of the 5 to 10 percent annual traffic volume growth that is occurring in the area. System performance evaluation was based largely on the ability to keep the freeway free-flowing in the face of ever-increasing traffic demands.

Denver, Colorado: This project, initiated by the Colorado Department of Highways, had recently become operational when the previously mentioned questionnaire was distributed—in 1984—and is described primarily as a ramp-metering system. At that time, the project was located in the central city only, with control upstream of congested freeway segments based upon detectors located only in the vicinity of the controlled entrance ramps. The system was planned for expansion in 1985, extending control to five ramps located in the adjacent suburban area. The ramp meters were controlled by means of 170 type microprocessor-based controllers that may be overridden by the central computer processor. The ramp-meter operation was controlled by means of queue, demand, and passage detectors located at the ramp signal. Each of the controlled ramps had been widened to provide two-lane metering operation in consideration of ramp storage requirements and volume demand accommodation. In addition to the two-lane metering operation, HOV bypass lanes had been provided for buses and carpools at four of the controlled entrance ramps, with a fifth to be added in the near future. This freeway traffic management system had no motorist information advisory elements or freeway incident management elements.

The objective of this freeway operational control system is to minimize the duration and severity of congestion, and to maximize the volume flow on the freeway. In 1984, the metering rates were selected by the local controller in response to traffic conditions in the immediate vicinity of the controlled ramp; however, the rates could be overridden by the central computer. The rate changes were based upon lane occupancy measured both locally and on a systemwide basis. The Department had encountered no public resistance to the expansion of the metering system, and in 1984 was programming funding to expand the system at the rate of approximately five meters per year.

System status and traffic conditions were displayed on color-graphic CRT's, with additional CRT's for data display. Freeway operation detection was provided only on the freeway lanes adjacent to the metered ramps, and spacing on the main line varied from approximately 800 feet to one mile. Ramp volume detection was provided only on the controlled entry ramps. The software used in the control system was developed by a consultant, with operational revisions and maintenance of the software performed by in-house staff. There was no integration of the freeway control system with the parallel or intersecting arterial street system. The control facility occupied approximately 450 square feet of space. The performance of the operation of the system was monitored by periodic field observation by staff, and by responding to calls from the motoring public regarding possible equipment malfunctions.

Phoenix, Arizona: This project was implemented by the Arizona Department of Transportation, Highways Division, in 1979. The project is basically a ramp-metering system located entirely within the central city, with a total of 16 ramps within the controlled segment, all of which are metered. While central computer control was provided at the time of the questionnaire in 1984, the ramps were metered by means of microprocessor-based local controllers that operated in an independent mode, providing pretimed metering rates based upon historical traffic patterns on the ramps and freeway main line. This freeway traffic management system had no motorist information or incident management elements.

The ramp meters were initially installed based upon volume flows in the range of 1,800 vehicles per hour per lane. Future expansion of the metering system was considered to be limited in 1984 because of manpower shortages. The system did have central system control capability; however, there was no system status and operation display, and no exercise of control by the central control center over the local controllers in the field. Software for the system operation was furnished by the contractor, and any operational revisions or maintenance of the software package were performed by contract. The central control center occupied approximately 144 square feet of space.

Systems with Ramp Metering Operating on Independent Local Control Basis with No Central Control or Continuous Freeway Surveillance Capability

State of Texas Flexible Freeway Corridor Management System: The following three projects, all in the State of Texas, are reported herein as individual project activities. However, in 1984, the Texas Department of Highways and Public Transportation was developing a flexible freeway corridor management system specifically for application in three cities: Houston, El Paso, and Corpus Christi. The system would be applied to other cities in Texas also. The system was designed to incorporate freeway and HOV lane surveillance, and to combine components of the freeway traffic control system and components of the surface arterial street traffic control system into an integrated freeway corridor central system. The concept is based on the utilization of one or more stand-alone minicomputer systems for freeway corridor traffic management. The minicomputer hardware and software components were being either developed or purchased by the Texas Department of Highways and Public Transportation. This approach was intended to permit interchangeability of hardware and software within the minicomputer systems installed in Texas, as well as the interfacing of the Department's minicomputer systems with local computerized traffic signal systems, where necessary. The Department reported in 1984, "At present, eight freeway corridor systems are under development through the cooperation of the Department's Houston District Office and Central Office in Austin (Traffic Engineering Section and Division of Automation), the Houston District Office, the Houston Metropolitan Authority, and the City of Houston. The system in the City of Houston will consist of control and surveillance for HOV lanes located within the median area of freeways, freeway surveillance and control, and freeway corridor surface street surveillance and control (including frontage roads). Included in the system will be: 1) HOV lane controls, changeable message signs, and closed circuit TV; 2) freeway ramp meter and gate control, changeable message signs, and closed circuit TV; and 3) freeway corridor street traffic-responsive control. Surveillance and incident management will be provided in addition to control for recurring peak period congestion." Software for the computer system was being developed by the Department's Division of Automation, and the equipment was being purchased and furnished by Department personnel to ensure equipment interchangeability and compatibility. The traffic management activity reported for each of the projects underway in Texas at the time of the questionnaire is indicated below.

Houston, Texas: The traffic management project in effect in Houston in 1984 was initiated by the Texas Department of Highways and Public Transportation in 1975. The project was essentially a ramp control project utilizing local controllers operating in a traffic-responsive mode without the supervision of a central control. Forty entrance ramps adjacent to congested freeway segments were metered. The local controllers were programmed so that they could begin and end metering operation throughout the day, as conditions required; however, meter operation was not permitted by time clock program late at night or on weekends. The meters operated in a responsive mode, with queue detectors and demand detectors on the entrance ramps, along with merge override detectors and mainline detectors immediately adjacent to the entrance ramps. No passage detectors were provided, since a fixed length of green, yellow, and red was given upon the register of a demand at the metering signal. HOV bypass lanes were provided on three metered entrance ramps, and were limited to use by buses. This traffic management system had no motorist information element.

The control objective of this ramp meter operation is to minimize the duration and severity of congestion on the freeway segment in which the ramps are metered. Installation criteria were based upon warrants developed by the Texas Department of Highways and Public Transportation. The metering rates were selected based upon lane occupancy measured in the immediate vicinity of the entrance ramp. Additional meters were being installed as funding and programming permitted, without local objection. Freeway volume flow was the only traffic datum gathered routinely. All other data and analysis were performed as special studies. In conjunction with the objectives of the Texas Highway Department, there was substantial activity underway in the Houston toward the provision of expanded freeway surveillance and control. This work was being accomplished in cooperation with the local transit authority as part of several projects in progress at the time of the questionnaire, including the construction of designated authorized vehicle lanes (more commonly referred to as HOV lanes) for buses, carpools, and vanpools in the medians of several major freeways. The control systems for the HOV lanes and the freeway surveillance and control system were in the process of being installed.

Fort Worth, Texas: The traffic management project in Fort Worth was implemented in 1977, and included ramp metering and changeable message signs. The project was essentially a ramp-metering project on a section of approximately six miles on IH 30. The project was described as corridor-specific, with a total of 25 freeway entrance ramps in the controlled segment, of which 12 were metered. The metering was accomplished with local controllers operating in a traffic-responsive mode. Seven of the ramp meters were interconnected to form two subsystems of three and four ramp meters operating under the supervision of a master local controller to provide some system response to downstream bottleneck conditions. The metering strategy and selection of metering rates were based upon lane occupancy, measured locally for those controllers operating in a local mode. For the interconnected systems, the rates were changed based on freeway corridor conditions at the downstream bottleneck location.

The project included the use of four portable, trailer-mounted, changeable message signs of a light bulb matrix type. The signs were used in site-specific situations to provide motorists with information on unusual congestion and on route diversion. In addition, motorist information was provided by means of local commercial radio traffic reports.

Freeway incident management was provided by means of service patrols in addition to the normal patrols offered by the law enforcement agencies. The service patrol consisted of three vehicles, with two in use at any one time. The courtesy patrol functioned from 4:00 p.m. to 8:00 a.m. on weekdays (in two shifts), with continuous service provided 24 hours a day on weekends and holidays, beginning at 4:00 p.m. Friday through 8:00 a.m. Monday. The courtesy patrol was staffed with 15 people. System evaluation and performance were performed at infrequent intervals by helicopter surveillance and occasional drive-through observation. Data collected on a routine basis included freeway vehicular volume flow and freeway accident data. Also, special studies were conducted of freeway vehicular flows, freeway travel times, fuel consumption, and ramp-metered queue lengths.

San Antonio, Texas: The San Antonio project was implemented in 1977 and is essentially a ramp-metering system at isolated locations. In 1984, eight freeway entrance ramps and one freeway-to-freeway connecting ramp were metered at locations adjacent to congested freeway segments. The meters were controlled with local controllers operating in a traffic-responsive mode. Ramp-meter detection was by means of a demand detector, merge override detector, and mainline detectors in the vicinity of the entrance ramp. Unlike the other Texas projects described, no passage detector was used in this project. Some motorist information was provided by means of three portable changeable message signs that were trailer-mounted and located in the field. Messages were relayed over leased telephone lines using remote teletype units.

Freeway incident management was provided by routine law enforcement agency patrols, maintenance patrols, and a service patrol. The service patrol fleet contained two vehicles and was operated with a staff of 14. The service patrol was provided from 5:00 p.m. to 8:00 a.m. weekdays, and 24 hours a day on weekends and holidays—from 5:00 p.m. Friday until 8:00 a.m. Monday. Towing and wrecking service was provided by city contracts that required one-half-hour response time and a 12-wrecker fleet available during peak hours.

The objective of the freeway control was to minimize the duration and severity of congestion, and maximize the volume flow. Metering rate changes were based upon lane occupancy measured locally and reflecting the conditions in the vicinity of the metered ramp. While no central system control or motoring capability was available, the Texas Department of Highways and Public Transportation was installing loop detectors in the vicinity of the central business district for continuous freeway surveillance capability. Detection would be provided at approximately one-half-mile intervals, with all entrance and exit ramps and freeway-to-freeway connections counted.

San Francisco Bay Area, California: This traffic management project was initiated by the California Department of Transportation in 1974. The project is essentially a ramp-metering system. As of 1984, 35 directional miles of freeway were controlled with 44 entrance ramp meters, and two freeway-to-freeway ramp connections were also metered. The ramp meters were generally corridor-specific, with metering controlled by 170 type microprocessor-based local controllers operating in a traffic-responsive mode, and with demand and passage detectors on the ramp and detectors on the freeway main line in the immediate vicinity of the controlled entrance ramp. HOV priority treatments included one exclusive HOV entrance ramp for buses and carpools, two metered ramps with HOV bypass lanes for buses and carpools, and several segments of dedicated lanes for buses and carpools. There were 13 directional miles of contiguous bus and carpool lanes, and four miles of contra-flow bus and carpool lanes.

An expanded traffic management system for the San Francisco-Oakland Bay Bridge was in the process of being developed in 1984. This facility had no shoulders and any incident created abnormal delay problems. Vehicle detectors were being installed to provide incident detection capability, which would be confirmed by closed circuit television. Emergency vehicles would be dispatched to clear the incident, while changeable message signs would provide warning information to motorists entering the bridge. The system was being integrated with the 15-lane metered operation at the toll plaza entrance to the bridge. The installation of most of the equipment was scheduled for completion in 1985, with the CCTV to be installed shortly thereafter. The new system was expected to be fully operational by 1986. In addition to the incident management system described for the San Francisco-Oakland Bay Bridge, motorist call boxes were provided on several bridges and tunnels. Spacing for the call boxes varied from 250 to 800 feet.

Two automatic congestion warning signs were installed in April 1983. The signs, together with roadway detectors and controllers, were a demonstration project to determine the feasibility of automatic congestion warning signs in locations having poor sight distance. An evaluation conducted of this project indicated that these signs were cost-effective.

The objective of this corridor-specific ramp control system is to minimize the duration and severity of congestion.

Some degree of resistance to the extension of ramp-metering operation had been expressed by city representatives. Other factors limiting extension of the ramp metering were staff and funding limitations. Measures of traffic performance routinely gathered included freeway vehicular volume flow, person volume flow observed on a quarterly basis where HOV facilities were located, freeway travel times, freeway operating speeds, freeway accidents, ramp-meter delay, ramp-meter queue lengths, and ramp-meter violation rates. In addition, special studies were conducted of arterial street performance before and after implementing a new ramp control system.

Sacramento, California: This system, implemented by the California Department of Transportation, District 3, is a ramp-metering system located on a five-mile segment of USH 50. In 1984, the project included nine ramp-meter installations operating during the morning peak period only, and controlled by traffic-responsive 170 type microprocessor-based local controllers. The ramp meters typically included queue, demand, and passage detectors, and mainline detectors for local determination of metering rate. HOV bypass lanes were provided at four metered entrance ramps, one for buses only and three for buses and for carpools with two or more occupants. This project had no motorist information advisory elements or incident management elements.

The objective of this ramp-metering project is to minimize the duration and severity of congestion, and to maximize the volume flow on the freeway. The project was installed as a demonstration project in 1983. Public acceptance had generally been positive, and in 1984, the California Department of Transportation was planning to extend the project during 1986 and 1987. Data gathered at the local ramp-metering controller by means of a cassette recorder included vehicular volume flow, ramp-meter queue lengths, and ramp-meter violation rates, as well as mainline lane occupancy measurements. The tape was picked up once a week and converted to a paper summary. Under this project, special studies were conducted of freeway travel times and freeway operating speeds.

Portland, Oregon: This project was implemented by the Oregon State Highway Division in January 1981, and in 1984 consisted of a ramp-metering system installed on a six-mile segment of IH 5 (North Pacific Highway) and on a five-mile segment of IH 84 (the Banfield Freeway). There were approximately 142 freeway entrance ramps located in the metropolitan area, of which 16 were metered. The metering application was described as corridor-specific and located upstream of congested freeway segments. The Department had plans to install six additional ramps in the fall of 1985, with planning underway for the installation of ramp meters at 20 additional locations. The metered ramps were controlled by local controllers operating in a pretimed mode. Ramp-meter detection included queue, demand, and passage detectors for actuated operation of metering signals, and freeway mainline detectors for data gathering and determination of metering rates. HOV bypass lanes were provided on 15 of the 16 metered ramps, with one of the bypass lanes exclusively for buses and the remaining 14 for buses and for carpools with two or more persons.

Commercial radio stations broadcast motorist information regularly provided by the Oregon State Highway Division. Freeway incident management was provided by means of motorist aid call boxes located on three bridges in the Portland area, with the City of Portland police and the Oregon State Highway Department's maintenance crews being responsible for responding to reported incidents.

The objectives of this freeway traffic management system are to minimize the duration and severity of congestion, maximize the volume flow on the freeway, and maintain a minimum operating speed of 30 mph. Ramp meters were installed based on the following criteria: a freeway volume flow rate of 1,800 vehicles per hour per lane, a volume-to-capacity ratio equal to or greater than 0.9, and frequent occurrences of freeway operating speeds below 30 mph for 20 minutes. Also considered were the types of accidents occurring on the freeway system, and the time of the accidents. Metering rates were pre-timed and based upon historical traffic patterns and the calculated demand and service volume relationships in the freeway corridor.

The Oregon State Highway Division is committed to maintaining a balanced freeway system with smooth flow, and in 1984 had intentions to expand ramp controls to other areas. Monitoring of the system in place in 1984 was performed by collecting data on cassette tapes at the local ramp controller, and then processing the data on a microcomputer for analysis. Routine evaluation was performed of the system and control strategies in place. The data collected on a routine basis included freeway vehicular volume flow, freeway travel times, freeway operating speeds, and ramp-meter violations. Also, special studies were conducted of person volume flow, freeway accidents, modal shifts, fuel consumption, air pollution, ramp-meter delay, and ramp-meter queue lengths. Arterial street performance was also evaluated on a special study basis.

<u>Future Expansion of Existing Metering Systems and System Administration</u>

Only three of the projects contacted offered any indication that public resistance was a factor in not extending their ramp-metering program. These projects were located in Los Angeles, Detroit, and San Francisco. While there was some indication of public objection, the installation of ramp metering is continuing in Los Angeles and San Francisco on a regular basis, but the California Department of Transportation has adopted a policy of reaching formal agreement with the local municipalities before proceeding with the installation of further ramp control. The extension of several projects, including those in Seattle, Denver, and Houston, had encountered no public objection, and in Denver and Portland, the state highway departments have a program for the regular extension of ramp-metering installations. On several of the projects, ramp metering had not been extended because installation criteria did not indicate that further metering was warranted, or because the incremental benefits did not justify the incremental costs. These projects were those in Los Angeles, Chicago, Toronto, San Diego, San Antonio, and Portland. In addition, in Chicago a lack of ramp storage was the reason for not extending ramp metering in some areas. Extension of the ramp-metering program in Minneapolis, Denver, and San Francisco has been limited, to some degree, by funding limitations, while manpower shortages have limited the extension of the system in the Phoenix area.

Regarding system administration, virtually all the project personnel reported that the state highway department was responsible for daily freeway operations, determination of the location of future ramp meters, freeway maintenance and operation, and the development of the freeway operation management strategy. One exception was the Detroit project, where the determination of the freeway operation and management strategy was a function of a joint advisory committee with members from the Michigan State Highway Department (both central office and district representatives), City of Detroit, Wayne County, State Police, Detroit City Police, Federal Highway Administration (FHwA), and Regional Planning Commission. The Committee was created at the suggestion of the FHwA because the above agencies had historically differed on broad issues. The Committee functioned during the planning and design stages, with concerns directed toward ultimate system operation and traffic management during construction. As of 1984, the Committee continued to meet on a monthly basis to discuss and approve issues of operational and management strategy, and to accomplish interagency coordination of traffic management efforts.

Law enforcement was generally the responsibility of the state highway patrol except in Chicago, Virginia, Denver, Houston, San Antonio, and Portland, where local police enforcement agencies had some responsibilities within their jurisdictional boundaries.

Innovative Technology

The agencies contacted reported the following innovative technologies or successful experiences with unusual operational techniques:

Ramp Metering:

1. Project personnel in San Diego reported they have been very successful in freely mixing a variety of metering operations, and that such metering has been well accepted and understood by the motorist. In 1984 they had in place ramp-meter signal sequencing requiring one vehicle per green operation and two vehicles per green operation, and single-lane metering as well as two-lane abreast metering, all within the same system.

2. Freeway-to-freeway ramp metering has been used very successfully in San Diego and in Minneapolis. A total of 19 metered freeway-to-freeway ramps had been reported nationwide as of 1984. Twelve of these were located in the Minneapolis-St. Paul area and four in the San Diego area.

Vehicle/Incident Detection:

1. Monitoring of citizen band radios in response to electronically detected incidents has proven to be a successful element of the Chicago traffic management system. Such monitoring is used to verify the occurrence of an incident and to gather information about the nature of the incident, the number of lanes blocked, and the probability of personal injury so that appropriate emergency vehicle equipment may be dispatched promptly.

Communications:

1. In conjunction with the reconstruction of Chicago area freeways, the Illinois Department of Transportation (IDOT) has incorporated, within the concrete median barriers, ducts for housing IDOT-owned cables, including those cables necessary for communication for the expressway surveillance project.

2. The Ministry of Transportation and Communications in Ontario is seriously considering utilizing fiber optics technology for communication systems on future freeway control projects in lieu of the traditional hardware—twisted pairs or coaxial cables—because of the increased capacity for transmission of data, and the longer lengths of cable that might be utilized before amplification of the transmission signals is necessary.

3. The New York Department of Transportation, in planning the IMIS project, is incorporating the capability of automatic switching from one coaxial cable loop to another in the event of interruption on one leg of the cable to provide for redundancy in the communication system.

4. The California Department of Transportation reports that use of the 900-megahertz radio frequency, which provides a high degree of signal security, is being considered for possible use in controlling changeable message signing. This technology eliminates the need for an extensive hardware cable system, and in 1984 was being used by the New Jersey Department of Transportation for changeable sign control in the Meadowlands traffic control project.

Motorist Information Dissemination:

1. Chicago project personnel indicate that they are considering the following possible applications:

   a. Making available to home cable television systems the color graphics displayed on the CRT terminals in the control center for indicating freeway operating conditions, including areas of congestion, to provide motorist information for pre-trip planning.

b. Synthesizing computer voice-generated traffic reports for telephone inquiries or for use in highway advisory radio systems.

Administration:

1. In the Houston area, a unique working relationship has been established between the Department of Transportation and the Houston Transit Authority, which together are developing a joint use surveillance and control facility with joint responsibilities for funding and operation. The Transit Authority will retain responsibility for operation of the reversible authorized vehicle lanes, while the Department of Transportation will be responsible for the operation of the surveillance and control system. They will share use of the surveillance and detection system, communication cables, and closed circuit television used for monitoring performance in both the authorized vehicle lanes and the freeway traffic lanes.

BENEFITS OF FREEWAY TRAFFIC MANAGEMENT SYSTEMS AND COSTS OF MAJOR COMPONENTS

Comprehensive research has not been conducted of the actual benefits and costs of individual traffic management elements and components. However, individual projects have reported substantial and consistent benefits, based upon "before" and "after" project evaluations. The following are some of the reported benefits:

The California Department of Transportation reports the following benefits of the four major activities undertaken as part of the 42-mile Los Angeles area freeway surveillance and control demonstration project:

1. Traffic-responsive control using electronic surveillance coupled with computer-controlled ramp-meter signals reduces recurring freeway congestion. During the demonstration project, waiting time at the ramps was reduced by 20 percent, traffic volume on the freeway increased 3 percent, and the average speed of traffic increased by 100 percent, from 25 to 52 mph.

2. The duration of traffic congestion resulting from unusual incidents can be reduced by using electronic surveillance coupled with rapid verification, response, and removal. Under the demonstration project, the average duration of traffic obstruction resulting from an incident was reduced from 42 minutes to 21 minutes.

3. Time spent by vehicles disabled at the side of the road can be substantially reduced by having roving service patrols. During the demonstration project, the average time spent by disabled vehicles at the side of the road was reduced from 32 to 24 minutes.

4. Providing timely warnings and information to motorists regarding traffic conditions can reduce the number and severity of accidents. Under the demonstration project, there was a 17 percent reduction in accidents involving injuries and fatalities, and a 16 percent increase in the number of cars diverting to alternative routes a mile or more upstream of incidents.

Under the Chicago area expressway surveillance and control project, congestion was reduced by up to 60 percent, and accidents were reduced by up to 18 percent. During one two-year study on the outbound Eisenhower Expressway, expressway and ramp accidents during the peak period were reduced by 17 percent as a result of improved traffic flows. A special study at one ramp-meter location over a four-year period indicated a 35 percent reduction in accidents in the immediate freeway and ramp merge area. Detailed analysis showed an 11.6 percent reduction in traffic conflicts during the maximum metering rate. During analysis of the large-scale Chicago network with 54 controlled ramps, the estimated benefits were projected for the entire system; an annual benefit-cost ratio exceeding 4.0 was indicated when considering only the benefits of recurrent congestion reduction and accident savings. Consideration of other benefits such as incident detection, service response, and motorist information would produce even higher benefit-cost ratios.

The Minnesota Department of Transportation reports the following long-term results for projects located in the Twin Cities area:

1. IH 35E Ramp Control System—Thirteen years of experience with the operation of six isolated, local traffic-responsive ramp meters produced the following results:

a. The average peak-hour freeway speeds increased 16 percent, from 37 mph to 43 mph.

b. The average number of peak-period accidents decreased 24 percent, from 45 to 34 per year.

c. The peak-period average accident rate decreased 38 percent, from 3.72 to 2.31 accidents per million vehicle miles.

d. Average peak-period volumes increased by 25 percent.

2. IH 35W Bus-On-Metered-Freeway System—This traffic management system combines the benefits of a surveillance and control system, including continuous vehicle detection for incident detection, with on-freeway express transit service. The system in 1984 had 16 closed circuit television cameras, 38 ramp control signals, and five changeable message signs. After nine years' experience, the key findings are as follows:

   a. Average peak-period freeway speeds increased 35 percent, from 34 to 46 mph.

   b. The average number of peak-period accidents decreased 27 percent, from 421 to 306 accidents per million vehicle miles.

   c. The peak-period accident rate decreased 38 percent, from 3.40 to 2.12 accidents per million vehicle miles traveled.

   d. Express bus ridership increased 247 percent, from 3,600 to 12,500 peak-period passengers per day.

   e. Average peak-period volumes increased by 23 percent.

Under the project in Portland, Oregon, flow improved significantly in one direction of the controlled freeway, with average travel speeds increasing 76 percent, from 17 mph to 30 mph, and traffic volume during the three-hour peak period increasing 32 percent, from 6,800 to 9,100 vehicles. Data indicate that the conditions in the opposite direction remained relatively constant.

ANALYSIS

The success or failure of any major traffic management effort depends upon the appropriate blending of warranted traffic controls and management efforts, reliable technology, and justified and manageable operating strategies. System software, hardware, and technology form the basis of the operating system and provide the delivery mechanism of the traffic management system to the field. As such, the technology and hardware system represent a critical link in the system. System integration—that is, the blending of all component parts into a compatible matched system—is a major concern in writing performance specifications, selecting compatible working equipment, and programming the various components and software to result in a working system. This aspect of system design and construction has arisen as a major stumbling block in some systems.

The most critical element in any traffic management system relying upon traffic flow information and the provision of traffic-responsive controls and traffic management actions is the basic detection system for acquiring operational data for the decision-making process. Traffic data obtained from the continuous electronic detection system are used to determine warranted traffic controls or geometric improvements, and to determine the need for ramp metering, incident detection, changeable message signs, or highway advisory radio.

The weak link in the surveillance system is the vehicle detector itself. The induction loop detector has become the standard of the industry because of its versatility, accuracy, and reliability. The loop detection may function as a pulse detector, where only traffic volume information is required, or as a presence detector where information about both the volume of traffic and and the presence of vehicles is required. Yet, the induction loop detector is subject to false calls and drifting out of proper operation under changing environmental conditions, as well as equipment failures. Significant strides have been made in the development of reliable self-tuning detectors. Nevertheless, problems with detector systems, beginning with the loop in the pavement through splices in the underground cable to the control panel in the field and the loop amplifier itself, continue to plague operating systems. A typical problem is the transmission of nonfunctioning or erroneous data to the control processor. Efforts have been made to reduce or eliminate the potential for failures by encasing loop installations in rigid conduit systems either placed in the pavement surface during paving operations, or sawed and sealed into the pavement at a later date. The repair of loops in freeway main lines, particularly on congested urban freeways, can be extremely costly, and may be extremely disruptive to traffic flow as one or possibly two lanes may need to be closed.

A major consideration in the implementation of a freeway traffic management system is central versus local control. A central computer offers the opportunity to make evaluations and decisions on a local, segmental, and network basis concurrently by focusing data into one central location. However, concentrating all the data analysis and decision-making in the central controller may result in the loss of control functions in the field with the loss or interruption of the central computer operation or communication links to the field. Experience has shown that the loss or down time of the central computer in major systems is relatively rare; nevertheless, such a situation may occur as a result of the loss of power to the computer or an interruption of the communication links within the system. Where some independent controller capability exists, freeway control may continue to be exercised with the loss of communication or direction from the central controller. While independent control may not be desirable for all traffic management elements—such as motorist information systems utilizing changeable message signs—the ability to maintain ramp-metering control during peak periods rather than losing control altogether is a major consideration.

The requirements for data transmission capacity are reduced where some capability for pre-processing data from vehicle detectors also exists in the field. The local ramp-meter controller can accept detector inputs and process the data for transmission to the central processor. In the event of loss of the communication link between the field and the central processor, or of a nonfunctioning central computer, the local controller can continue to function by providing pre-timed metering or traffic-responsive metering in the field. The advantage of concentrating all of the software and program decision-making in the central processor is that system operation at virtually all levels may be re-programmed simply through a software change in the central processor. Under many of the newer traffic management systems, local ramp-metering controllers have the capability to pre-process data from detectors and to transmit that data to the central computer when polled, generally at about 20-second intervals. The local controllers also have the capability to maintain metering operation in the case of interruption of the communication link or loss of the central computer operation. The local controllers may revert to a simple pre-timed metering program or may provide a fully traffic-responsive metering operation with virtually the same range of metering rates provided by the central control.

Another major decision when implementing a freeway traffic management system is the communication link between the field and the central control. The number of field components and individual functions requiring the transmission of data or detector impulses from the field to central, and from central to the field, rapidly add to the capacity requirements of the communication system. Leased telephone lines were used in the development of the early pioneering systems. While they functioned satisfactorily and dependably, recent increases in tariff rates have made the cost of leased systems prohibitively expensive. More recent control systems have tended to utilize communication cable owned by the operating state agency and installed as part of the project. While this element represents a major cost component of an extensive system, experience indicates that the investment is cost-effective compared to the cost of leasing private telephone lines. Initial communication systems utilized twisted pair multi-conductor communication cables. More recent systems have tended to use coaxial cable, particularly where closed circuit television is an element of the traffic management system. More recent technological developments in the state-of-the-art are causing operating agencies to consider the use of fiber optics because of the increased capacity for data transmission and improved television signal transmission. The selection of the appropriate communication medium involves consideration of the size and configuration of the system and of the hardware components used in the system. In some cases, a combination of communication systems may achieve the best results.

Another hardware component requiring serious consideration is closed circuit television. The main function served by closed circuit television is the verification of incidents detected by other means, such as electronic detection. Closed circuit television may also be useful for observing system operation, such as at metered ramps. The effectiveness and performance of closed circuit television may be limited by environmental conditions such as rain and snow and early darkness in the winter. Also, roadway alignments on curves, bridges, and other structures over the freeways may obstruct the line of sight of television cameras. Operators of systems that incorporate extensive closed circuit television are enthusiastic about its merits; however, closed circuit television systems are a high-cost item which may not be totally effective under all conditions.

In addition to the technological and hardware considerations involved in developing a traffic management system, certain management and operational strategy decisions are required. These decisions range from the selection of the appropriate systematic operation of the ramp meter itself to the selection of the operational control strategy.

In the design of the ramp-metering signal and operation sequence, basic considerations are the number of signal faces to be used, whether signals are to be located on both sides of the controlled ramp or on a single post on one side of the ramp, and whether two-color or three-color ramp meters should be used. A wide variety of ramp display configurations and metering operation systems are employed throughout the United States. Some systems—for example, those in Texas and Minnesota—employ a three-color system for the metering process, utilizing a short yellow between the alternating green and red indications. In the Midwest, a simple two-color signal sequence consisting of a red and green indication, without the yellow during the metering process, is primarily used—in particular, in Chicago, Detroit, and Milwaukee.

The western states tend to use a slight variation, incorporating a three-color traffic signal head used primarily for turning the signals from a nonmetering to an active metering mode by introducing a yellow between the dwell green and first red indication. After initialization of the metering process with the signal resting in its initial red, the metering operation then uses a two-color sequence alternating between green and dwell red upon actuation the metering signal. This system, which is extensively used in California, has advantages in that a turn-on sequence is greatly simplified by introducing a steady yellow indication before changing from a dwell green to a dwell red indication. This sequence eliminates the need to detect a safe gap in traffic, and can be adopted to multiple car or platoon metering. In systems utilizing a simple two-color system, the queue detector is used to determine that there is an adequate gap in traffic, and that no vehicles are approaching the signals so that the signals may change from dwell green to dwell red. A two-color system necessitates a slightly more complex turn-on mechanism and a queue detector is desirable, although in Detroit a system for safe turn-on has been developed without utilizing a queue detector. Three-color systems may, nevertheless, need to use queue detectors to monitor the length of ramp queues and to provide queue override operation.

A system management component influencing operational strategy that should be carefully selected is the software. The advent of the digital computer has enabled complex logic systems to be programmed to provide a systematic and detailed decision-making process considering numerous alternatives. The temptation is to develop very sophisticated operational strategies involving a complex and detailed decision-making process since the capability exists. The incremental benefits gained from a more complex decision-making process may be difficult to identify and quantify as being truly beneficial, and may actually obscure the true effectiveness and responsiveness of the control system. Often, the greatest benefits accrue from the introduction of a simple control as opposed to no control at all. The incremental benefits accruing from a more complicated decision-making process and sophisticated operational strategies may be difficult if not impossible to determine.

SUMMARY AND CONCLUSIONS

It became quite apparent to urban traffic engineers that expanding urban freeway systems, once constructed and opened to traffic, did not always operate freely by themselves, but experienced periods of congestion, intensified by continually increasing traffic volume demands, and were in need of day-to-day management to operate at optimum levels of capacity and efficiency. Continued efforts have been made to identify the causes of congestion and to develop management solutions to recurrent peak-period congestion problems, as well as the nonrecurrent problems occurring as the result of random incidents. Early traffic engineering research and operational studies in Detroit, Chicago, and Houston have led to freeway traffic management efforts in numerous and varied urban freeway situations.

Freeway traffic management is basically an effort directed at achieving or maintaining a balance in the traffic volume-demand and capacity-available relationship. Recurrent or regular congestion are the result of loading the system with traffic demand in excess of available capacity. Congestion may also be influenced by geometric or physical conditions such as lane drops or steep grades. A substantial amount of nonrecurrent congestion occurs at random times and locations due to unanticipated incidents such as accidents, disabled vehicles, or spilled loads. Another type of nonrecurrent congestion problem, but one that may be anticipated and planned for, is freeway construction work that causes a temporary lane closure, or special events that generate an unusually heavy traffic concentration. Traffic management actions designed to handle these problems have been applied to varying degrees on many urban freeway systems. Freeway traffic management elements, including ramp metering, incident management, and motorist information systems, have been applied on a large scale in major metropolitan areas such as Los Angeles and Chicago, where many traffic management efforts are utilized on a day-to-day basis. Freeway traffic management may also be undertaken on a smaller scale where only limited traffic management efforts are required.

Freeway traffic management activity has been undertaken and accepted on a broad scale, with the scope of management actions tailored to the problems, needs, and resources of the specific freeway systems and operating agencies. Whether undertaken on a broad scale—i.e., central computer processing of systemwide data gathered by means of electronic surveillance systems—or on a site-specific basis, i.e., ramp metering—improvements in operation, efficiency, and safety have been achieved. Simple local control ramp-metering projects have resulted in improvements in freeway operation, increases in freeway volume, and reductions in freeway accidents. Larger scale projects providing central control and continuous electronic detection for real time surveillance have increased the ability to make control decisions on a local, segment, or network basis, and have provided improved system analysis and management capabilities through the use of incident management and motorist information systems.

Experience has shown that not all elements of a freeway traffic management system need to be developed in one major effort, but that staged development can be an effective approach to implementing an areawide traffic management system. Under a staged development process, staff expertise in system design, implementation, and operation can be acquired during the early stages of implementation, enhancing the development of future stages. The development of staff expertise in the early stages of project planning and implementation is a key ingredient to the ultimate successful operation of the operating hardware and software elements of the system. Experience has shown that large-scale traffic management systems—such as those in Chicago, Los Angeles, and Minneapolis—incorporating surveillance and control systems that have been developed in stages have been successful in increasing the efficiency of freeway traffic control and the safety of the freeway system.

Based upon the experience of the Wisconsin Department of Transportation and of agencies responsible for the operation of freeway traffic management systems nationwide, it is recommended that the following recommendations with respect to hardware, technology, and operating strategy subsystems be given special consideration when designing alternatives for a comprehensive traffic management system for the greater Milwaukee area freeway system:

1. It is recommended that the initial step in the development of a traffic management system be the development of a system surveillance and monitoring capability through the provision of a central computer processor and connection of all existing loop detectors on the freeway system to the central computer. The existing detection system includes 25 freeway traffic counting stations in the Milwaukee metropolitan area which have loop induc-

tor detectors in all freeway lanes, and which are located on nearly all approaches to major interchanges on the freeway system. Eight of the traffic counting stations have a double set of detectors for speed monitoring purposes. It is also recommended that all detectors currently part of the independent local ramp control system be connected as part of the surveillance system. The gaps in between the existing detectors should be closed with additional freeway detectors installed in all lanes to reduce spacing between successive stations to approximately one-half-mile intervals. The system will serve as the basis for gathering operational data for use in making decisions on future traffic controls and capacity improvements, and will provide the traffic information for making operational decisions.

2. It is recommended that the existing ramp-metering system be connected to the central computer to provide system-responsive ramp control, and that ramp-meter controls be extended to other freeway entrance ramps contributing volume directly to freeway segments experiencing recurrent peak-period congestion. The 170 type local controller under central control should be utilized, but with the ability to operate in an independent local control mode to provide traffic-responsive metering control in the event of loss of supervision by the central computer. The local controller would also accumulate and pre-process detector information from the field for transmission to the central control when polled.

3. It is recommended that an incident management element be developed based upon the incident detection capability provided by the electronic surveillance detector system, and with a direct communication link between the central control center and the Milwaukee County Sheriff's Department for dispatch of the appropriate enforcement, fire, and rescue equipment. Additional detection capabilities may be provided by:

   a. Citizen band radio base stations strategically located in the field and monitored from a central location to verify the occurrence and nature of incidents detected by the electronic surveillance system.

   b. A limited number of closed circuit television cameras in critical areas to provide specific information as to the location and nature of incidents detected by the electronic surveillance system. Locations of special concern are IH 43 southbound in the vicinity of the Courthouse Annex and the State Street entrance ramp; IH 94 eastbound between the Stadium Interchange and 35th Street; and IH 94 westbound between the Marquette Interchange and 16th Street.

4. It is recommended that a limited motorist information system utilizing changeable message signs be provided on the freeway main line, primarily on the freeway approaches to the Milwaukee County Stadium and the State Fair Park area, to be used for traffic management during special events at the stadium and the fairgrounds. Also, a communication link with commercial radio stations should be developed to provide timely traffic information, including the occurrence of confirmed incidents. The objective of the motorist information system would be to provide advisory alternative route information and warnings of unexpected traffic congestion in order to reduce the potential for rear-end accidents.

5. It is recommended that HOV bypass lanes be provided at locations where buses enter the freeway on metered ramps and, where traffic volumes warrant, that carpools be allowed to use the priority lanes.

6. It is recommended that the administration and operation of the freeway traffic management system be the responsibility of the Wisconsin Department of Transportation. It is recommended that staff be expanded during the system design process to add personnel with expertise in the area of communications and computer hardware and programming. This additional staff would assist in the development of adequate contract specifications during equipment acquisition stages.

7. It is recommended that permanent corridor management teams be developed consisting of representatives of the agencies

responsible for operation of adjacent local street facilities, and of fire and police agencies providing service on the freeway system. The teams would include traffic engineers from the local communities adjacent to the freeway system, representatives of appropriate fire and police agencies, and representatives of the Milwaukee County Sheriff's Department, the Milwaukee County Department of Public Works, the Milwaukee County Transit Authority, and the Wisconsin Department of Transportation, District Traffic and Maintenance sections. The corridor management teams would be established for individual corridors, with each corridor requiring representation from different agencies.

Chapter IV

FREEWAY SYSTEM CAPACITY AND USE

INTRODUCTION

This chapter presents the basic data regarding freeway system capacity and use required to prepare a freeway traffic management system plan. Data are provided on the physical and operational characteristics of the freeway system and freeway system traffic volumes and patterns. Those freeway segments which present capacity restrictions and exhibit traffic congestion during weekday peak traffic periods are identified. Alleviating the traffic problems on these congested freeway segments is the primary objective of the freeway traffic management system alternatives being considered under this study.

Some of the information presented in this chapter was collated from the planning data files assembled by the Regional Planning Commission through its continuing, comprehensive, areawide transportation system planning program. Additional information was collated from the files of the Wisconsin Department of Transportation, Milwaukee County, and the City of Milwaukee. The detailed information on Milwaukee area freeway system travel patterns was obtained from license plate origin-destination surveys conducted by the Commission on the freeway system in April and October of 1983 specifically for the purposes of this study. Peak-period freeway travel time data were collected in conjunction with the license plate surveys.

MILWAUKEE AREA FREEWAY TRAFFIC CAPACITY

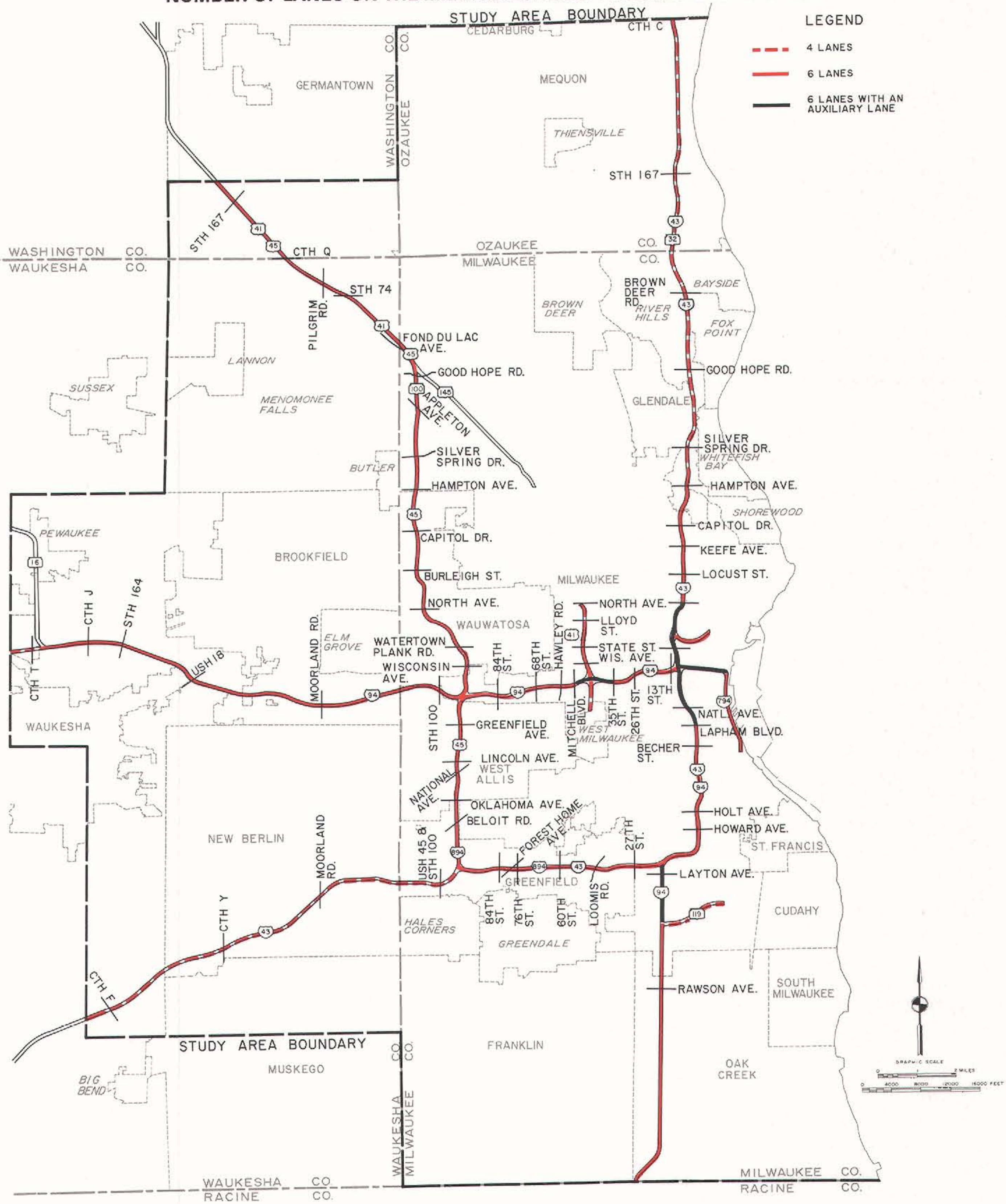
The physical and operational characteristics of a freeway segment establish its ability to service traffic demand. One measure of this ability is the maximum capacity of the freeway segment, or the maximum number of vehicles which the freeway segment can carry in one hour. The maximum capacity of a freeway segment is also referred to simply as capacity. The most important physical or operational characteristic in establishing the capacity of a freeway segment is the number of traffic lanes provided. Map 4 identifies the number of lanes on the various segments of the Milwaukee area freeway system. The capacity of a freeway lane typically ranges from 1,700 to 2,000 vehicles per hour. The other freeway physical and operating characteristics which can influence the capacity provided by a lane of freeway include: 1) freeway lane width, 12 feet being the standard width; 2) lateral clearance between roadside obstacles and the edge of the freeway lane, 6 feet being the standard clearance; 3) horizontal and vertical alignment; and 4) proportion of trucks and buses in the traffic stream.

Considering these physical and operational characteristics as determined from the inventories, the maximum capacity of each segment of the Milwaukee area freeway system was determined in accordance with the procedures set forth in Transportation Research Circular No. 81, Proposed Chapters for the 1985 Highway Capacity Manual, published by the Transportation Research Board, National Research Council. These proposed chapters update the 1965 publication of the Board entitled, Highway Capacity Manual. The computed capacities of critical segments of the freeway were field-checked through observation of peak traffic flows.

Freeway lanes in the Milwaukee area generally have ideal physical characteristics for providing traffic capacity. Freeway lanes in the Milwaukee area are 12 feet wide except for the westbound lanes of the Airport Freeway (IH 894) through the Greenfield Interchange and the north- and southbound lanes of the North-South Freeway (IH 43) between W. Lexington Boulevard and W. Silver Spring Drive, where the lanes are 11 feet wide. All segments of area freeways have design speeds of 70 miles per hour (mph) except the East-West Freeway (IH 94) between the Zoo Interchange and the Marquette Interchange, and the Stadium Freeway (USH 41), which have a design speed of 60 mph; and the Airport Spur, which has a 55-mph design speed between the Airport Spur Interchange and S. 6th Street, and a 60-mph design speed between S. 6th Street and W. Howell Avenue. There are numerous locations where the lateral clearance is less than 6 feet, particularly on the East-West Freeway (IH 94); however, field observation of peak-hour freeway traffic volume indicates these less-than-

Map 4

NUMBER OF LANES ON THE MILWAUKEE AREA FREEWAY SYSTEM: 1987



The most important characteristic determining the capacity of a freeway segment, and therefore its ability to service the traffic demand, is the number of traffic lanes provided. As shown on the map, four lanes are provided on approximately 20 miles of IH 43 and the Stadium Freeway, with six lanes being provided on the remainder of the freeway system in the Milwaukee area.

Source: SEWRPC.

ideal clearances do not significantly affect freeway capacity. During the peak hours, trucks and buses account for 3 to 7 percent of the traffic volume on area freeways.

Freeway-to-freeway interchanges also can affect the capacity of area freeways, as the substantial volume of lane changing which necessarily occurs upstream and downstream of the interchange reduces the lane capacity of segments of freeway just before and after freeway interchanges. Maps 5 and 6 show the location of such interchanges in the Milwaukee area, as well as all on-ramps and off-ramps of the freeway system.

COMPARISON OF MILWAUKEE AREA FREEWAY CAPACITY TO TRAFFIC VOLUME

Average weekday peak-hour traffic volumes, as measured by the Wisconsin Department of Transportation in 1986, are shown for selected sites on Map 7 for the morning peak hour (7:00 a.m. to 8:00 a.m.) and on Map 8 for the evening peak hour (4:30 p.m. to 5:30 p.m.). The volumes were compared to the capacities of area freeway segments which were calculated as described earlier.

There are a number of problem freeway segments where the current peak-hour traffic demand is equal to or in excess of freeway capacity. When traffic demand equals capacity, freeway operating speed is reduced to about 30 mph, and when traffic demand exceeds capacity, operating speeds are generally below 30 mph, as stop-and-go operating conditions are experienced. The segments of freeway which are currently operating at capacity or over capacity are identified on Map 9 for the morning peak hour, and on Map 10 for the evening peak hour. Also noted on these maps are those isolated freeway stretches where the combined traffic volume of a freeway on-ramp or off-ramp and the outer freeway lane exceeds freeway capacity solely in the lane adjacent to the ramp.

The freeway segments on which demand equals or exceeds capacity freeway could substantially benefit from the implementation of a freeway traffic management system. Figures 3 through 12 show the results of travel speed runs conducted concomitantly with the survey of freeway travel patterns in April and October 1984. The figures graphically identify problem freeway segments currently operating at 30 to 40 mph—that is, at or approaching capacity—and those segments operating at less than 30 mph, or over capacity. These travel speed analyses confirm the results of the freeway traffic demand-to-capacity comparison.

MILWAUKEE AREA FREEWAY PEAK-HOUR TRAFFIC PATTERNS

The proper design and evaluation of a freeway traffic management system in the Milwaukee area requires information regarding the travel patterns of the vehicles utilizing the freeway system on an average weekday. This travel pattern information identifies for each vehicle the on-ramp that was used to enter the freeway system and the off-ramp that was used to exit the freeway system, as well as the time of entry and exit. These data can be used to establish the degree to which each freeway on-ramp contributes to freeway congestion. Such information is necessary to evaluate the potential impacts of alternative freeway traffic management systems, and to determine which alternative best meets freeway operation objectives in the Milwaukee area.

In order to obtain such information, it was necessary to conduct a vehicle license plate origin-destination survey. To conduct the survey, observers were stationed at freeway on- and off-ramps in the Milwaukee area to record license plates. To facilitate data collection, the Milwaukee area freeway system was divided into 14 segments which were designed so that the data obtained could be merged to identify systemwide travel patterns for the morning and evening peak travel demand periods. The seven morning peak-period segments are shown on Maps A-1 through A-7 in Appendix A. The seven evening peak-period segments are shown on Maps A-8 through A-14 in Appendix A.

Data were collected at a total of 124 freeway on-ramps and 149 freeway off-ramps throughout the Milwaukee area. License plate identifications were recorded at five-minute intervals during the three-hour peak traffic period at each ramp. Vehicle types were noted to identify buses and trucks, the latter being defined as vehicles other than buses having six or more wheels. In addition, the number of occupants in each vehicle was noted and recorded. Any particular pair of freeway ramps that the vehicles utilized to make their trip was identified by matching the observed license plates. The total observations and total matchable observations are noted in Table 2. The total vehicle traffic volume observations at each on-ramp and at each off-ramp during the morning peak hour are shown on Maps 11 and 12, respectively. The total vehicle traffic volume observations at each on-ramp and off-ramp during the evening peak hour are shown on Maps 13 and 14, respectively.

Based upon the license plate matches, two key indicators of freeway travel patterns were computed for peak-hour, peak-direction travel on a typical weekday. The first indicator is the percentage of total entering volume at each on-ramp that travels through a congested freeway segment. This indicator was computed for each of the seven congested freeway segments for both the morning and evening peak hours, and is displayed on Maps B-1 through B-14 in Appendix B. Maps 15 and 16 are composite representations of the seven morning and evening segments. These maps permit the identification of those on-ramps which contribute significantly to freeway congestion and which could be considered for metering under an expanded freeway traffic management system.

The second indicator is the percentage of the traffic volume of a congested freeway segment that is contributed by the entering volume of each on-ramp. This indicator was also computed for both the morning and evening hours for each of seven congested freeway segments, and is displayed on Maps B-15 through B-28 in Appendix B. A composite representation, showing the highest percentage calculated for each on-ramp, is shown on Maps 17 and 18. These two indicators make it possible to identify those freeway ramps which contribute significantly to freeway congestion.

CHARACTERISTICS OF MAJOR ARTERIAL STREET ROUTE ALTERNATIVES TO AREA FREEWAYS

One potential impact of a freeway traffic management system is the diversion of current freeway traffic to surface streets. The primary determinant in a driver's decision to divert will be whether freeway travel time—including the delay incurred due to metering—will be greater than travel time over arterial streets. Current freeway travel times are generally less than travel times over arterial street routes. Because the freeway traffic management system will result in higher freeway operating speeds, any delay at on-ramps due to metering may be partially, if not totally, offset.

It will be necessary to determine the degree to which diversion may occur, particularly for short trips. Therefore, a number of major arterial street routes paralleling the freeway system were identified as the most likely routes to which some vehicles may be expected to be diverted under some freeway traffic management system alternatives. These parallel arterial routes are shown on Map 19. The travel times on these routes are primarily a function of the operating speed along the route between signalized intersections and the delay at signalized intersections. The delay at such intersections is dependent upon the degree to which the intersection volumes approach the capacity of the intersection, and whether or not traffic signal timing progression is provided along the route.

Intersection capacity is governed principally by the width of each intersection approach, the presence of exclusive turn lanes, the proximity of on-street parking, and the type of intersection control. Detailed data regarding these physical characteristics have been collected for each arterial intersection for the parallel routes shown on Map 19. Intersection capacity was calculated based on the procedures outlined in Transportation Research Circular No. 281, <u>Proposed Chapters for the 1985 Capacity Manual</u>, published by the Transportation Research Board, National Research Council, and the <u>NCHRP Signalized Intersection Capacity Method</u>, published by the U. S. Department of Transportation—both of which update the 1965 publication of the Transportation Research Board, <u>Highway Capacity Manual</u>. Based on these procedures and on existing traffic demand data collated from Wisconsin Department of Transportation and City of Milwaukee files, each arterial intersection was evaluated to determine whether it carries traffic volumes approaching or exceeding capacity during the peak hour. Intersections operating at design capacity during the morning and evening peak hours are shown on Maps 20 and 21, respectively.

CHARACTERISTICS OF TRANSIT SERVICE ON AREA FREEWAYS

All rapid transit service in the Milwaukee area is currently provided by buses operating on the freeway system primarily during the morning and evening peak travel periods. This service consists of 13 freeway bus routes connecting 19 park-ride lots to the Milwaukee central business district with nonstop service, as shown on Map 22. Morning peak-period operating characteristics for the freeway bus routes are noted in Table 3, and similar data for the evening peak period are noted in Table 4.

Rapid transit service operating on the freeway system carried about 7,000 passengers on an average weekday during 1983. Map 23 shows the average weekday travel demand on the rapid transit system. Approximately 24 percent of the passengers utilized buses operating over the North-South Freeway (IH 43); 36 percent over the North-South Freeway (IH 94); and 40 percent over the East-West Freeway (IH 94). It is estimated that 70 percent of all passengers ride during the peak hours. Therefore, about 1,000 persons ride 27 buses during each morning peak hour and 32 buses during each evening peak hour on the East-West Freeway (IH 94). About 870 persons ride 23 buses during each morning peak hour and 21 buses during each evening peak hour on the North-South Freeway (IH 94); and about 600 persons ride 14 buses during the morning and evening peak hours on the North-South Freeway (IH 43). In the absence of rapid transit service in those three travel corridors, an additional volume of about 800 vehicles could be expected to use the East-West Freeway (IH 94) each peak hour in the peak direction, or an increase of about 15 percent; about 700 vehicles the North-South Freeway (IH 94) each peak hour in the peak direction, an increase of about 12 percent; and about 500 vehicles the North-South Freeway (IH 43) each peak hour in the peak direction, an increase of about 10 percent.

SUMMARY

This chapter presents the important findings of the inventories conducted for the Milwaukee area freeway traffic management system study. The capacity of and current traffic volume on the Milwaukee area freeway system were described. Existing freeway traffic congestion was identified by comparing traffic volumes to estimated capacities and by analysis of peak-hour travel speed inventories of area freeways. Surface street route alternatives to the area freeway system were also identified in this chapter. The results of peak-hour freeway travel pattern inventories were also presented.

Among the more important findings of the study inventories were the following:

- A number of segments of Milwaukee area freeways operate at or over their capacity and experience severe traffic congestion in the morning and evening peak hours. These segments include the East-West Freeway (IH 94) from the Marquette Interchange to the Zoo Interchange; the North-South Freeway (IH 94) from W. National Avenue to the Mitchell Interchange; the North-South Freeway (IH 43) from W. Walnut Street to W. Capitol Drive, and from W. Silver Spring Drive to W. Good Hope Road; and the Airport Freeway (IH 894) from the Zoo Interchange to W. Lincoln Avenue. Stretches of these segments of freeways operate at 30 to 40 miles per hour (mph) during the peak traffic hours, and in some areas are limited to speeds of less than 30 mph, with stop-and-go traffic.

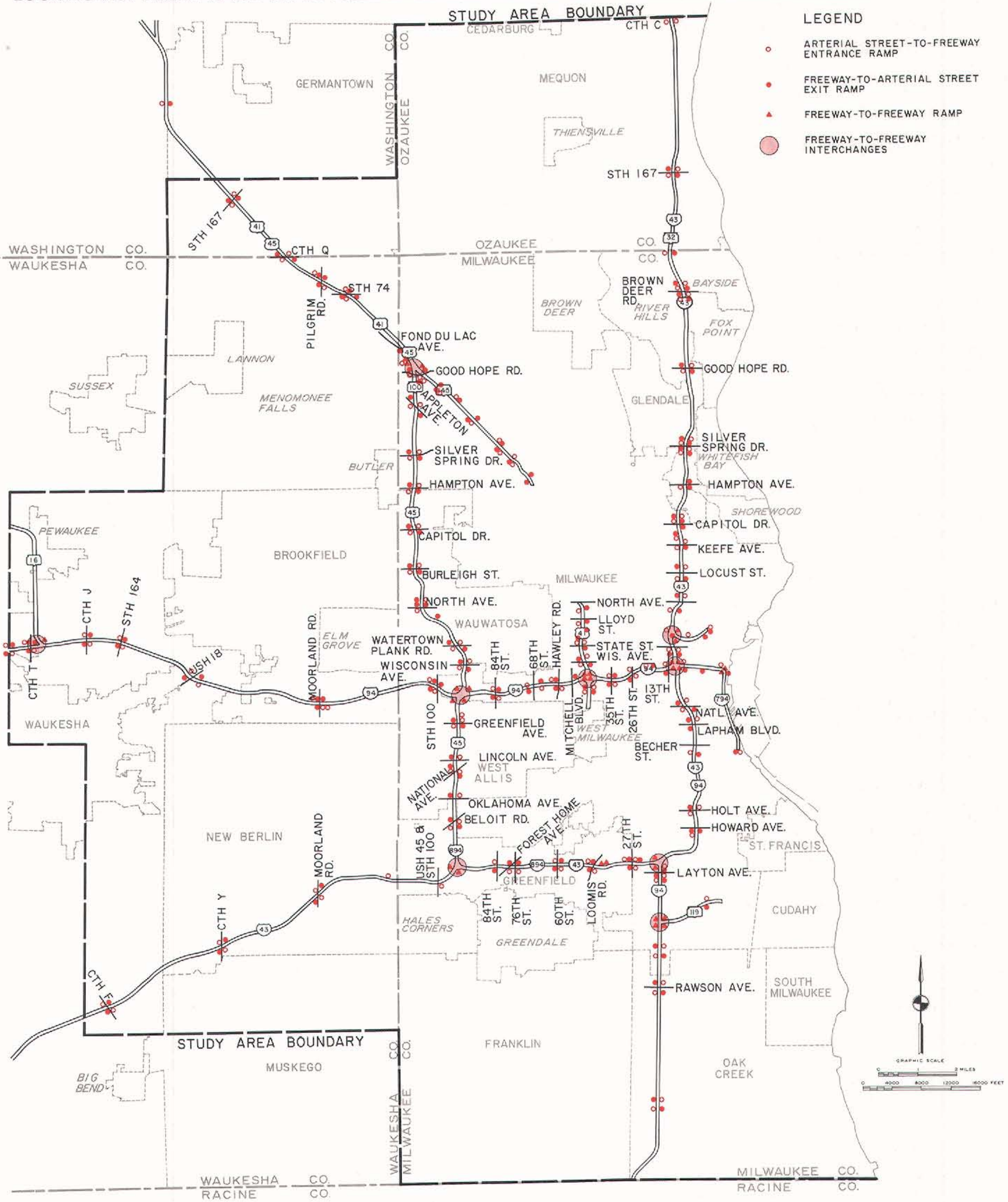
- Significant proportions of traffic volumes at outlying freeway on-ramps contribute to peak-hour congestion on freeways in central Milwaukee County. Between 20 and 25 percent of the total morning peak-hour traffic volume on the freeway on-ramps on the East-West Freeway (IH 94) and the Rock Freeway (STH 15) as far west as central Waukesha County travels through and contributes to congested freeway segments in central Milwaukee County. As much as 70 percent of the morning peak-hour traffic volume on the freeway on-ramps in southern Ozaukee County contributes to congested freeway segments on the North-South Freeway (IH 43) in Milwaukee County.

- There are a number of surface arterial street route alternatives to area freeways. The potential for these routes to carry any current freeway traffic which may be diverted to surface streets as a result of the institution of an expanded freeway traffic management system may be limited. A number of intersections along these alternative routes currently operate at capacity.

- A substantial amount of rapid transit service is currently operated in the Milwaukee area over area freeways. This freeway flyer service includes 13 bus routes, connecting 19 park-ride lots to the Milwaukee central business district with essentially nonstop service. Approximately 7,000 passengers were served by such rapid transit service on an average weekday in 1983. It should be noted that if this service were not provided and existing transit riders used automobiles, the traffic on area freeways would increase during peak hours by 10 to 15 percent, which could result in substantial traffic congestion.

Map 5

LOCATION OF RIGHT-HAND OR OUTSIDE SHOULDER RAMPS ON THE MILWAUKEE AREA FREEWAY SYSTEM

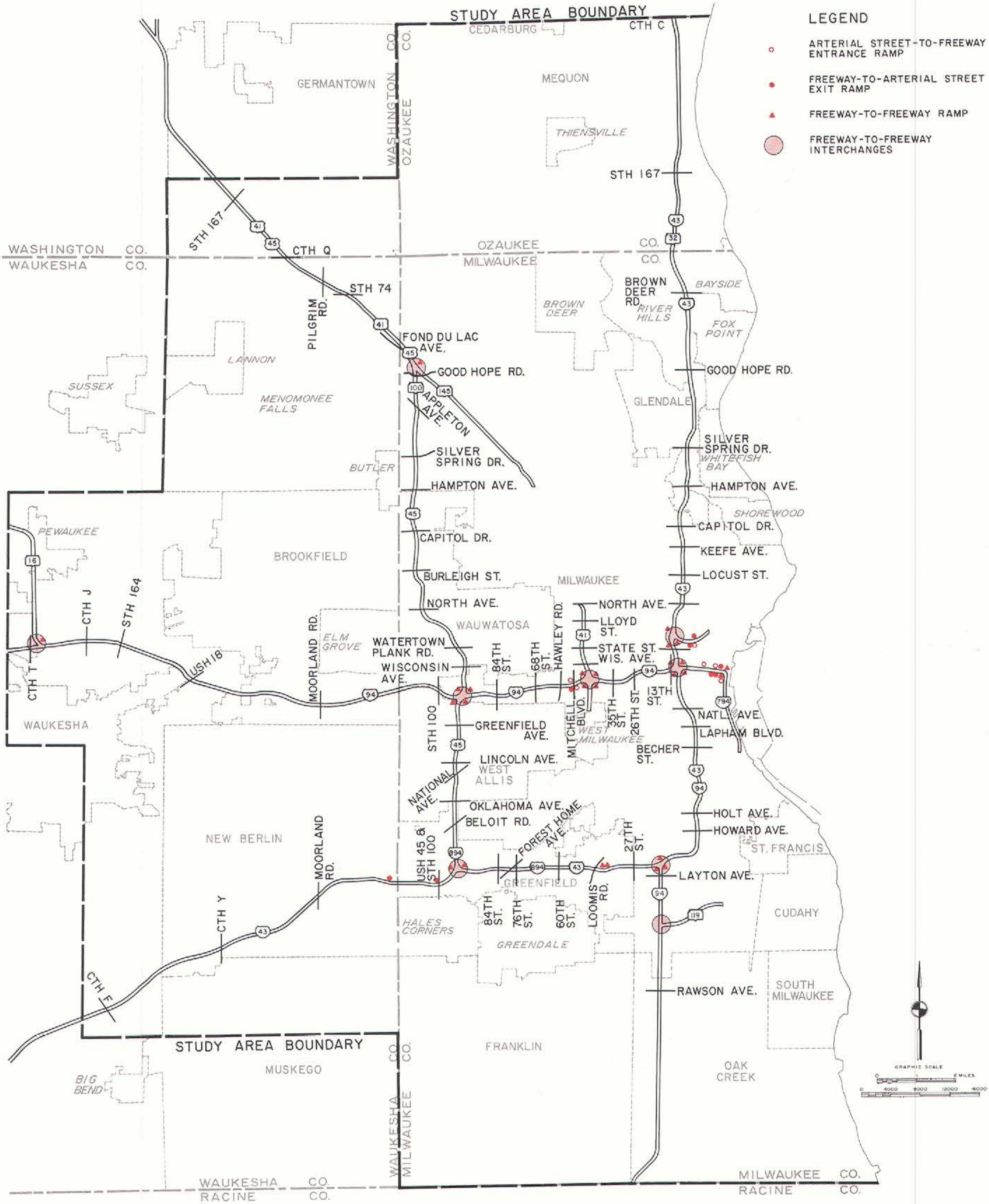


Most of the ramps on the Milwaukee area freeway system are associated with arterial street interchanges. Shown on this map are those ramps in the Milwaukee area that enter or exit the freeway system from the right-hand side of the freeway.

Source: SEWRPC.

Map 6

LOCATION OF LEFT-HAND OR MEDIAN RAMPS ON THE MILWAUKEE AREA FREEWAY SYSTEM

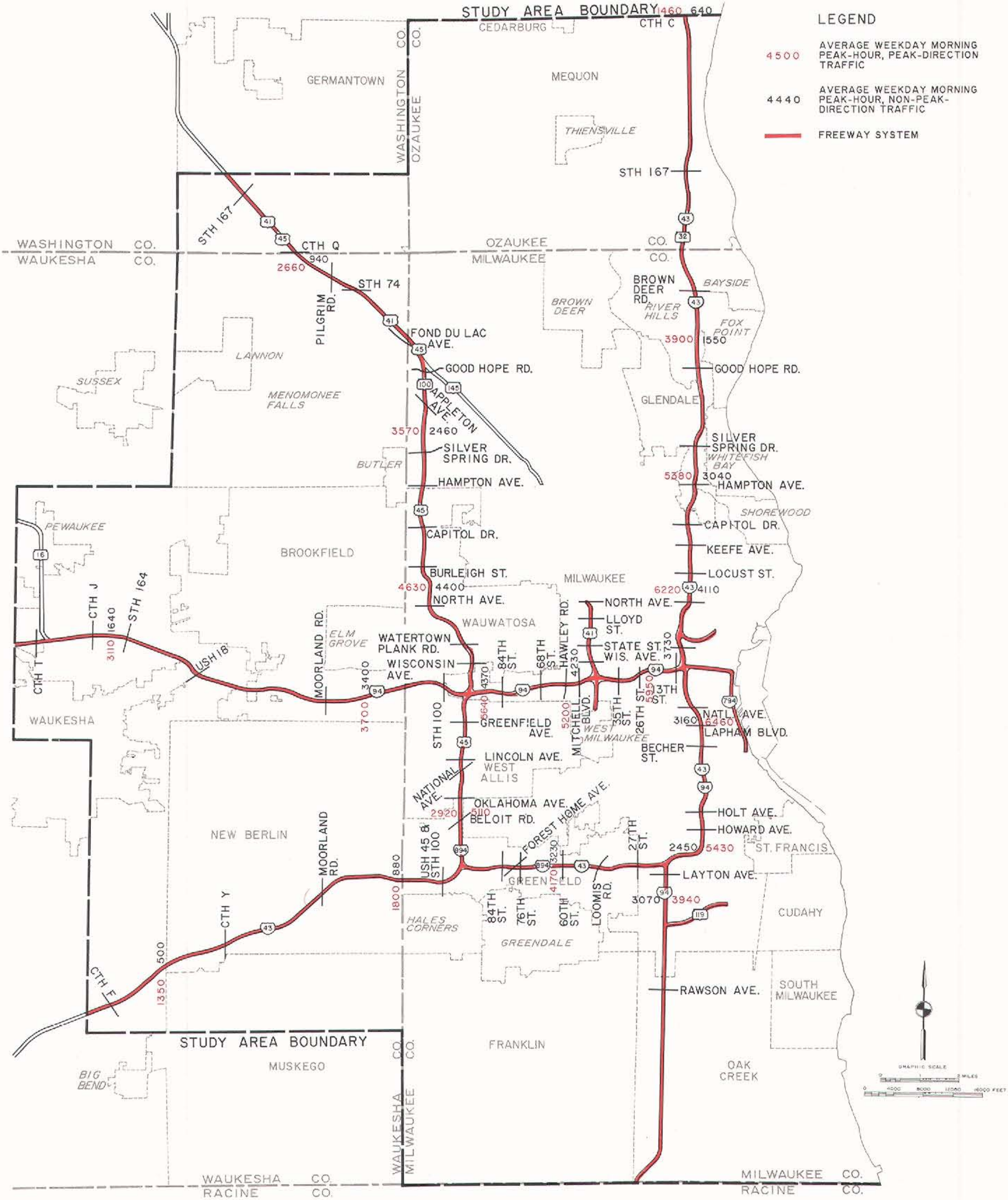


As shown on this map, there are a limited number of arterial street interchanges with the Milwaukee area freeway system served by ramps that enter or exit the freeway system from the left-hand side of the freeway. Also shown are those locations where freeway-to-freeway ramps enter and exit from the left-hand side of the freeway.

Source: SEWRPC.

Map 7

AVERAGE WEEKDAY TRAFFIC ON THE FREEWAY SYSTEM DURING THE MORNING PEAK HOUR: 1986

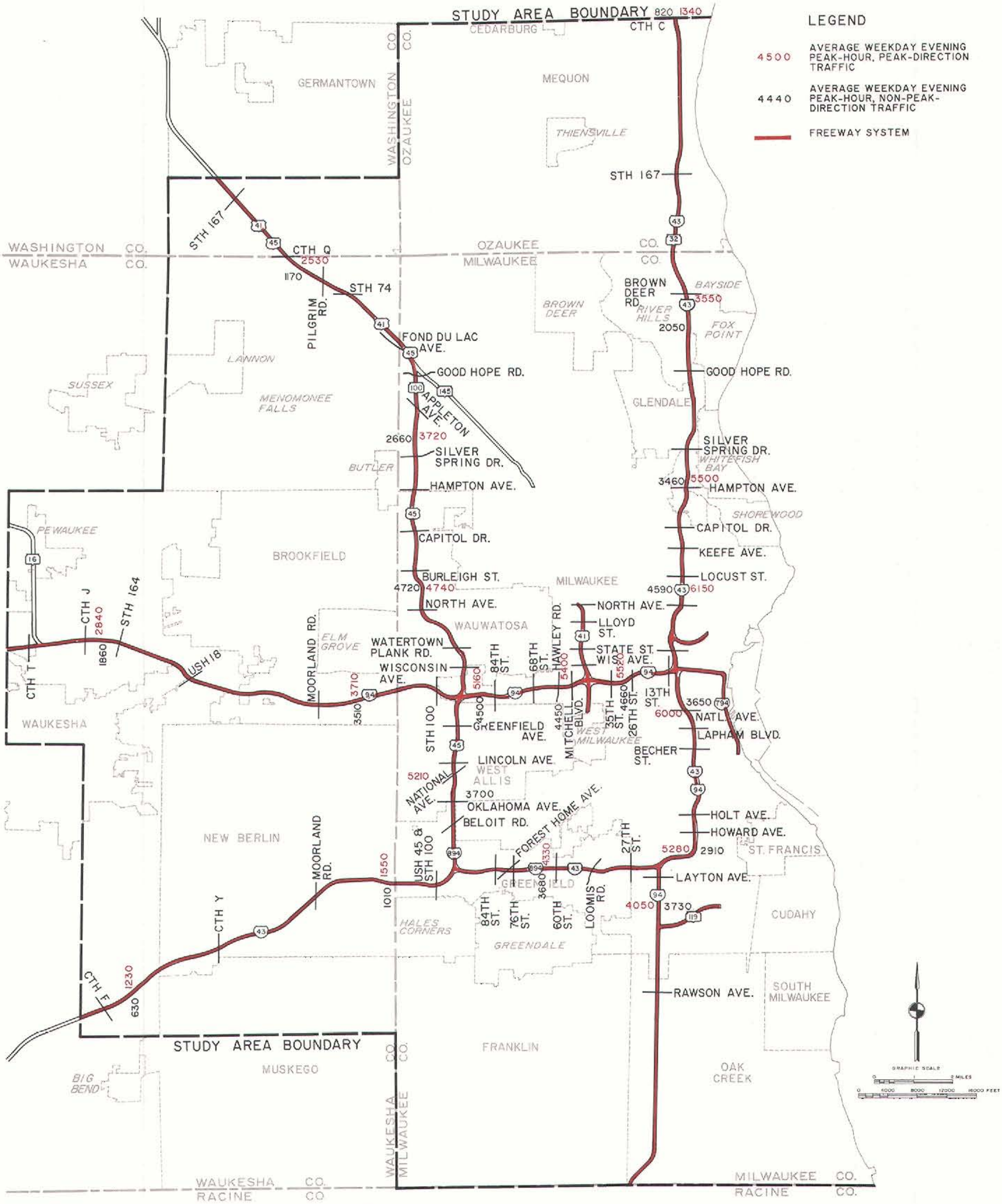


Shown on this map is the average weekday traffic demand on the Milwaukee area freeway system during the morning peak hour in both the peak and nonpeak directions. As might be expected, traffic demand is generally greater on segments of the freeway system within Milwaukee County than on segments in the surrounding counties.

Source: SEWRPC.

Map 8

AVERAGE WEEKDAY TRAFFIC ON THE FREEWAY SYSTEM DURING THE EVENING PEAK HOUR: 1986

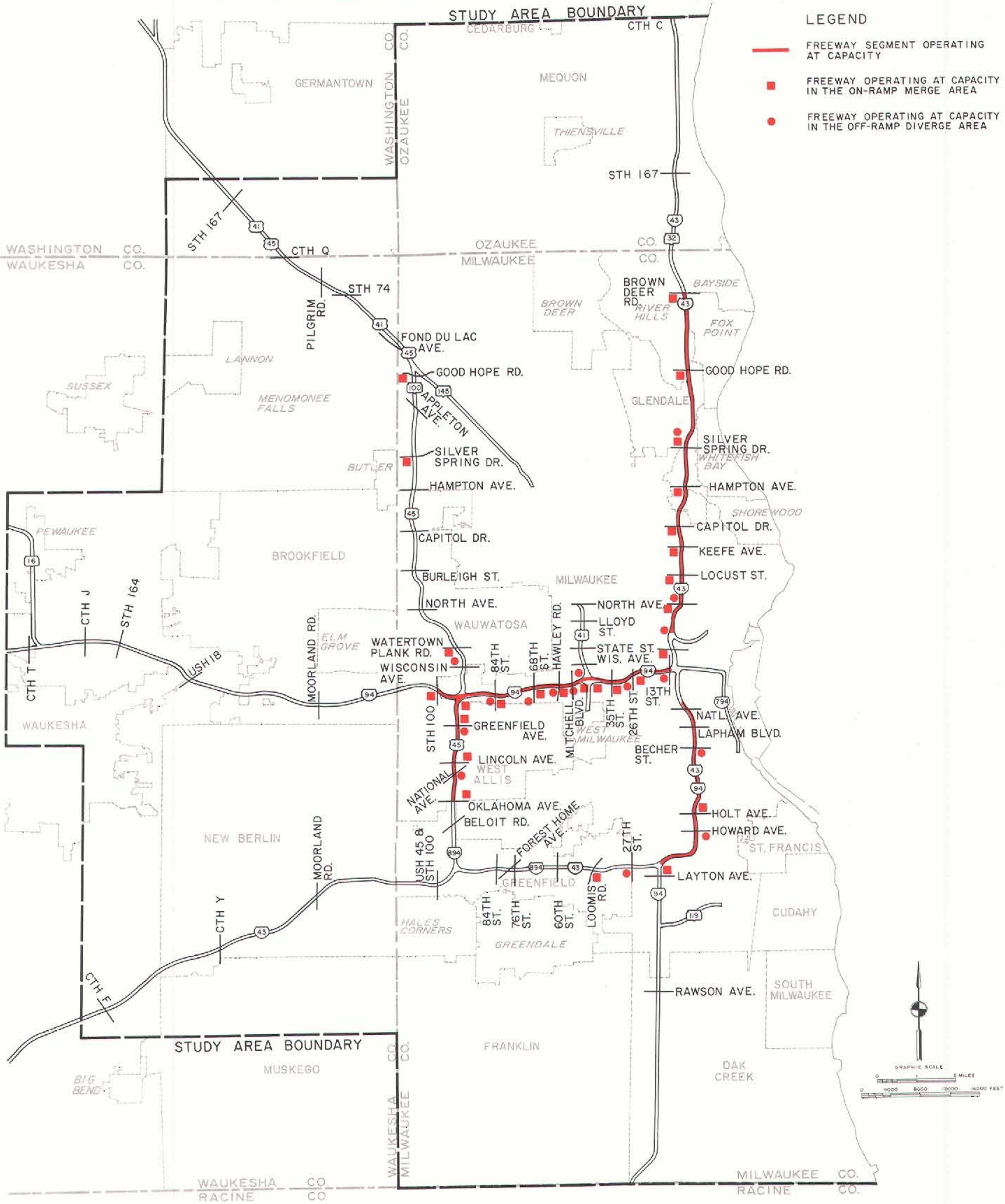


Shown on this map is the average weekday traffic demand on the Milwaukee area freeway system during the evening peak hour in both the peak and nonpeak directions. Again, as might be expected, traffic demand is greater on segments of the freeway system within Milwaukee County than on segments in the surrounding counties.

Source: SEWRPC.

Map 9

FREEWAY SEGMENTS OPERATING AT CAPACITY IN THE PEAK DIRECTION IN THE MILWAUKEE AREA DURING THE MORNING PEAK HOUR: 1986

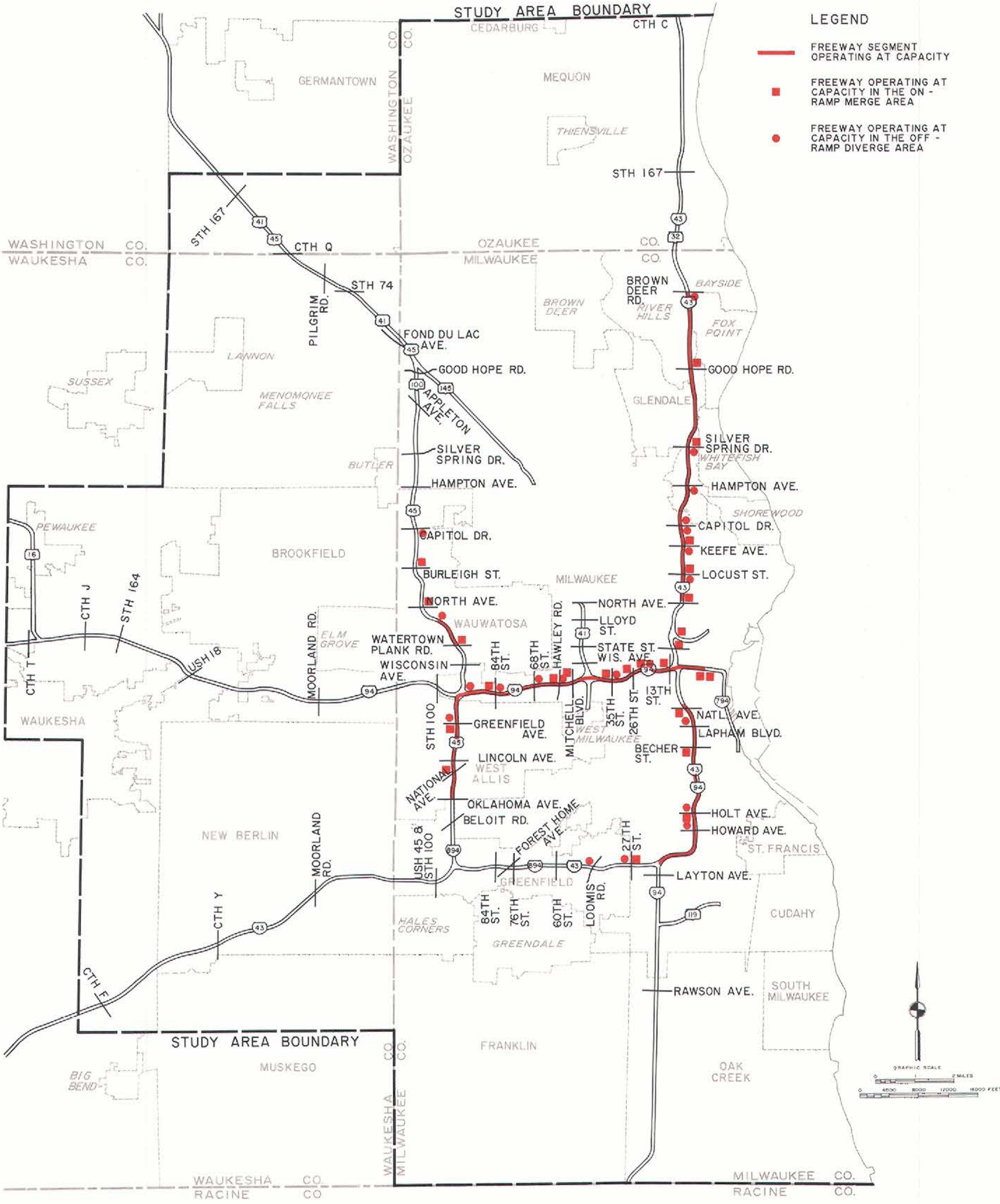


Certain segments of the Milwaukee area freeway system operate at capacity during the morning peak hour, as shown on this map. This means that the traffic demand on a freeway segment is approximately equal to the capacity of the segment. The operating speed on the freeway becomes 30 mph or less, and stop-and-go conditions may develop.

Source: SEWRPC.

Map 10

FREEWAY SEGMENTS OPERATING AT CAPACITY IN THE PEAK DIRECTION IN THE MILWAUKEE AREA DURING THE EVENING PEAK HOUR: 1986



Certain segments of the Milwaukee area freeway system also operate at capacity during the evening peak hour, as shown on this map. As already indicated, on such segments the operating speed becomes 30 mph or less, and stop-and-go conditions may develop.

Source: SEWRPC.

Figure 3

SPEED CONTOURS—IH 94 EAST-WEST FREEWAY: 1983

INBOUND CTH JJ—MILWAUKEE RIVER

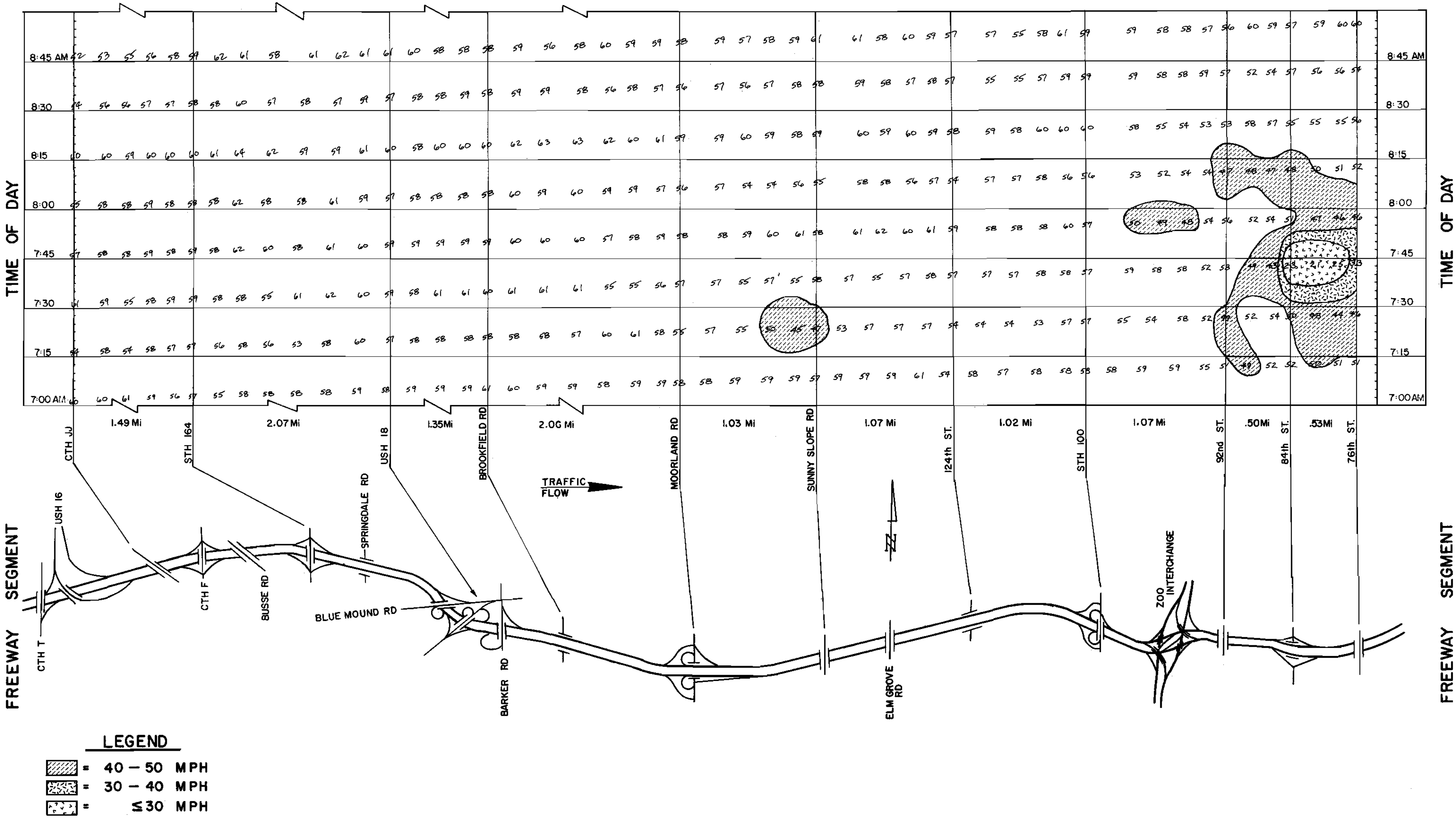
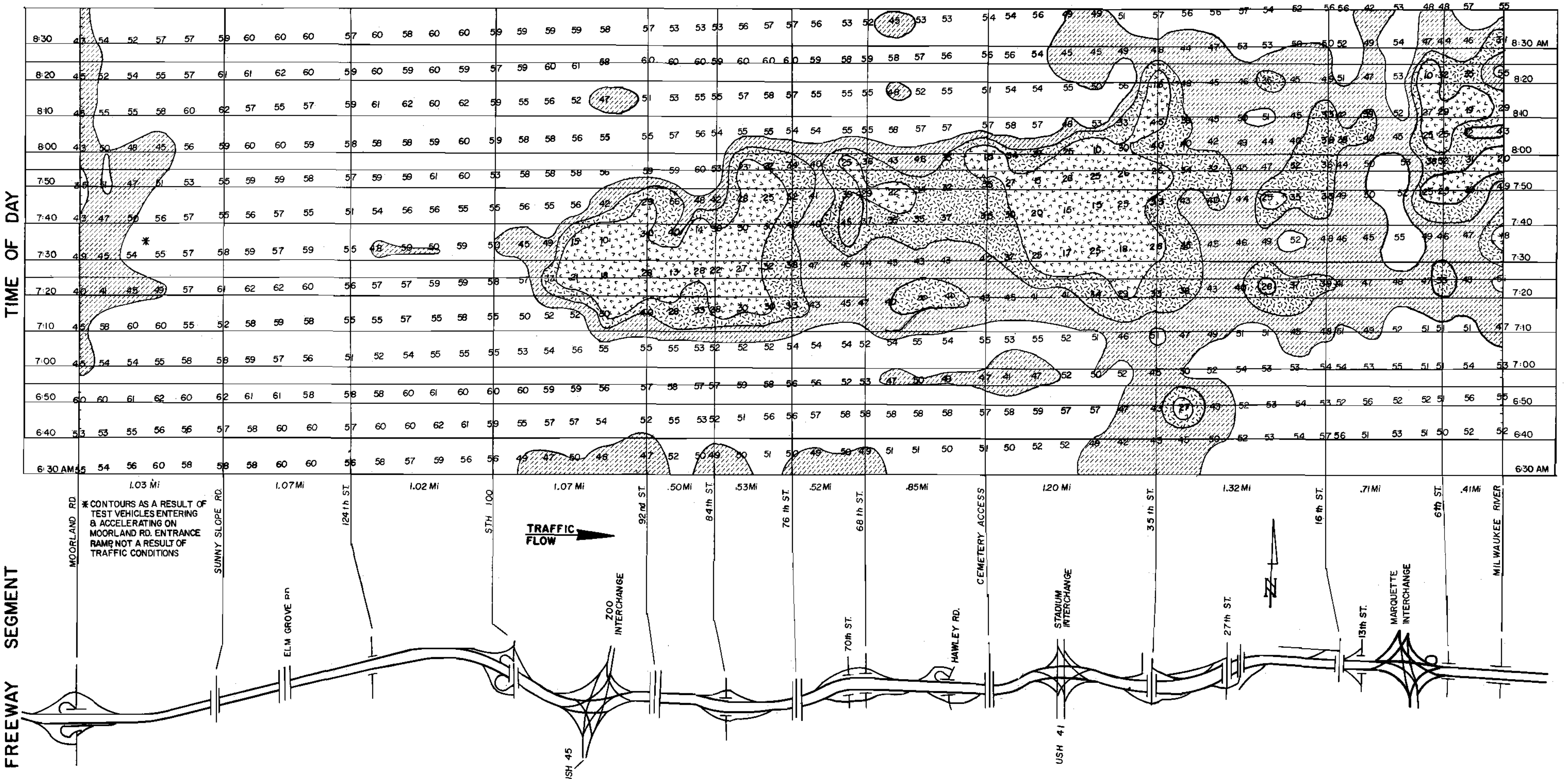
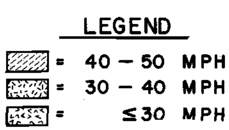


Figure 3 (continued)





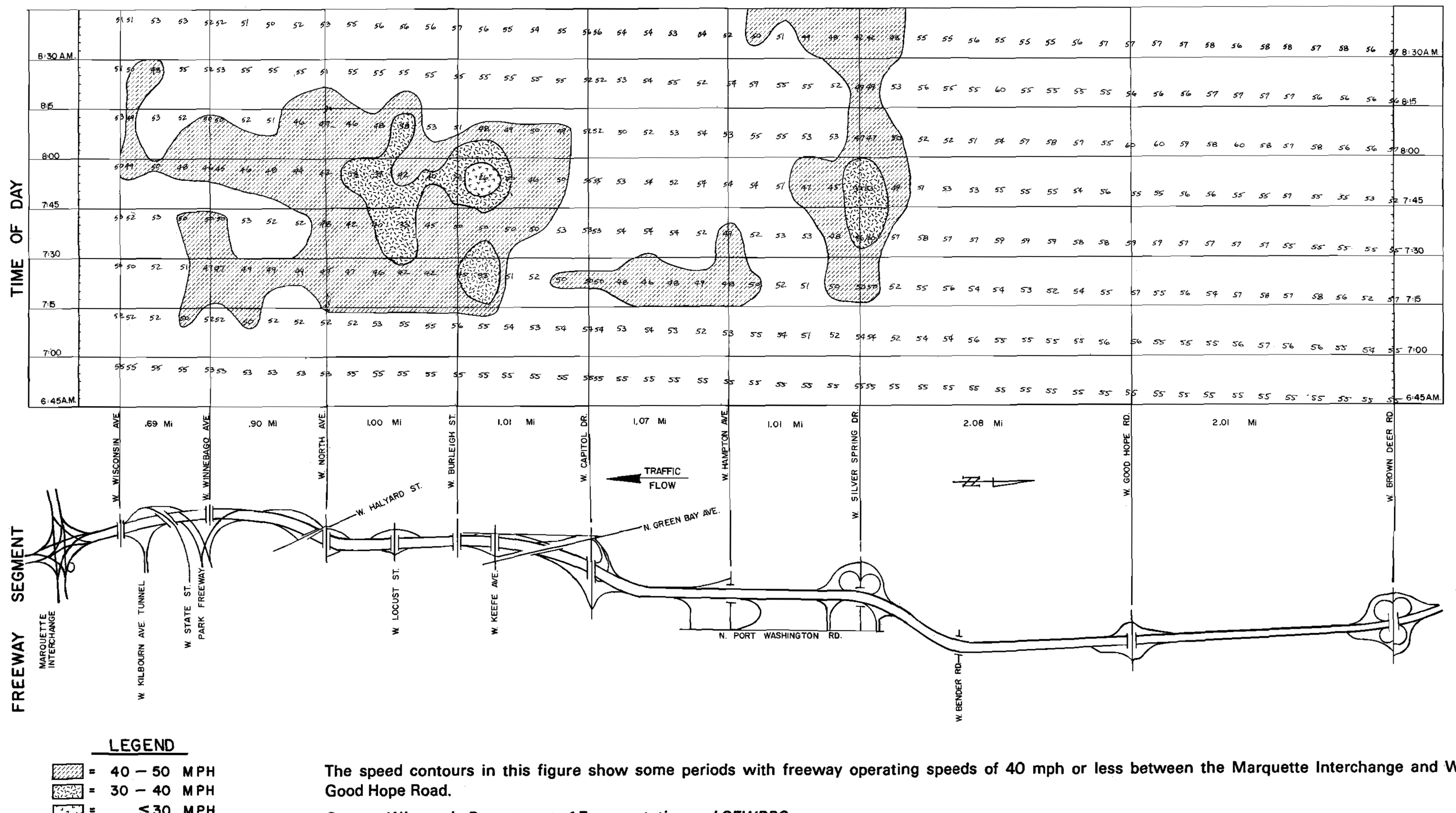
The speed contours in this figure show significant periods with freeway operating speeds of less than 40 mph between the Zoo and Marquette Interchanges.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 4

SPEED CONTOURS—IH 43 NORTH-SOUTH FREEWAY: 1983

INBOUND BROWN DEER ROAD-WISCONSIN AVENUE



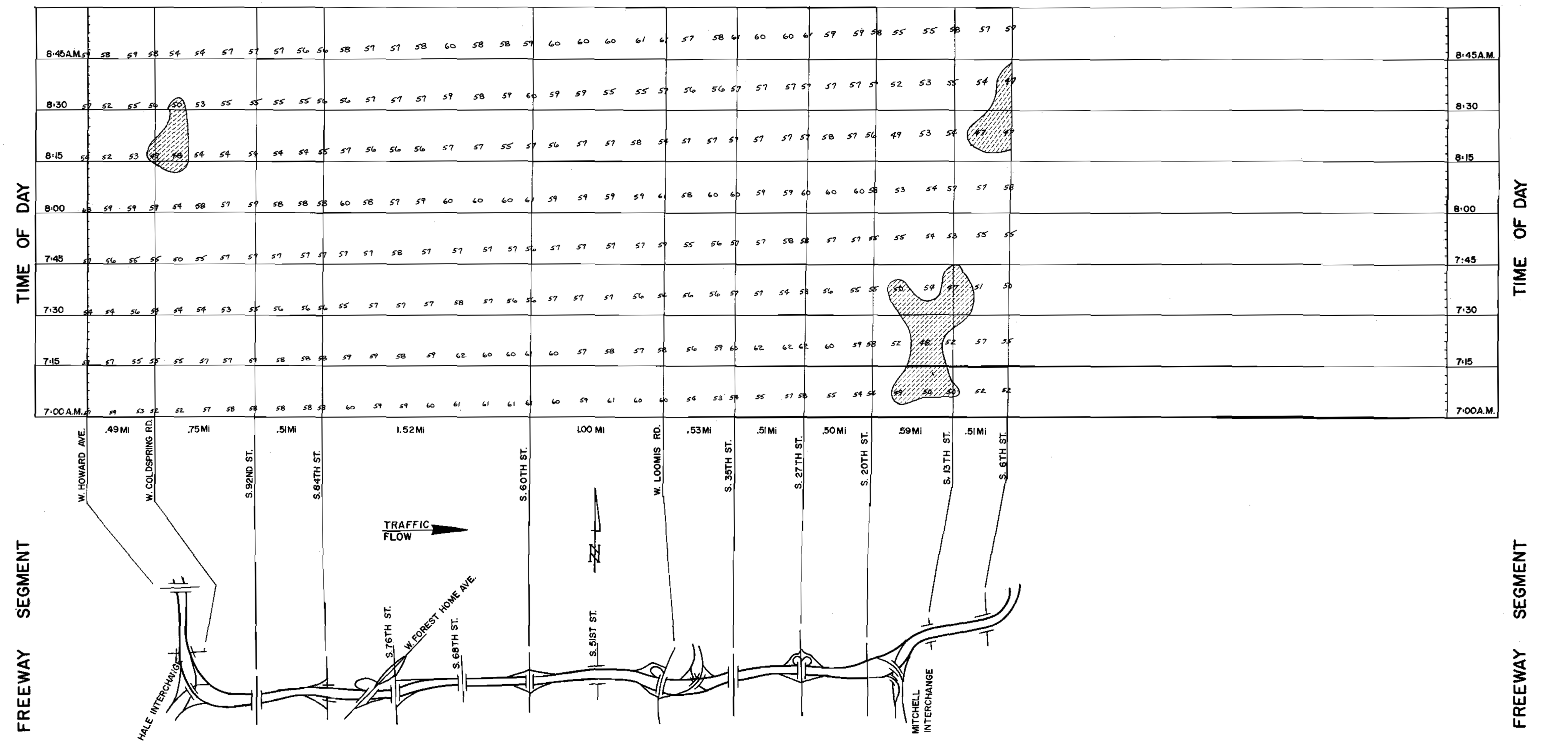
The speed contours in this figure show some periods with freeway operating speeds of 40 mph or less between the Marquette Interchange and W. Good Hope Road.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 5

SPEED CONTOURS—IH 894 AIRPORT FREEWAY: 1983

INBOUND HOWARD AVENUE-S. 6TH STREET



LEGEND

- = 40 – 50 MPH
- = 30 – 40 MPH
- = ≤30 MPH

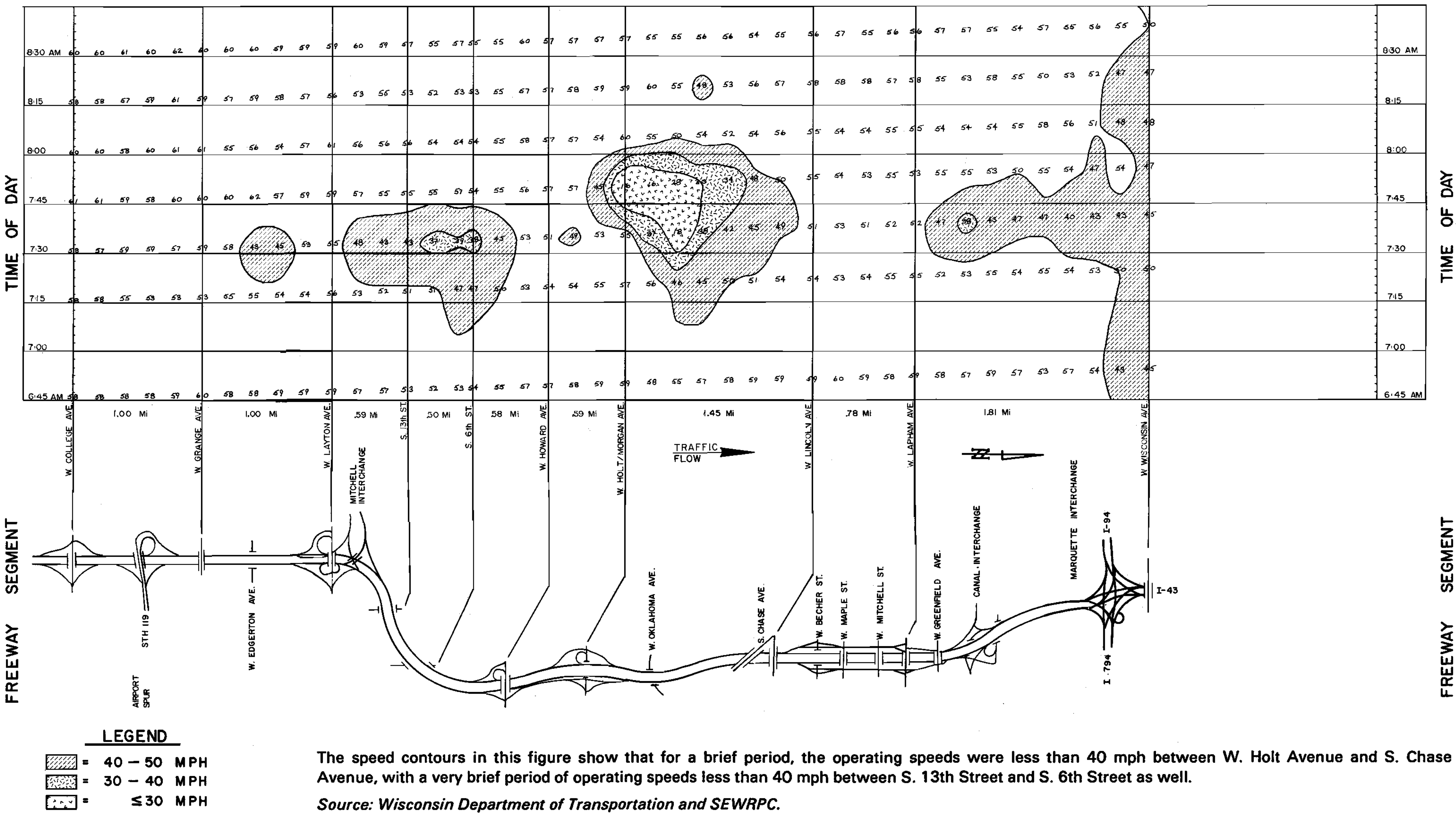
The speed contours in this figure show that operating speeds remained in excess of 40 mph between the Hale and Mitchell Interchanges on IH 894, or the eastern portion of the total freeway segment studied. The remainder of this segment—IH 43 between CTH F and the Hale Interchange—had operating speeds in excess of 40 mph as well.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 6

SPEED CONTOURS—IH 94 NORTH-SOUTH FREEWAY: 1983

INBOUND COLLEGE AVENUE-WISCONSIN AVENUE



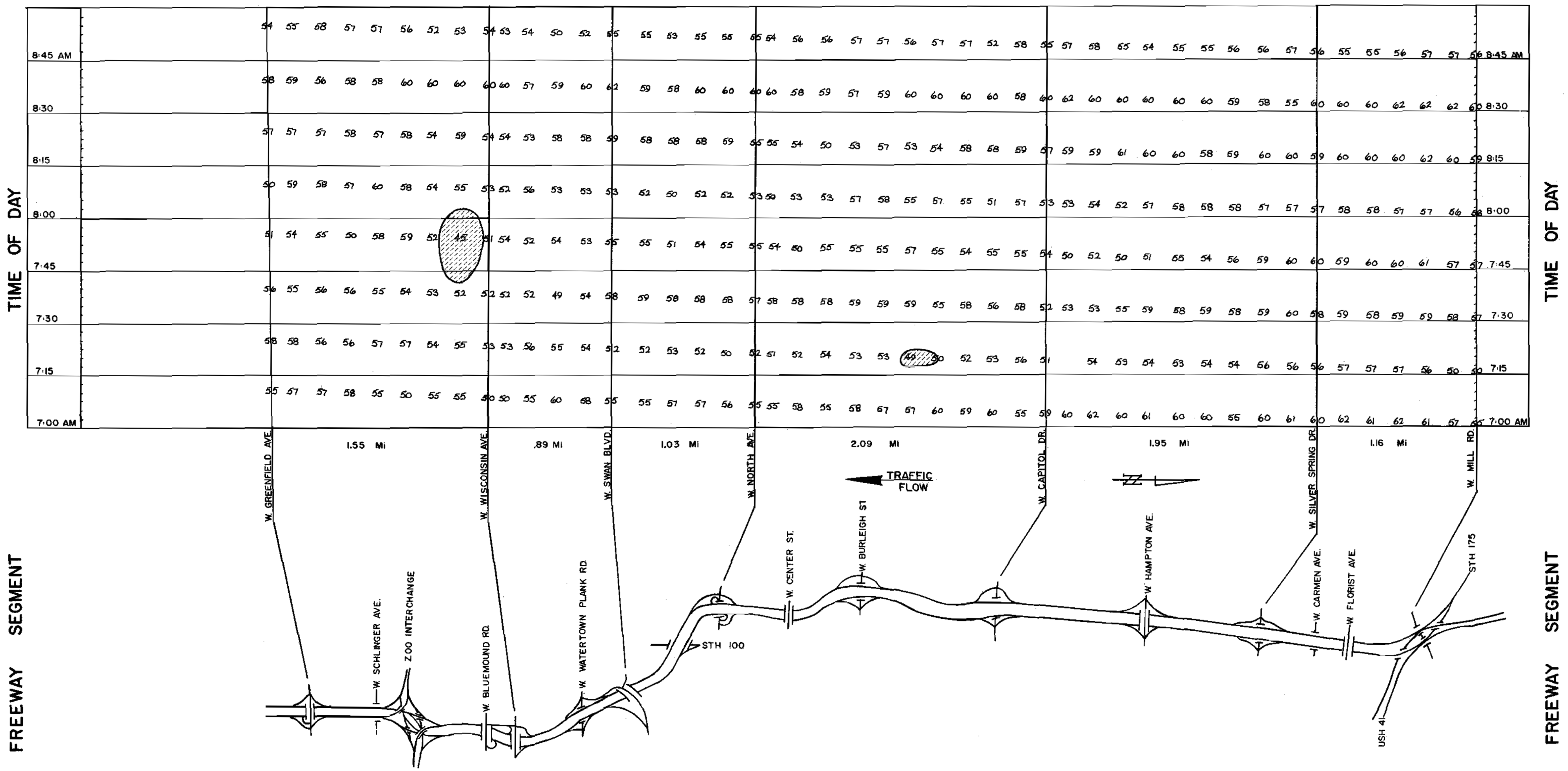
The speed contours in this figure show that for a brief period, the operating speeds were less than 40 mph between W. Holt Avenue and S. Chase Avenue, with a very brief period of operating speeds less than 40 mph between S. 13th Street and S. 6th Street as well.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 7

SPEED CONTOURS—USH 45 ZOO FREEWAY: 1983

INBOUND MILL ROAD-GREENFIELD AVENUE



LEGEND

- 40 – 50 MPH
- 30 – 40 MPH
- ≤30 MPH

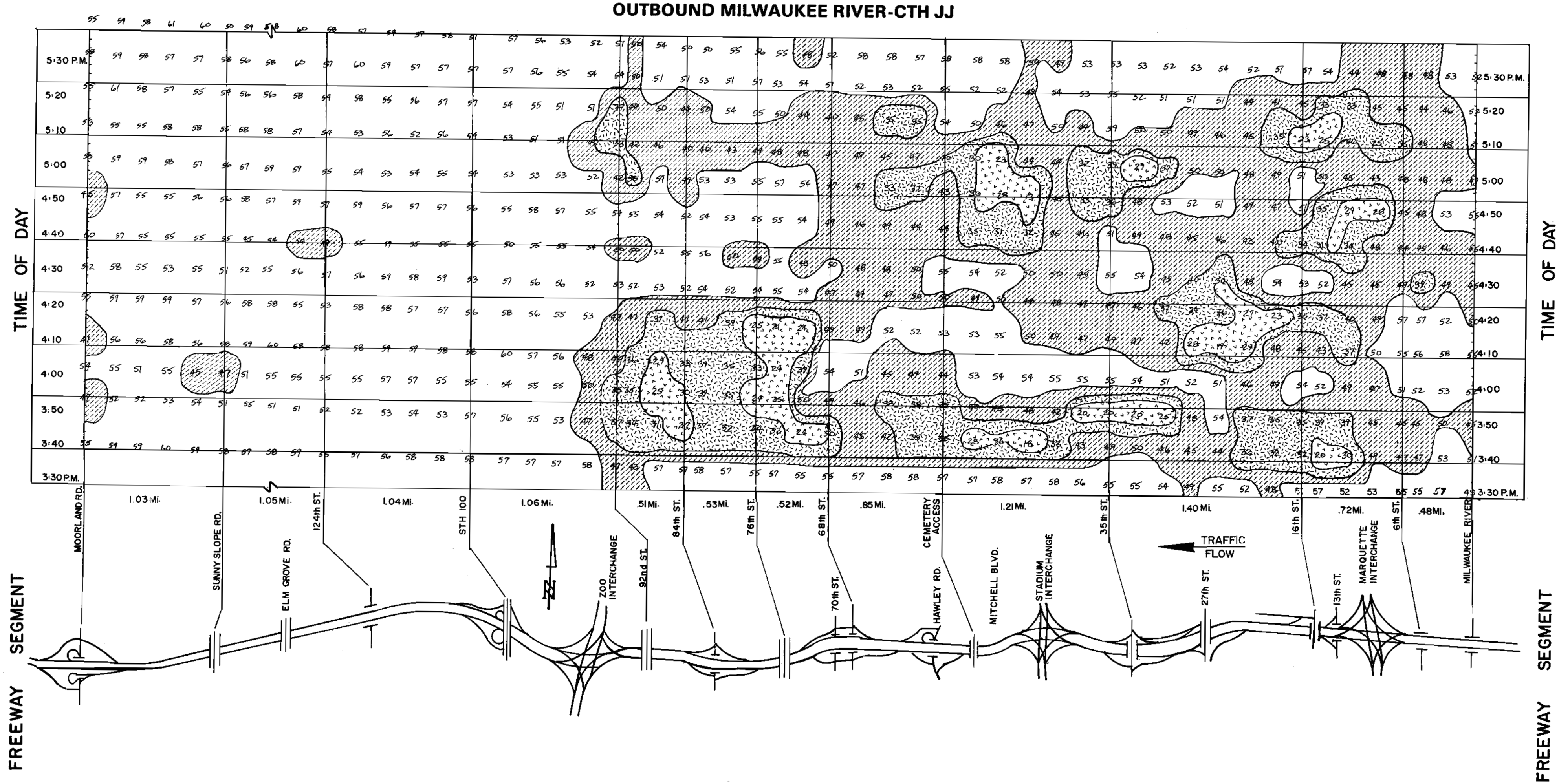
The speed contours in this figure show that freeway operating speeds remained in excess of 40 mph between STH 175 and the Zoo Interchange, which represents the southern portion of the total segment studied. The remainder of the northern portion of this segment—from CTH Y in Washington County to STH 175—had operating speeds in excess of 40 mph as well.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 8

SPEED CONTOURS—IH 94 EAST-WEST FREEWAY: 1983

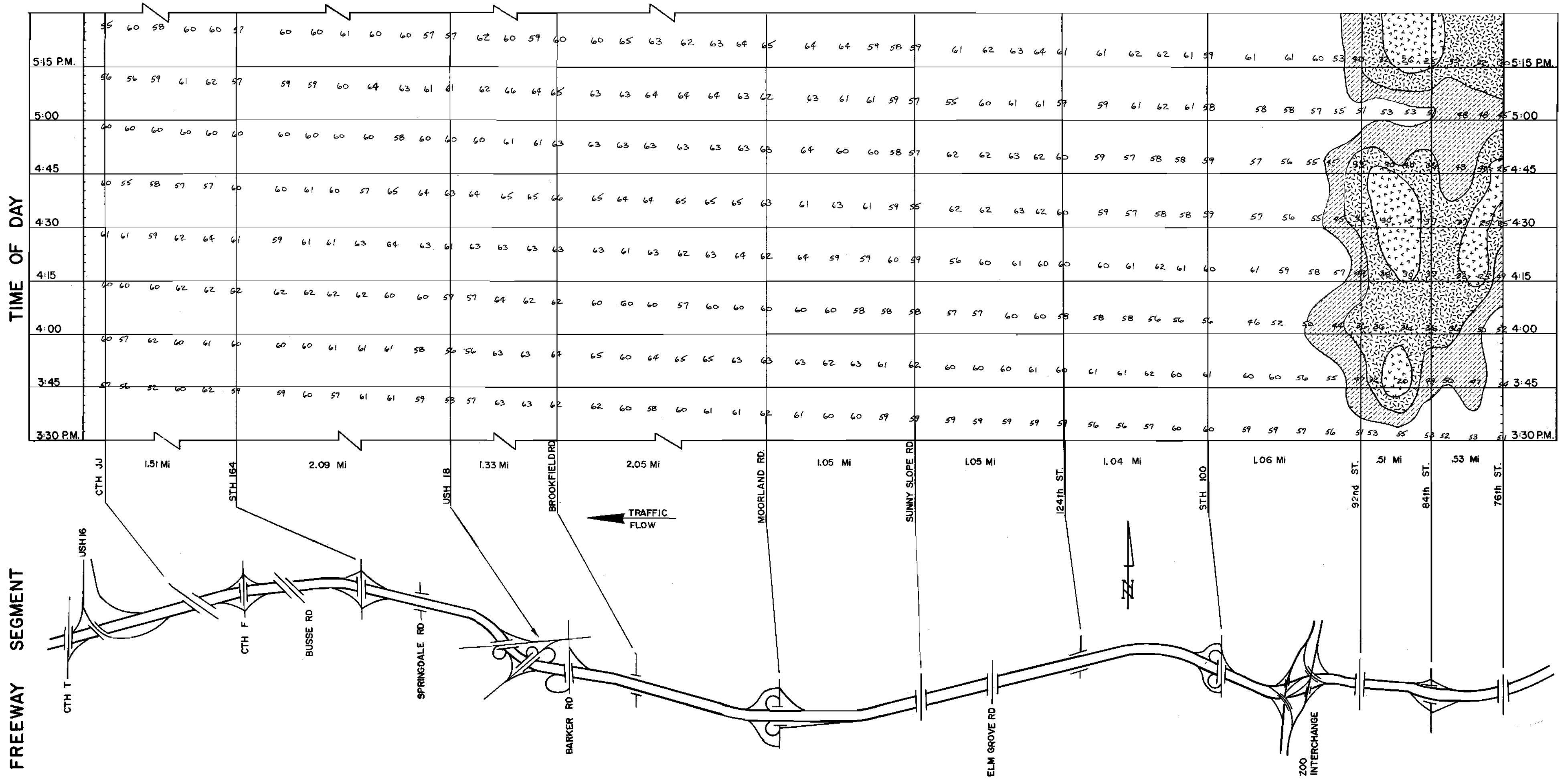
OUTBOUND MILWAUKEE RIVER-CTH JJ



LEGEND

- = 40 – 50 MPH
- = 30 – 40 MPH
- = ≤30 MPH

Figure 8 (continued)



LEGEND

- = 40 – 50 MPH
- = 30 – 40 MPH
- = ≤30 MPH

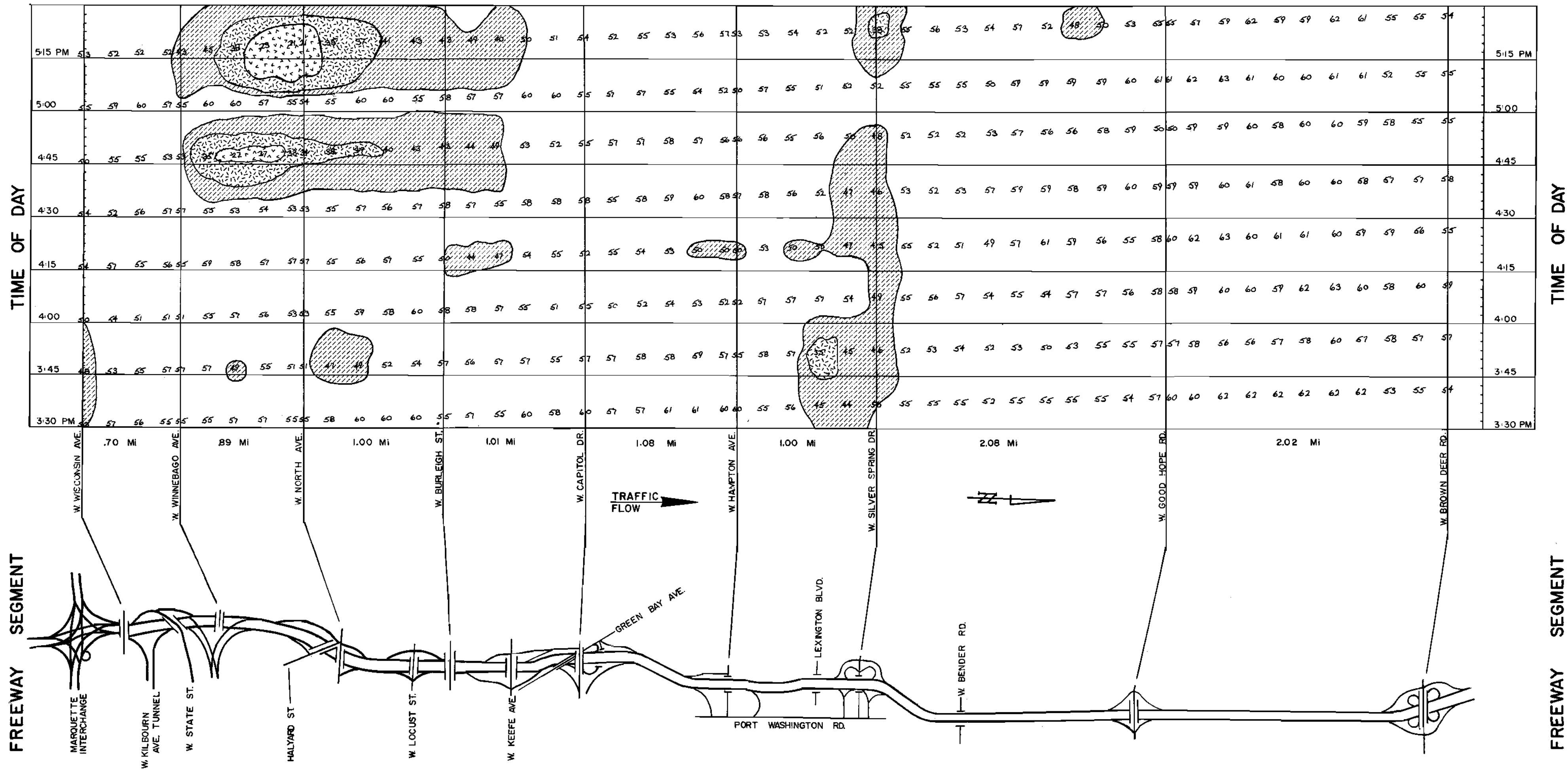
The speed contours in this figure show significant periods of freeway operating speeds of 40 mph or less between the Marquette and Zoo Interchanges.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 9

SPEED CONTOURS—IH 43 NORTH-SOUTH FREEWAY: 1983

OUTBOUND WISCONSIN AVENUE-BROWN DEER ROAD



LEGEND

= 40 – 50 MPH

= 30 – 40 MPH

= ≤30 MPH

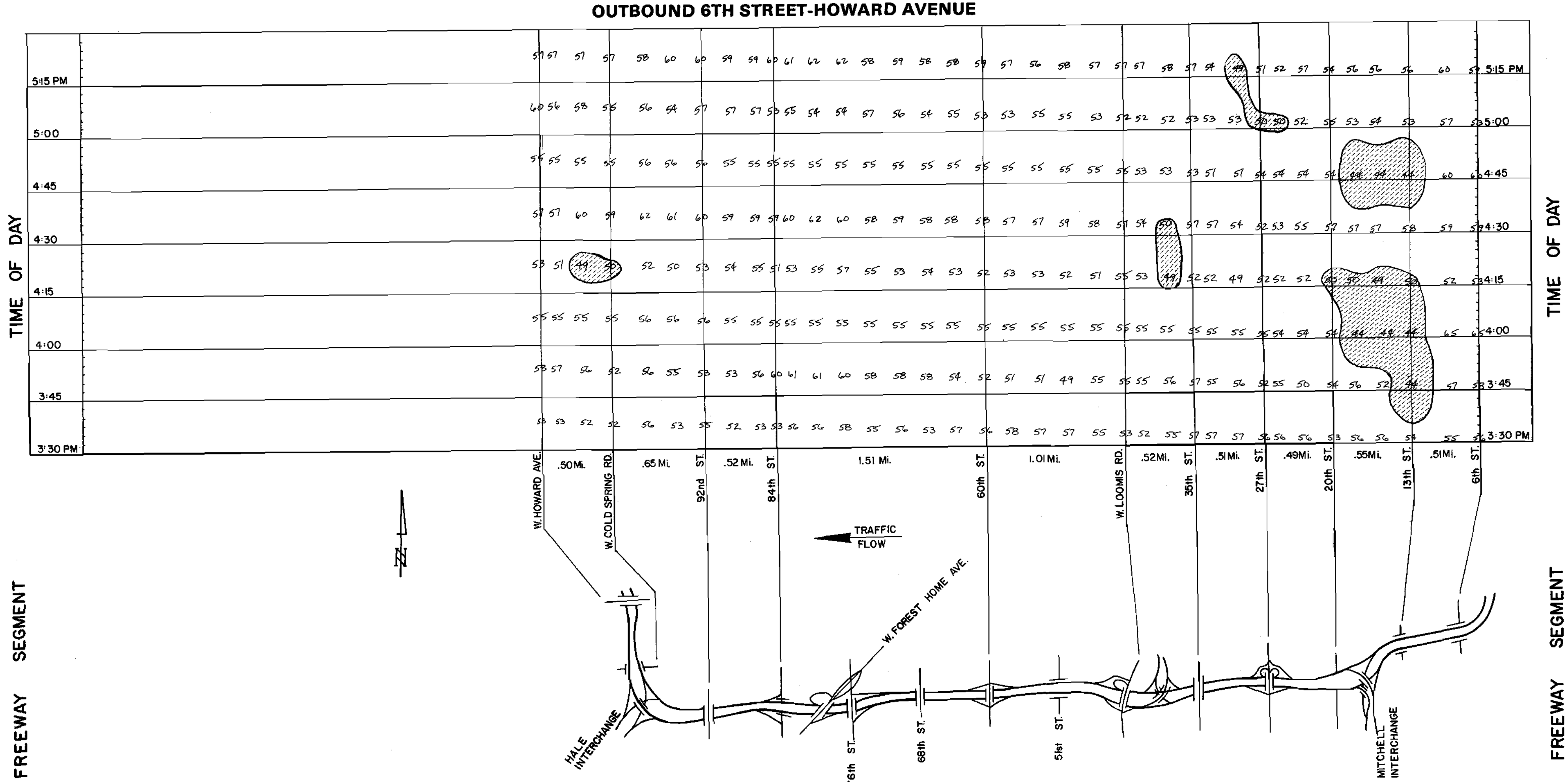
The speed contours in this figure show that for brief periods, the operating speeds were 40 mph or less between the Hillside Interchange and W. Burleigh Street in the southern portion of the total freeway segment studied. The northern portion of the segment—between W. Brown Deer Road and CTH C in Ozaukee County—had operating speeds in excess of 40 mph.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 10

SPEED CONTOURS—IH 894 AIRPORT FREEWAY: 1983

OUTBOUND 6TH STREET-HOWARD AVENUE



LEGEND

- = 40 – 50 MPH
- = 30 – 40 MPH
- = ≤30 MPH

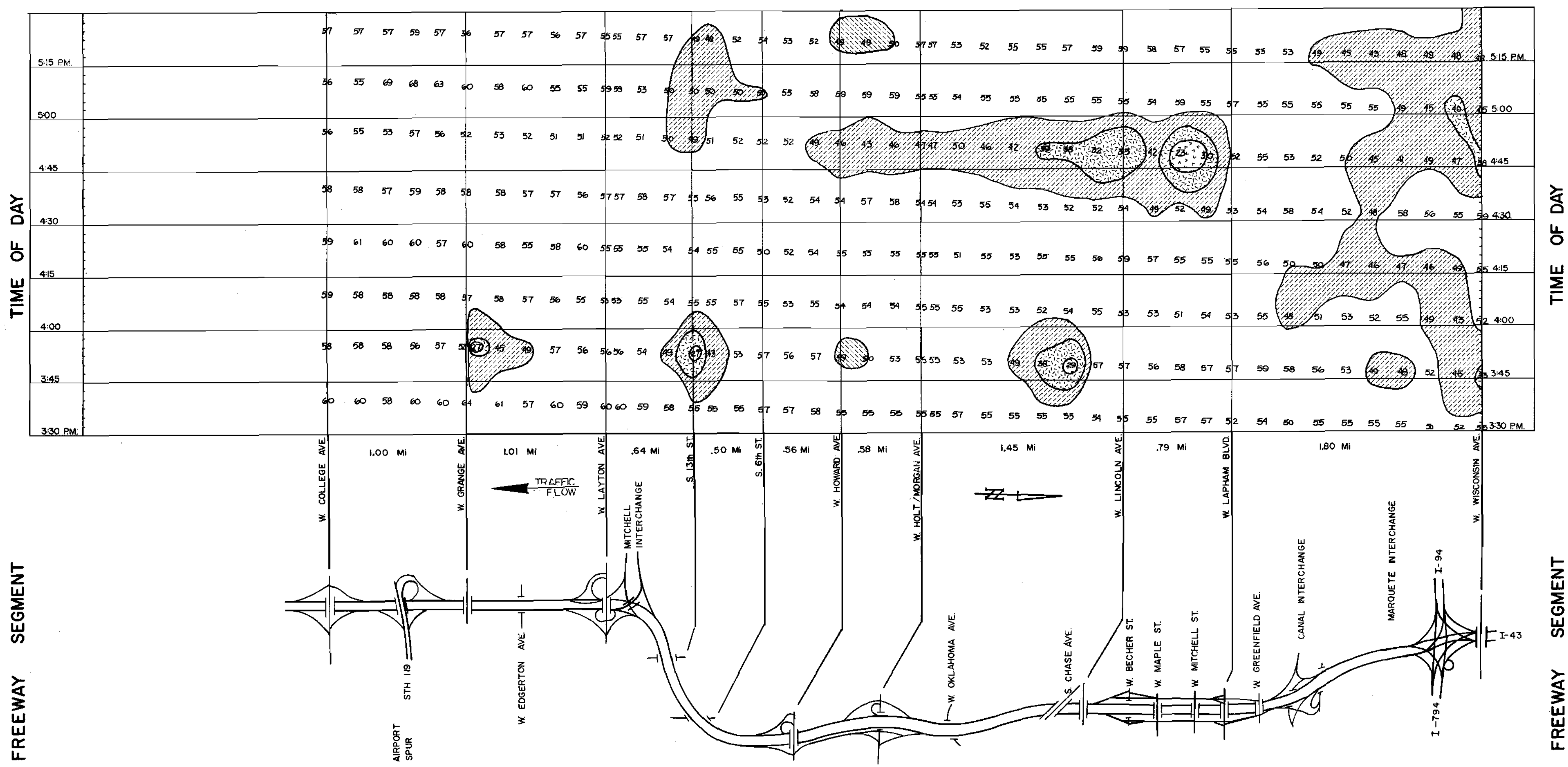
The speed contours in this figure show that operating speeds remained in excess of 40 mph between the Hale and Mitchell Interchanges on IH 94, or the eastern portion of the total freeway segment studied. The western portion of the segment—IH 43 between CTH F in Waukesha County and the Hale Interchange—had operating speeds in excess of 40 mph as well.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 11

SPEED CONTOURS—IH 94 NORTH-SOUTH FREEWAY: 1983

OUTBOUND WISCONSIN AVENUE-COLLEGE AVENUE



LEGEND

- = 40 – 50 MPH
- = 30 – 40 MPH
- = ≤30 MPH

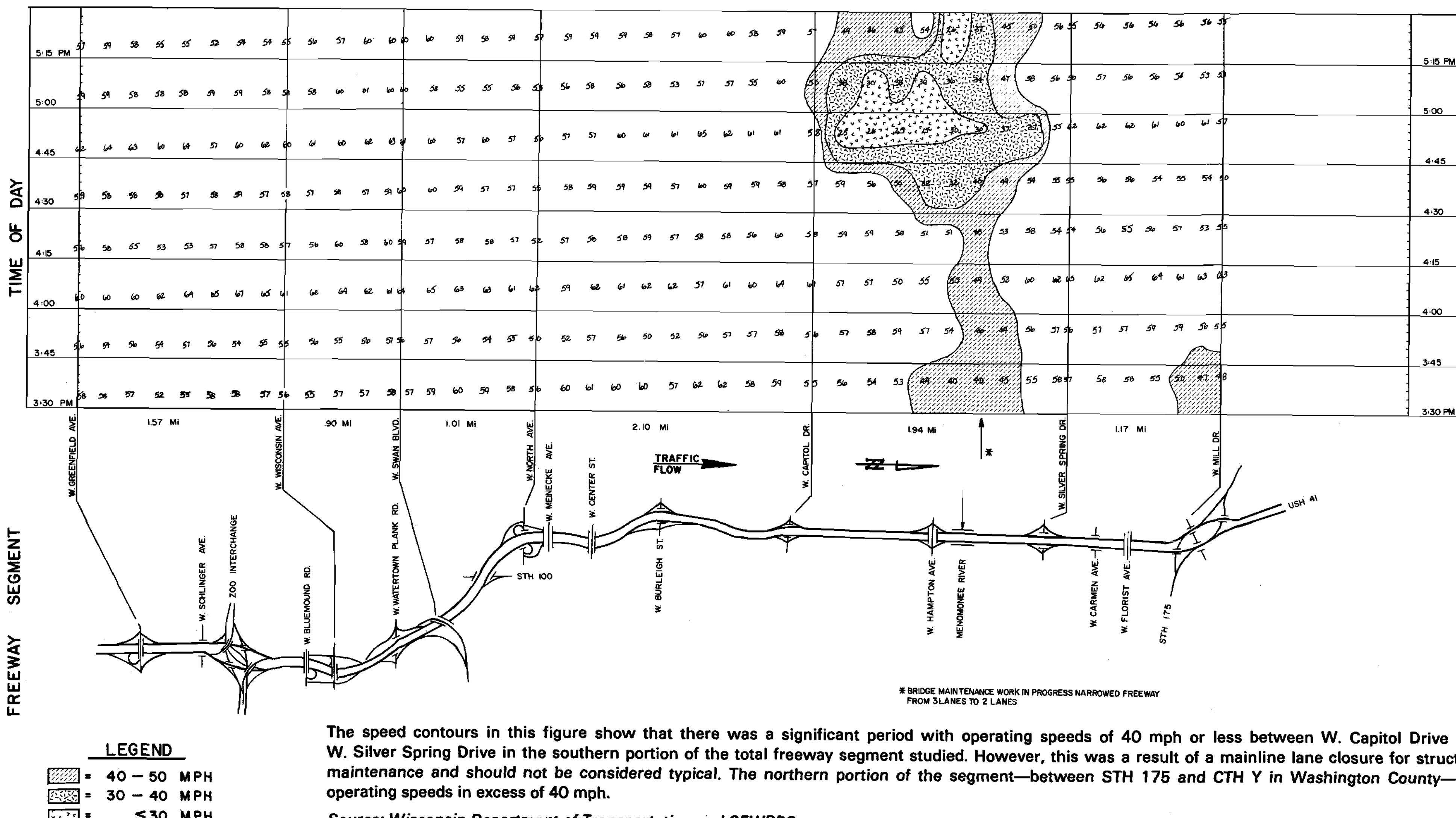
The speed contours in this figure show brief periods of operating speeds of 40 mph or less between S. Chase Avenue and W. Lapham Boulevard and at S. 13th Street in the northern portion of the total freeway segment studied. The southern portion of the segment—between the Milwaukee/Racine County line and W. College Avenue—had operating speeds in excess of 40 mph.

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 12

SPEED CONTOURS—USH 45 ZOO FREEWAY: 1983

OUTBOUND GREENFIELD AVENUE-MILL ROAD



The speed contours in this figure show that there was a significant period with operating speeds of 40 mph or less between W. Capitol Drive and W. Silver Spring Drive in the southern portion of the total freeway segment studied. However, this was a result of a mainline lane closure for structure maintenance and should not be considered typical. The northern portion of the segment—between STH 175 and CTH Y in Washington County—had operating speeds in excess of 40 mph.

Source: Wisconsin Department of Transportation and SEWRPC.

Table 3

SUMMARY OF DATA COLLECTED DURING LICENSE PLATE SURVEYS: 1983

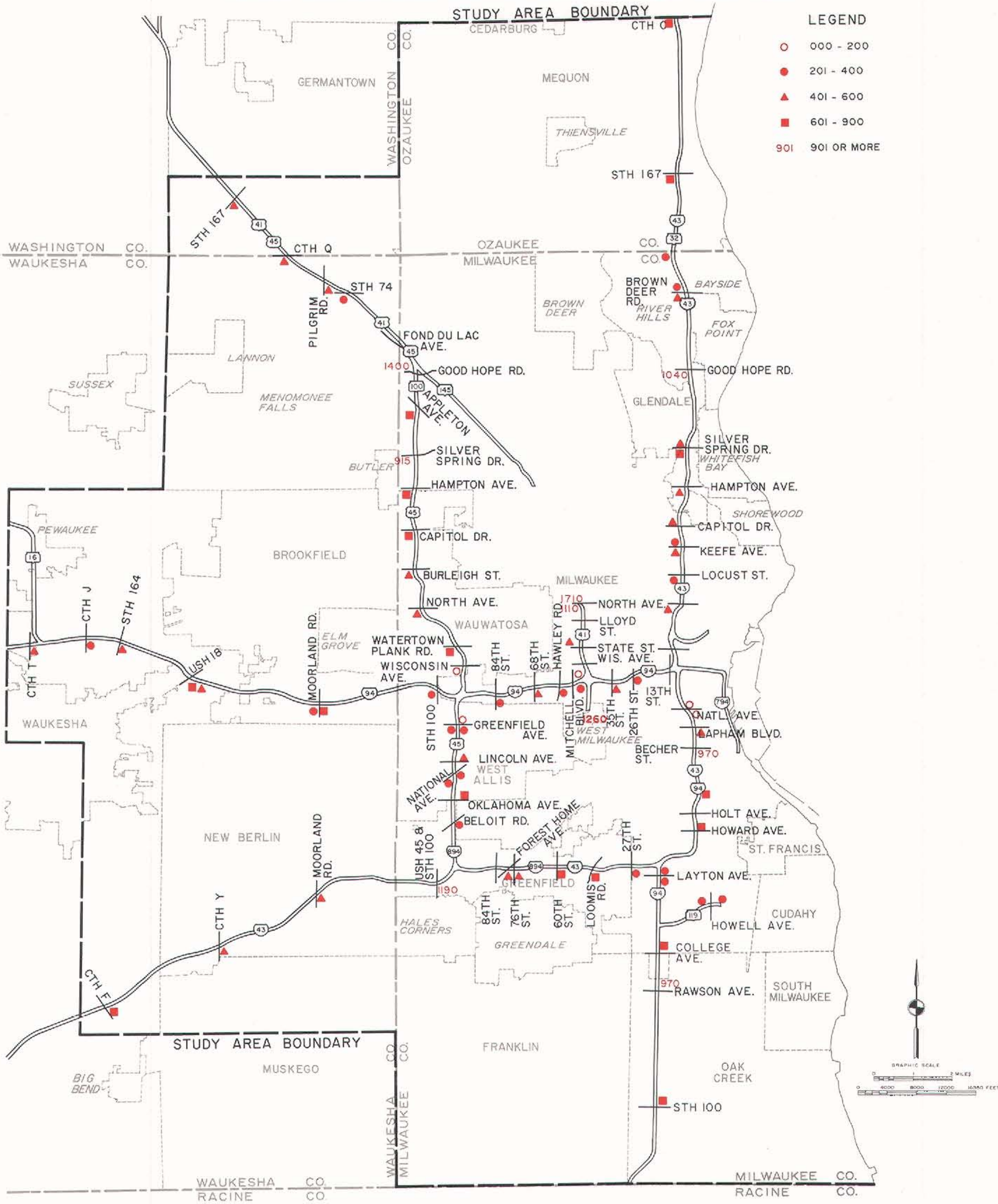
Segment	Survey Date	Time Period	Total Observations	"No Plate" Or Missed Number	"No Plate" Or Missed Percent of Total	Matchable Plates
IH43S	March 29, 1983	a.m.	38,260	4,140	10.8	34,120
IH894NE	April 5, 1983	a.m.	29,387	3,063	10.4	26,324
IH894SW	April 7, 1983	a.m.	46,823	6,066	13.0	40,767
IH94N	April 26, 1983	a.m.	45,684	5,044	11.0	40,640
IH94E1	May 3, 1983	a.m.	45,572	3,857	8.5	41,715
IH94E2	May 10, 1983	a.m.	52,763	3,857	7.3	48,905
IH94E3	May 11, 1983	a.m.	52,173	4,446	8.5	47,727
USH45SE	May 17, 1983	a.m.	46,507	6,288	13.5	40,219
IH43N	April 27, 1983	p.m.	57,476	8,469	14.7	49,007
IH94W1	May 4, 1983	p.m.	67,648	5,056	7.5	62,592
IH94W2	May 5, 1983	p.m.	61,279	5,265	8.6	56,014
IH94W3	May 12, 1983	p.m.	49,971	3,861	7.7	46,110
IH94S	April 28, 1983	p.m.	56,394	5,147	9.1	51,247
USH45NW	October 18, 1983[a]	p.m.	37,380	3,254	8.7	34,126
Total	- -	- -	687,317	67,813	9.9	619,504

[a]*Initially scheduled for May 18, 1983, but rained out.*

Source: SEWRPC.

Map 11

TOTAL ENTERING VOLUME AT SELECTED MILWAUKEE AREA FREEWAY ON-RAMPS DURING THE MORNING PEAK HOUR: 1986

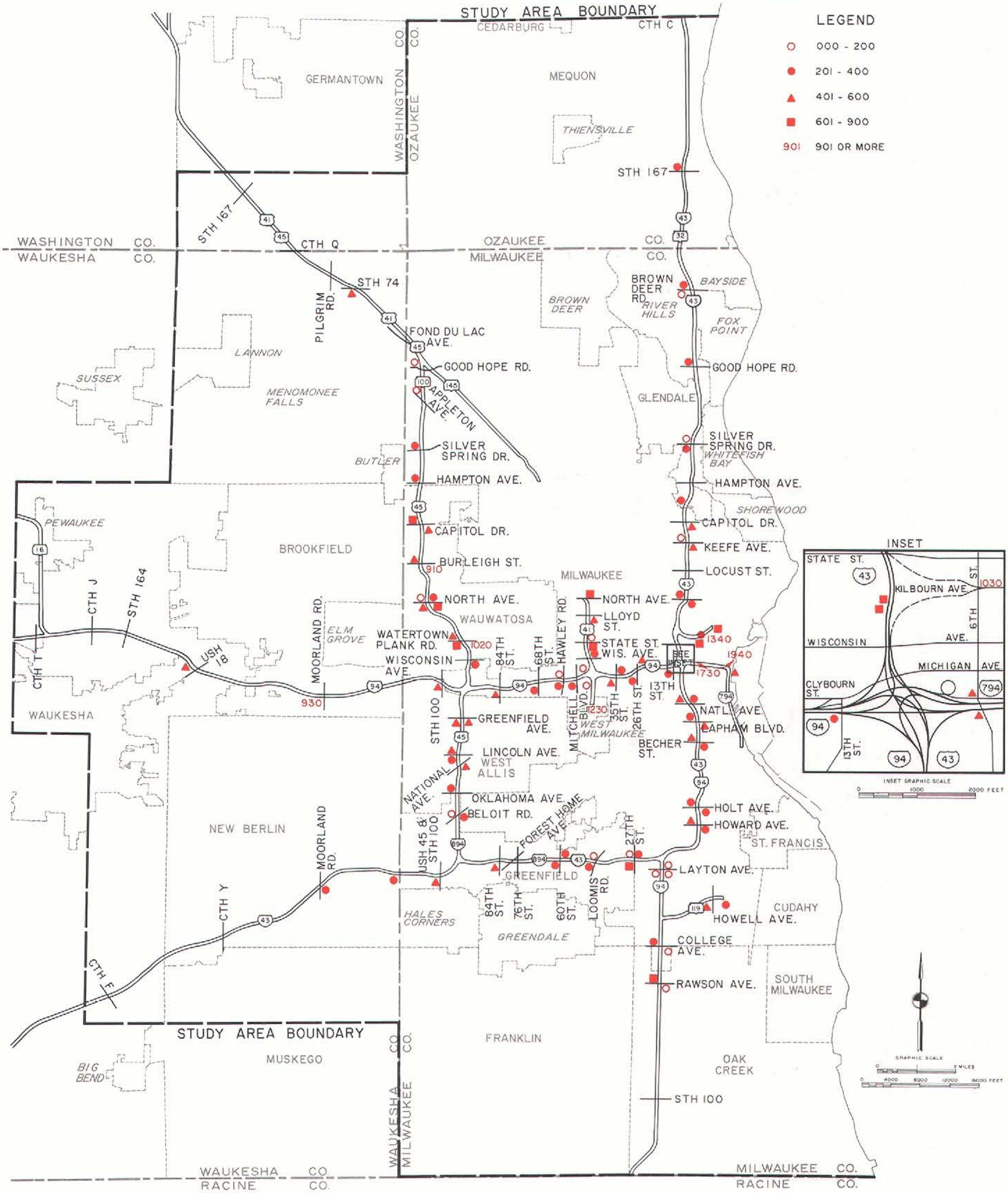


The traffic demand on a freeway segment is dependent on the traffic on that segment as it enters the Milwaukee area freeway system—some of which is "through" traffic—and on the traffic volume entering and exiting upstream of the segment via ramps at arterial street interchanges. This map shows the traffic volumes entering the Milwaukee area freeway system during the morning peak hour.

Source: SEWRPC.

Map 12

TOTAL EXITING VOLUME AT SELECTED MILWAUKEE AREA FREEWAY OFF-RAMPS DURING THE MORNING PEAK HOUR: 1986

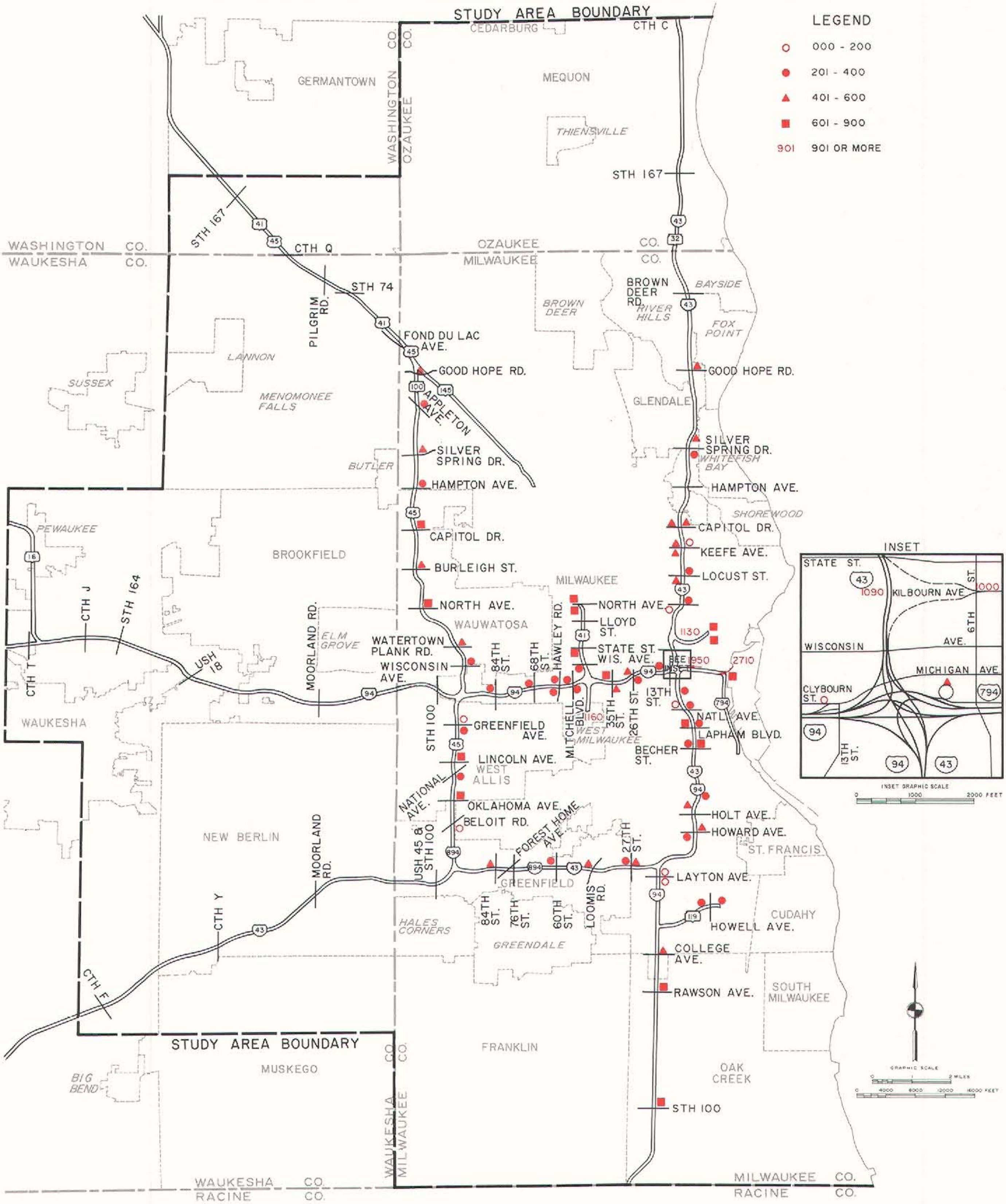


This map shows the traffic volumes exiting the Milwaukee area freeway system during the morning peak hour.

Source: SEWRPC.

Map 13

TOTAL ENTERING VOLUME AT SELECTED MILWAUKEE AREA FREEWAY ON-RAMPS DURING THE EVENING PEAK HOUR: 1986

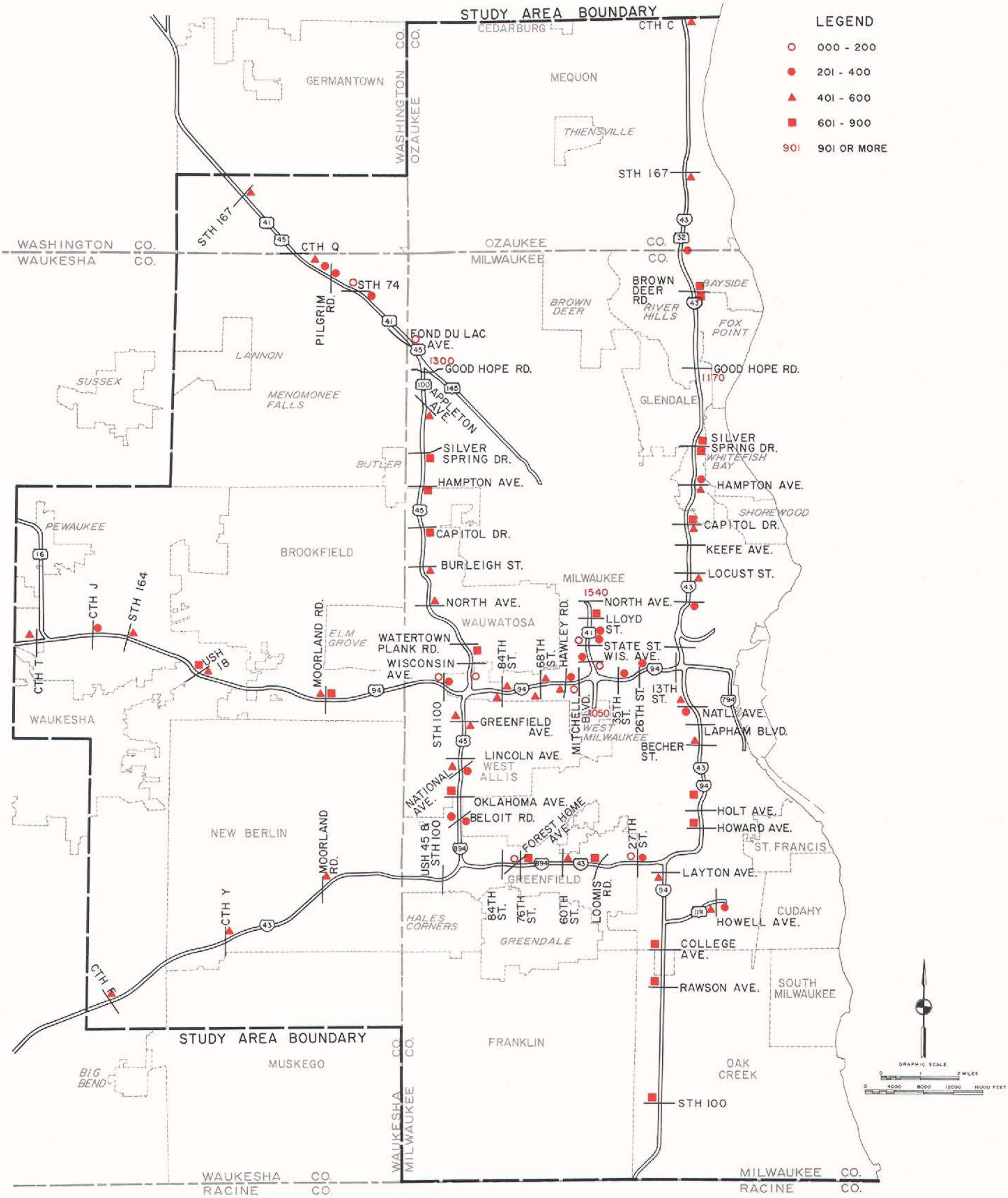


This map shows the traffic volumes entering the Milwaukee area freeway system during the evening peak hour.

Source: SEWRPC.

Map 14

TOTAL EXITING VOLUME AT SELECTED MILWAUKEE AREA FREEWAY OFF-RAMPS DURING THE EVENING PEAK HOUR: 1986

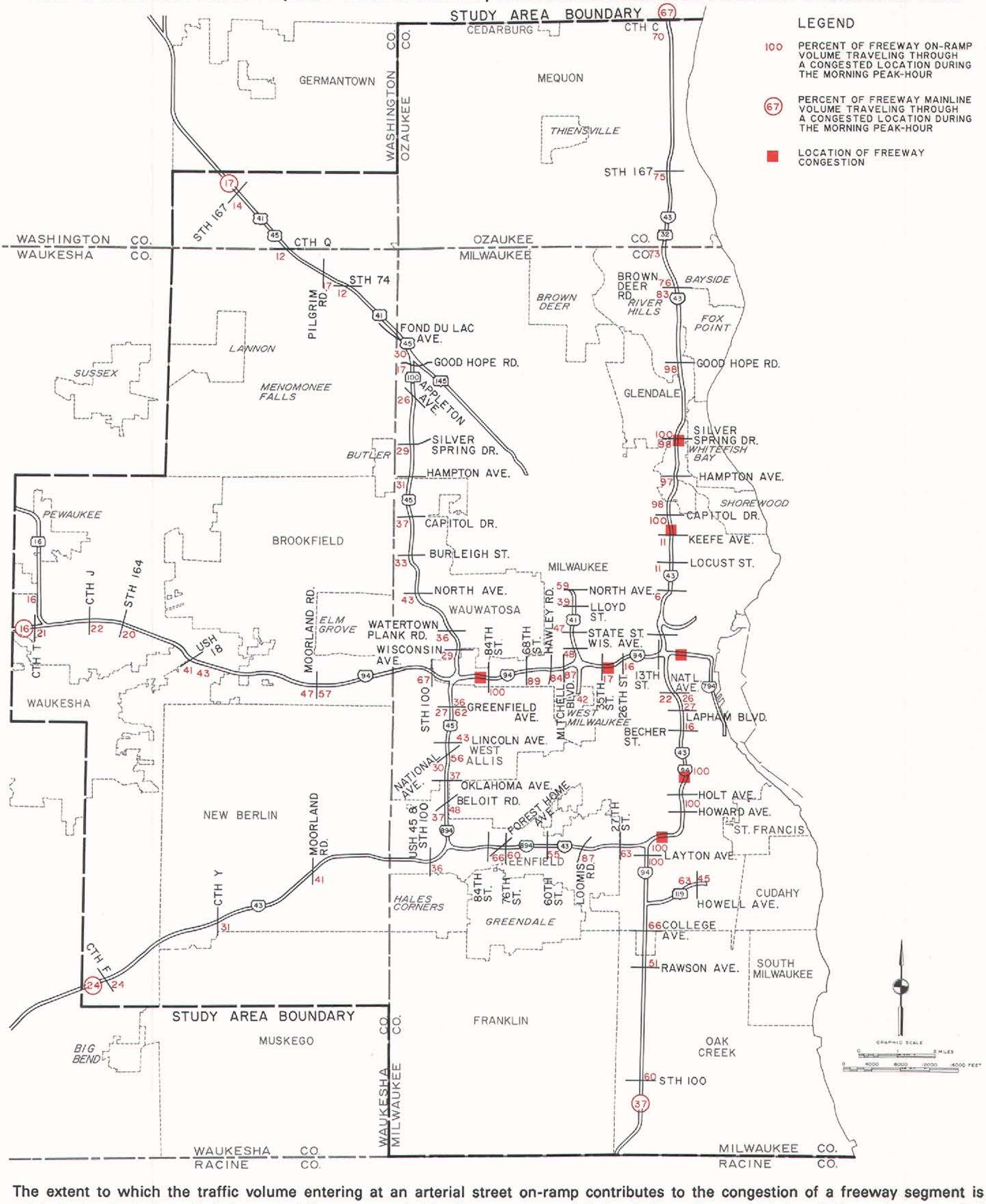


This map shows the traffic volumes exiting the Milwaukee area freeway system during the evening peak hour.

Source: SEWRPC.

Map 15

PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING SOUTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY); NORTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY); AND EASTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH CONGESTED FREEWAY SEGMENTS: 1983

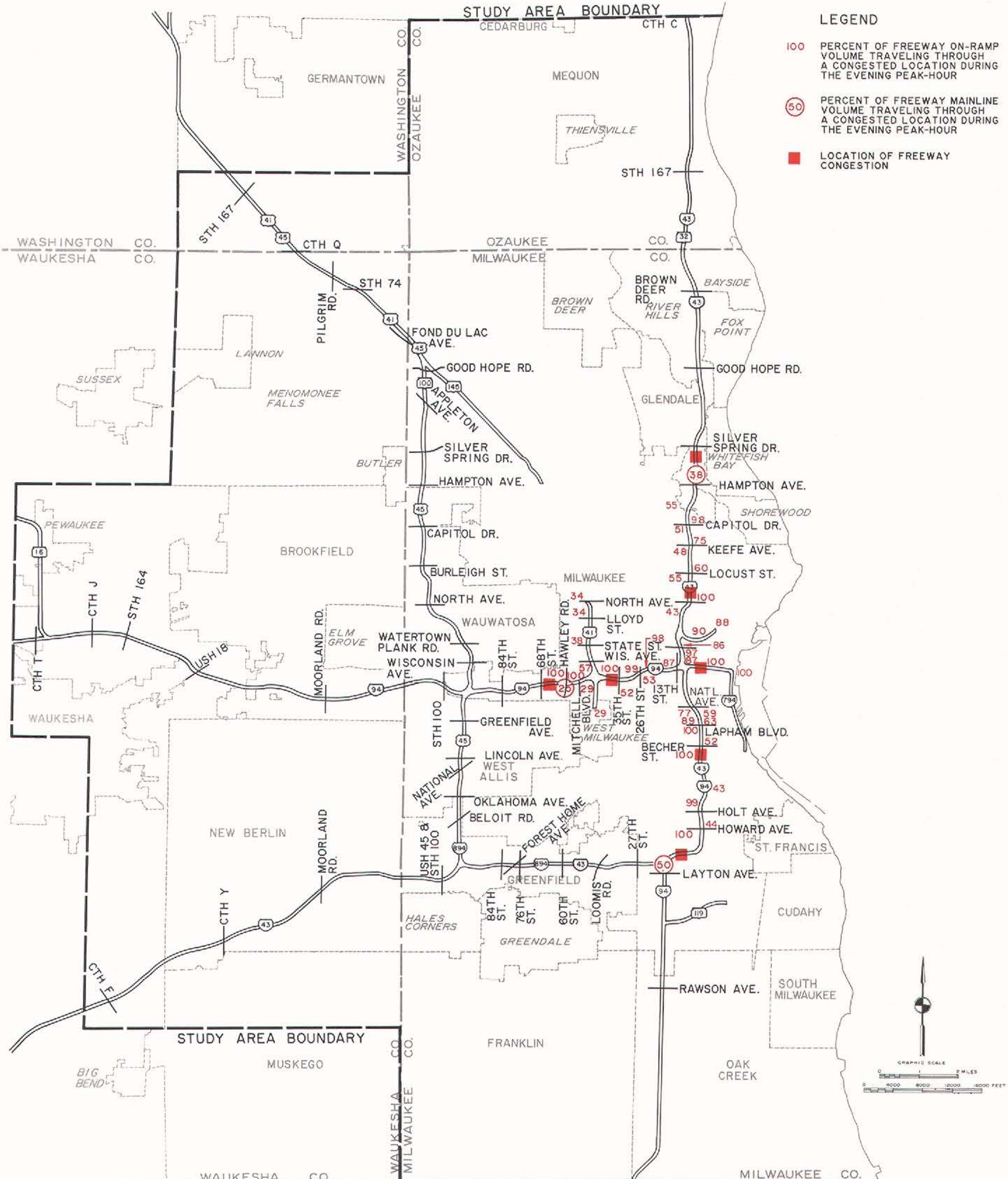


The extent to which the traffic volume entering at an arterial street on-ramp contributes to the congestion of a freeway segment is related not only to the actual demand at the on-ramp, but to the percentage of that entering volume which travels through a congested segment. Shown on this map is the percentage of the morning peak-hour traffic demand entering at upstream freeway mainline or upstream arterial street on-ramps and traveling through a congested freeway segment.

Source: SEWRPC.

Map 16

PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING NORTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY); SOUTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY); AND WESTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH CONGESTED FREEWAY SEGMENTS: 1983

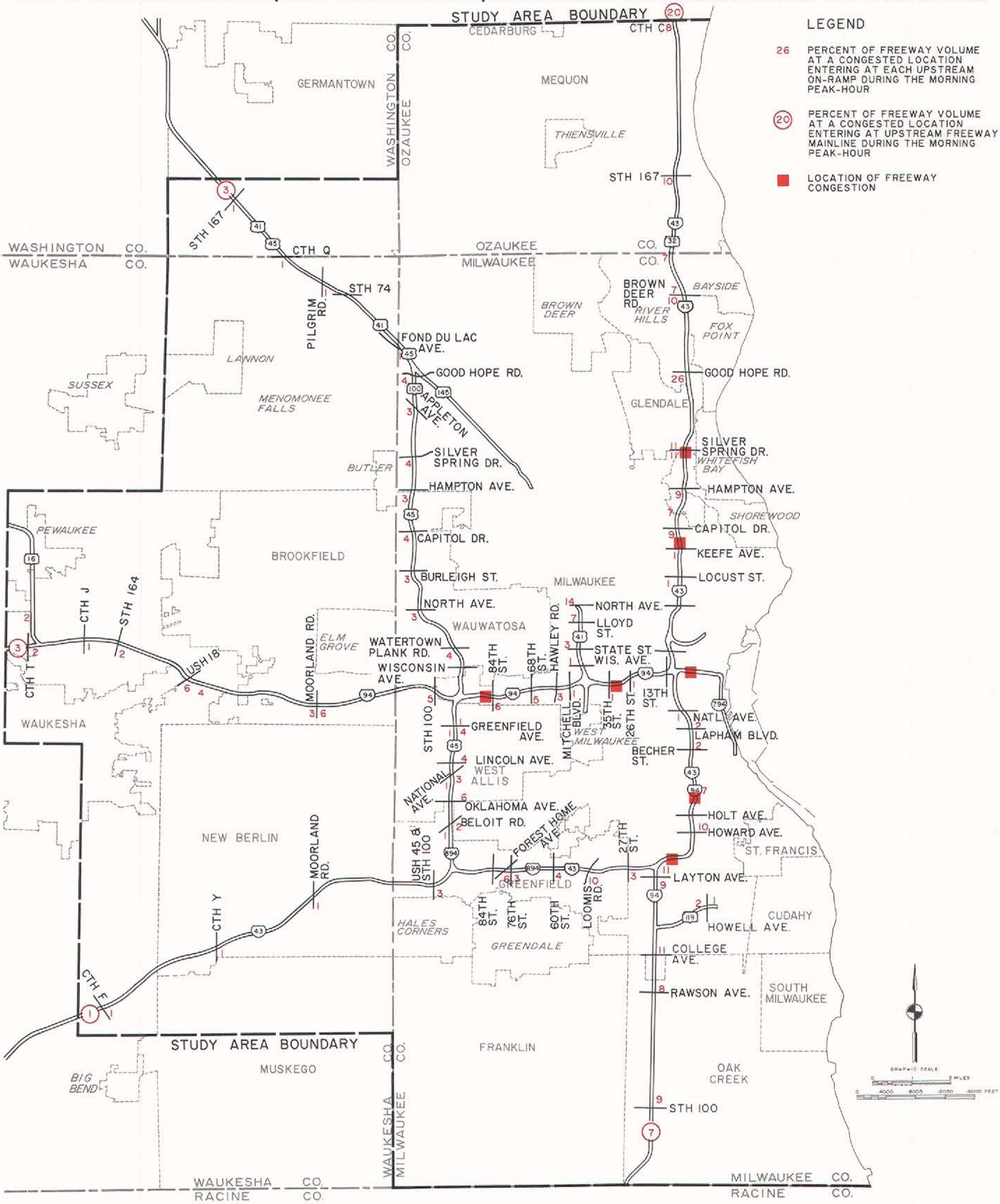


The traffic demand at any location on the freeway main line is the aggregate of the traffic entering at upstream arterial street on-ramps and traveling through the segment. Shown on this map is the percentage that upstream on-ramp volumes constitute of the total freeway mainline volume at selected locations during the morning peak hour.

Source: SEWRPC.

Map 17

PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT SELECTED LOCATIONS SOUTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY); NORTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY); AND EASTBOUND ON IH 94 (EAST-WEST FREEWAY) ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983

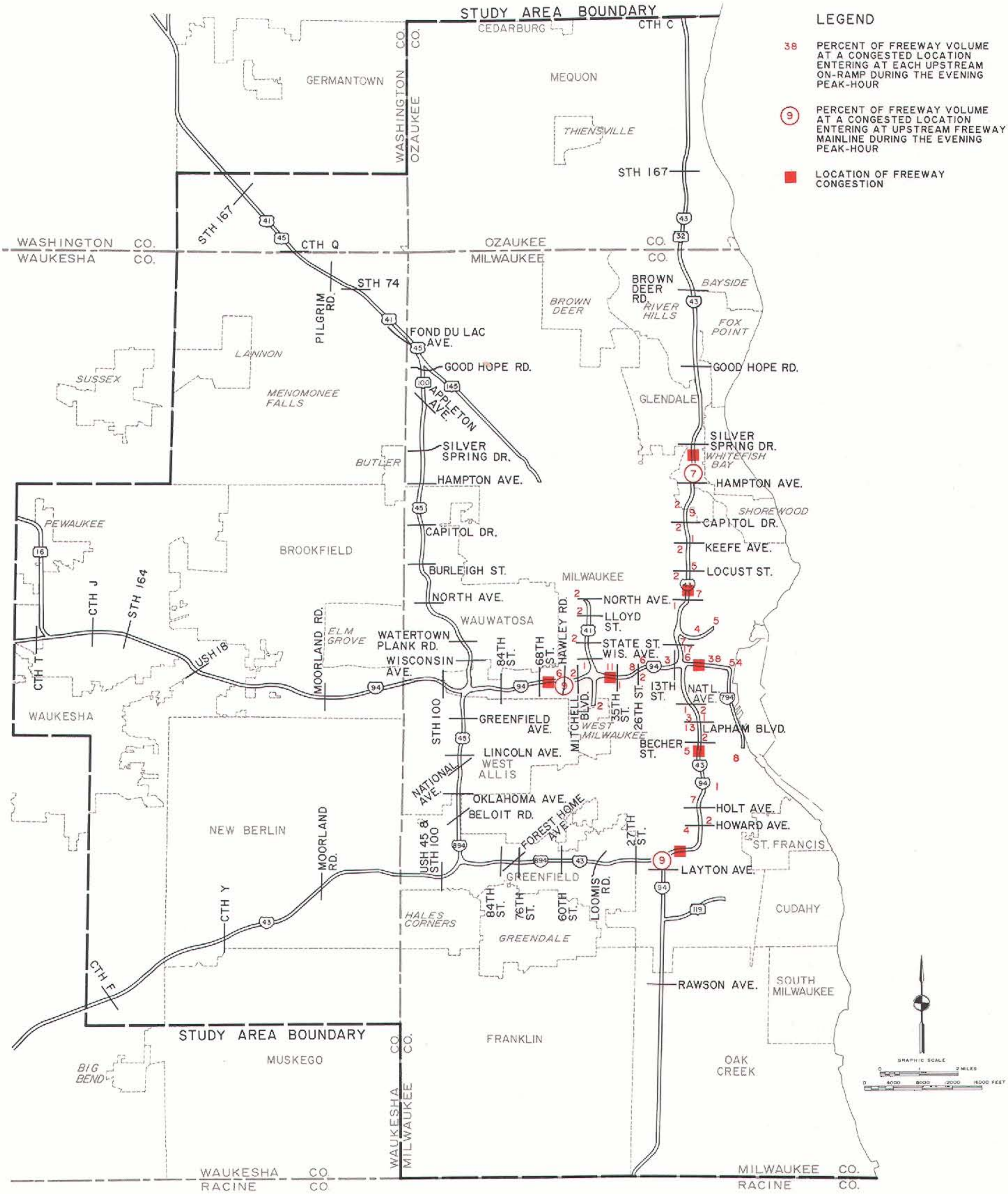


As already noted, the extent to which the traffic volume entering at an arterial street on-ramp contributes to the congestion of a freeway segment is related not only to the actual demand at the on-ramp, but to the percentage of that entering volume which travels through a congested segment. Shown on this map is the percentage of the evening peak-hour traffic demand entering at upstream freeway mainline or upstream arterial street on-ramps and traveling through a congested freeway segment.

Source: SEWRPC.

Map 18

PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT SELECTED LOCATIONS NORTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY); SOUTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY); AND WESTBOUND ON IH 94 (EAST-WEST FREEWAY) ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983

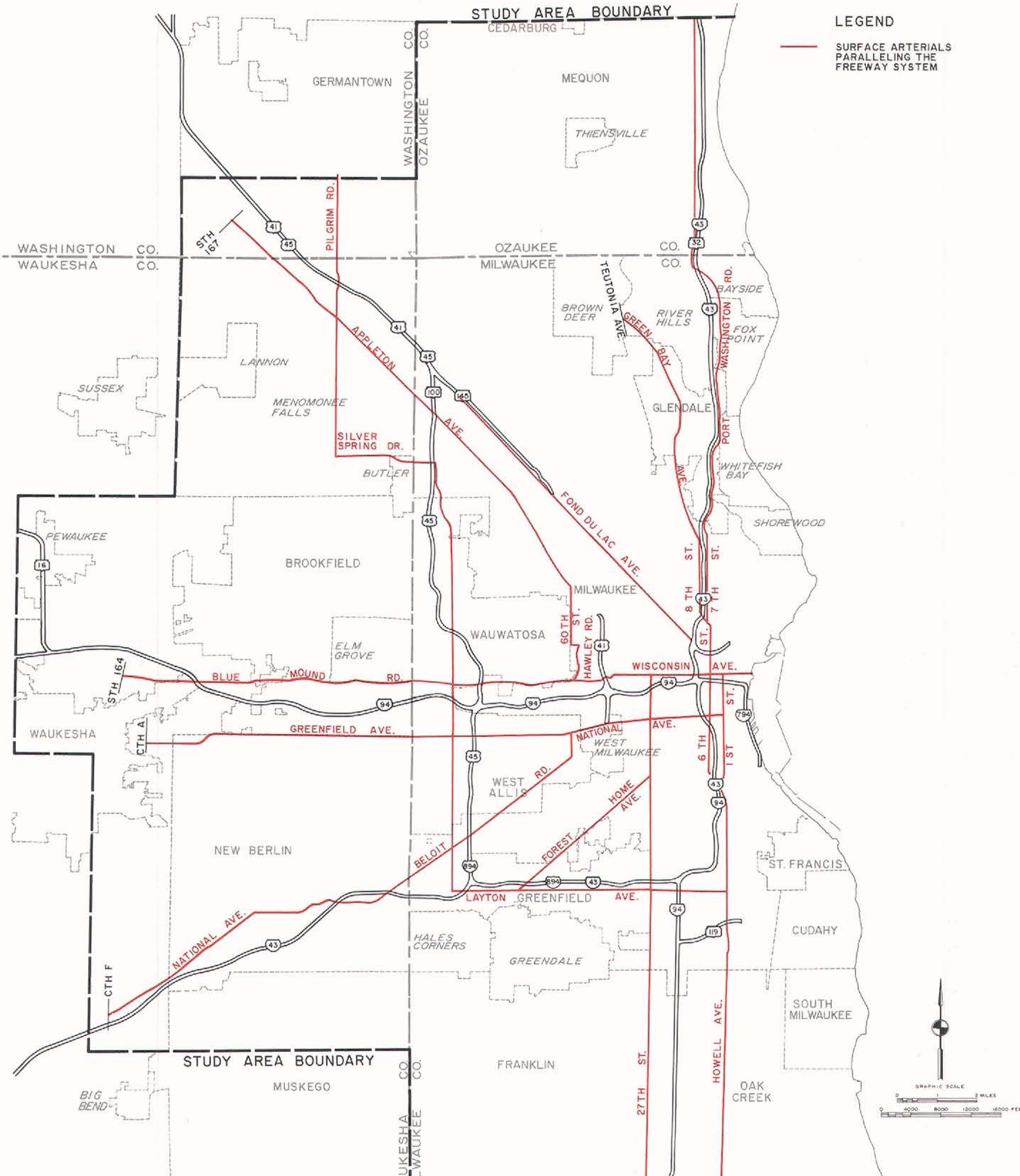


The traffic demand at any location on the freeway main line is the aggregate of the traffic entering at upstream arterial street on-ramps and traveling through the segment. Shown on the map is the percentage that upstream on-ramp volumes constitute of the total freeway mainline volume at selected locations during the evening peak hour.

Source: SEWRPC.

Map 19

SURFACE ARTERIALS PARALLELING THE FREEWAY SYSTEM TO WHICH TRAFFIC MAY BE DIVERTED BY A FREEWAY TRAFFIC MANAGEMENT SYSTEM

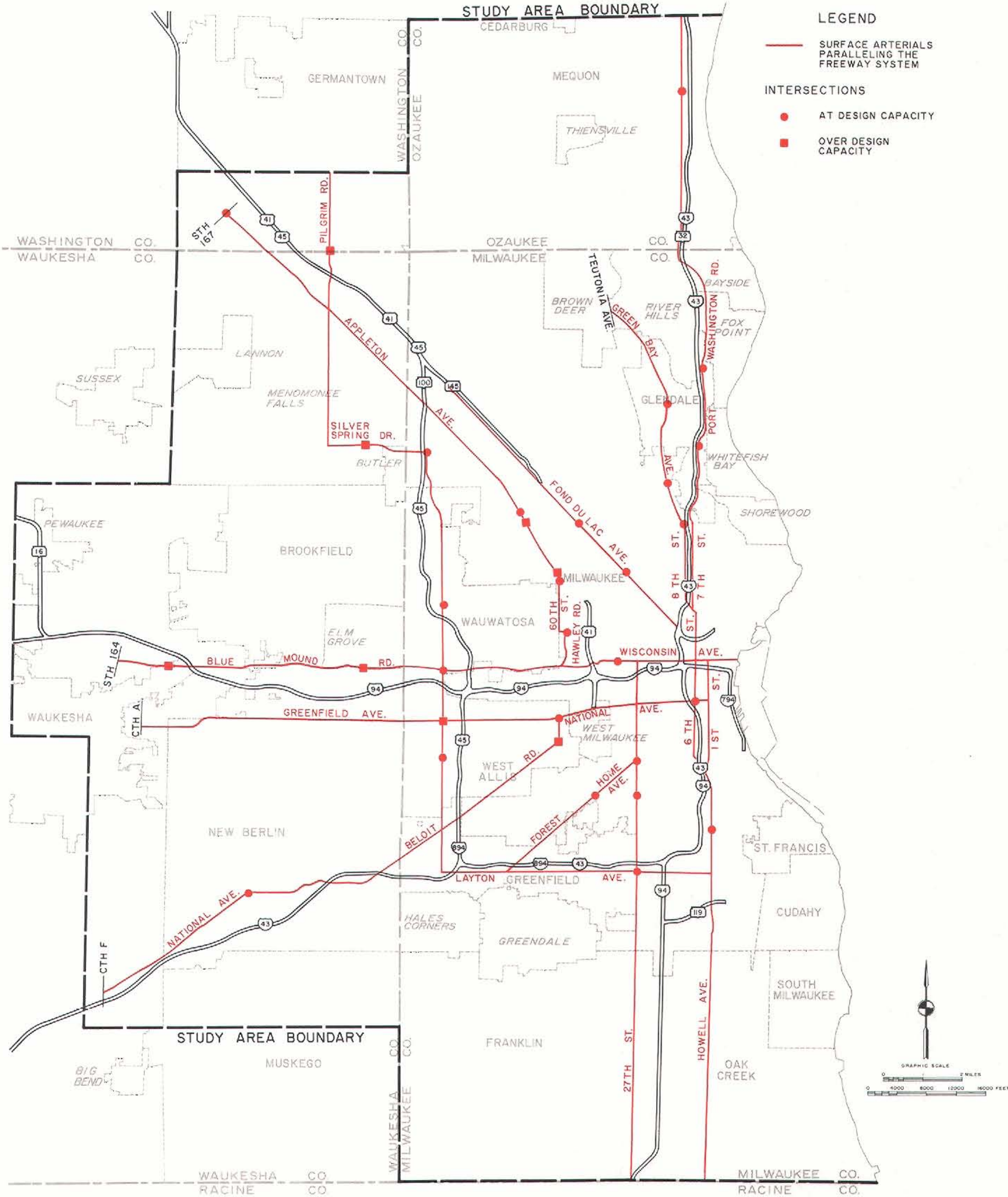


Some traffic currently utilizing the Milwaukee area freeway system could be diverted to the surface arterial system which parallels the freeway system in order to achieve a better balance between freeway traffic volumes and freeway capacity, and to maintain a minimum operating speed of 40 mph on the freeway system during the peak hours on an average weekday. Shown on this map are those surface arterials to which traffic may be expected to be diverted if more desirable operating conditions are to be achieved on the freeway system.

Source: SEWRPC.

Map 20

INTERSECTIONS ON THE ARTERIAL STREETS PARALLEL TO THE FREEWAY SYSTEM AT OR OVER CAPACITY DURING THE MORNING PEAK HOUR: 1983

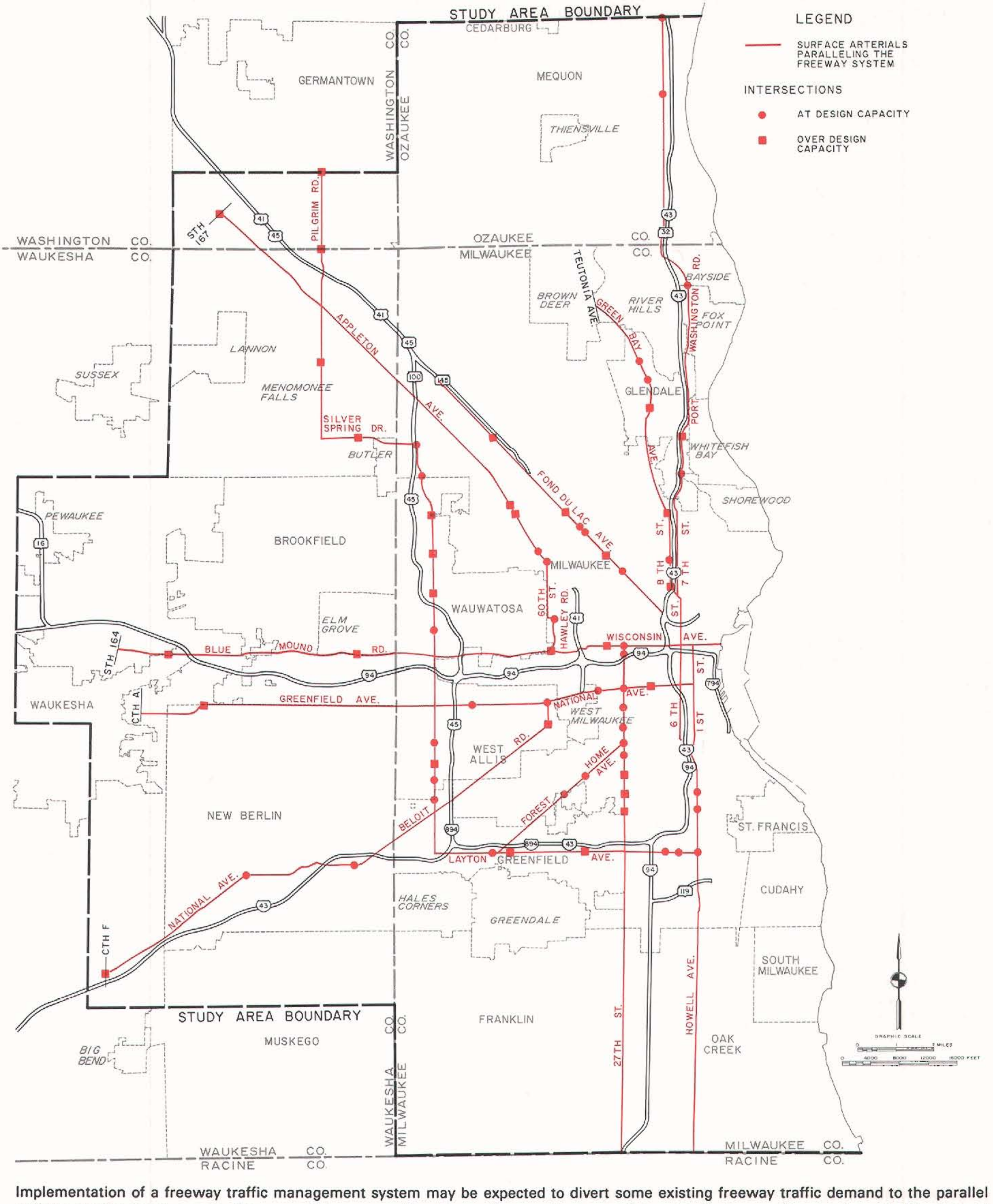


Implementation of a freeway traffic management system may be expected to divert some existing freeway traffic demand to the parallel surface arterial street system. Shown on this map are the intersections on those parallel routes that currently experience traffic demand at or over their design capacity during the morning peak hour and which may require improvement to accommodate additional traffic demand.

Source: SEWRPC.

Map 21

INTERSECTIONS ON THE ARTERIAL STREETS PARALLEL TO THE FREEWAY SYSTEM AT OR OVER CAPACITY DURING THE EVENING PEAK HOUR: 1983

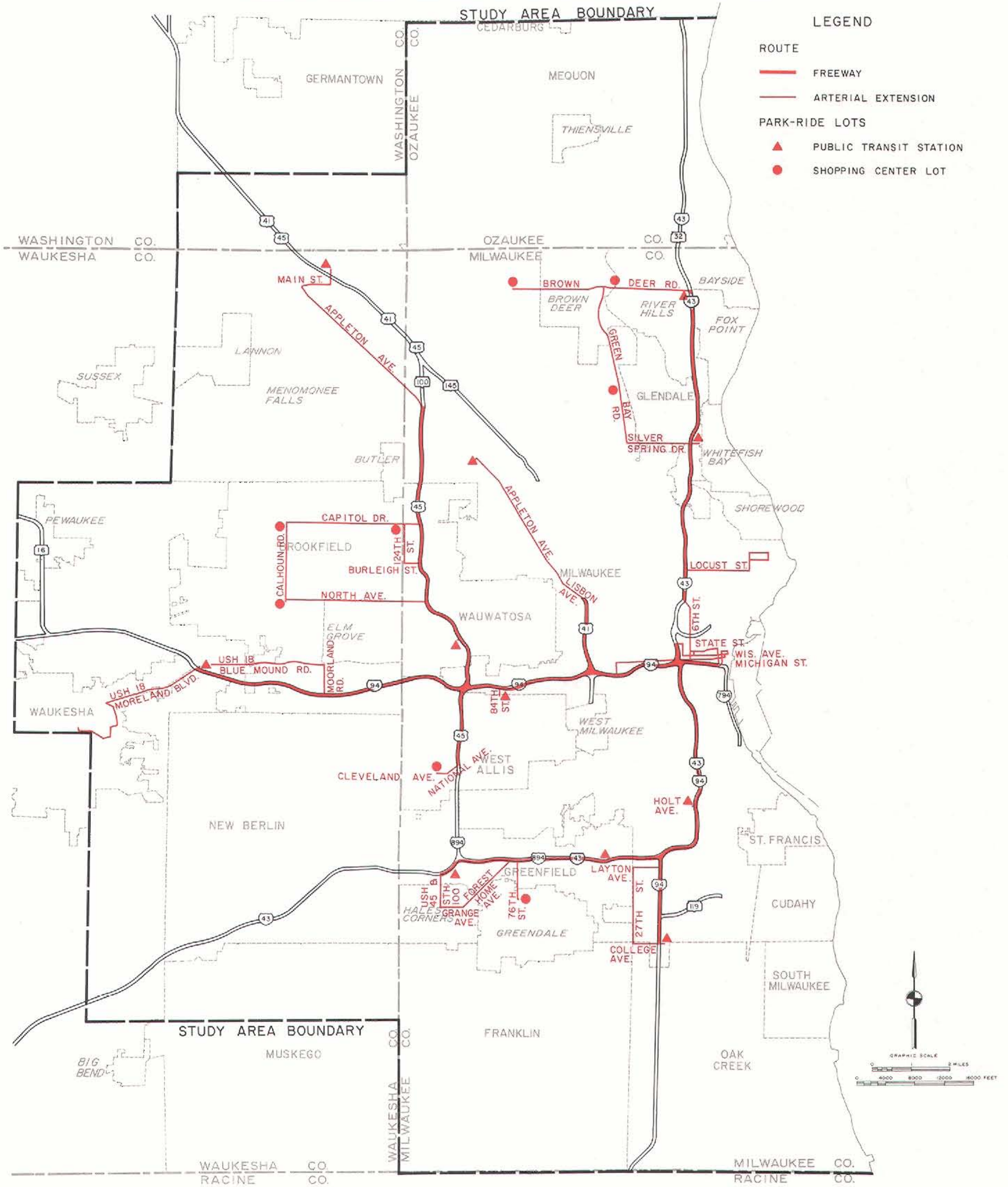


Implementation of a freeway traffic management system may be expected to divert some existing freeway traffic demand to the parallel surface arterial street system. Shown on this map are the intersections on those parallel routes that currently experience traffic demand at or over their design capacity during the evening peak hour and which may require improvement to accommodate additional traffic demand.

Source: SEWRPC.

Map 22

MORNING AND EVENING PEAK-PERIOD BUS-ON-FREEWAY PRIMARY TRANSIT SYSTEM IN THE MILWAUKEE AREA: 1983



Primary transit service in the Milwaukee area is provided by buses operating on the freeway system. As shown on this map, bus-on-freeway service is provided in all freeway corridors.

Source: SEWRPC.

Table 4

MORNING PEAK-PERIOD FREEWAY BUS ROUTE OPERATING CHARACTERISTICS: 1983

Originating Park-Ride Lot	Average Headway (minutes)	Travel Time[a] (minutes)	Number of Trips
Public Transit Stations			
W. College Avenue (Milwaukee)	15.3	17	8[b]
W. Watertown Plank Road (Wauwatosa)	25.2	14	6
North Shore (Glendale)	13.5	18	11[c]
Brown Deer (River Hills)	11.1	22	12[d]
Goerke's Corners (Brookfield)	18.8	27	5
W. Holt Avenue (Milwaukee)	26.8	10	5
Whitnall (Hales Corners)	15.9	22	9
Pilgrim Road (Menomonee Falls)	29.7	40	4
Timmerman Field (Milwaukee)	25.4	24	6
Loomis Road (Greenfield)	13.7	17	10[f]
State Fair Park[e]	23.2	12	6
S. 27th Street[h]	22.7	24	7
Shopping Center Lots			
Northland (Milwaukee)	13.8	29	11[c]
Zayre-Kohls (West Allis)	15.1	22	9
Zayre (Brookfield)	17.9	21	8[g]
Southridge (Greendale)	13.7	25	10[f]
Northridge (Milwaukee)	11.1	40	12[d]
Zayre (Brown Deer)	11.1	29	12[d]
Ruby Isle (Brookfield)	32.0	27	2
Sentry (Brookfield)	32.0	35	2

[a]*Excludes circulation time in central business district.*

[b]*Three trips serve the Holt Avenue park-ride lot as well.*

[c]*All trips serve the Northland and North Shore park-ride lots.*

[d]*All trips serve the Northridge, Zayre (Brown Deer), and Brown Deer park-ride lots.*

[e]*Service began in December 1983.*

[f]*All trips serve the Southridge and Loomis Road park-ride lots.*

[g]*Two trips serve the Watertown Plank Road park-ride lot as well.*

[h]*Trips serve no dedicated park-ride lot.*

Source: SEWRPC.

Table 5

EVENING PEAK-PERIOD FREEWAY BUS ROUTE OPERATING CHARACTERISTICS: 1983

Originating Park-Ride Lot	Average Headway (minutes)	Travel Time[a] (minutes)	Number of Trips
Public Transit Stations			
W. College Avenue (Milwaukee)	15.4	18	9[b]
W. Watertown Plank Road (Wauwatosa)	24.4	16	6[c]
North Shore (Glendale)	14.1	16	10[d]
Brown Deer (River Hills)	8.7	18	11
Goerke's Corners (Brookfield)	9.2	27	5
W. Holt Avenue (Milwaukee)	15.4	9	9[b]
Whitnall (Hales Corners)	13.6	22	8
Pilgrim Road (Menomonee Falls)	19.3	27	4
Timmerman Field (Milwaukee)	30.0	28	4
Loomis Road (Greenfield)	12.4	15	10
State Fair Park[e]	31.0	15	5
S. 27th Street[f]	19.2	25	6
Shopping Center Lots			
Northland (Milwaukee)	13.4	27	8
Zayre-Kohls (West Allis)	15.1	20	9
Zayre (Brookfield)	20.3	20	7[g]
Southridge (Greendale)	12.4	23	10
Northridge (Milwaukee)	8.7	37	11
Zayre (Brown Deer)	8.7	28	11
Ruby Isle (Brookfield)	33.0	26	2
Sentry (Brookfield)	33.0	32	2

[a] *Excludes circulation time in central business district.*

[b] *All trips serve the Holt Avenue and College Avenue park-ride lots.*

[c] *Two trips serve Zayre (Brookfield) as well.*

[d] *Eight trips serve the Northland park-ride lot as well; one trip serves the Brown Deer park-ride lot.*

[e] *Service began in December 1983.*

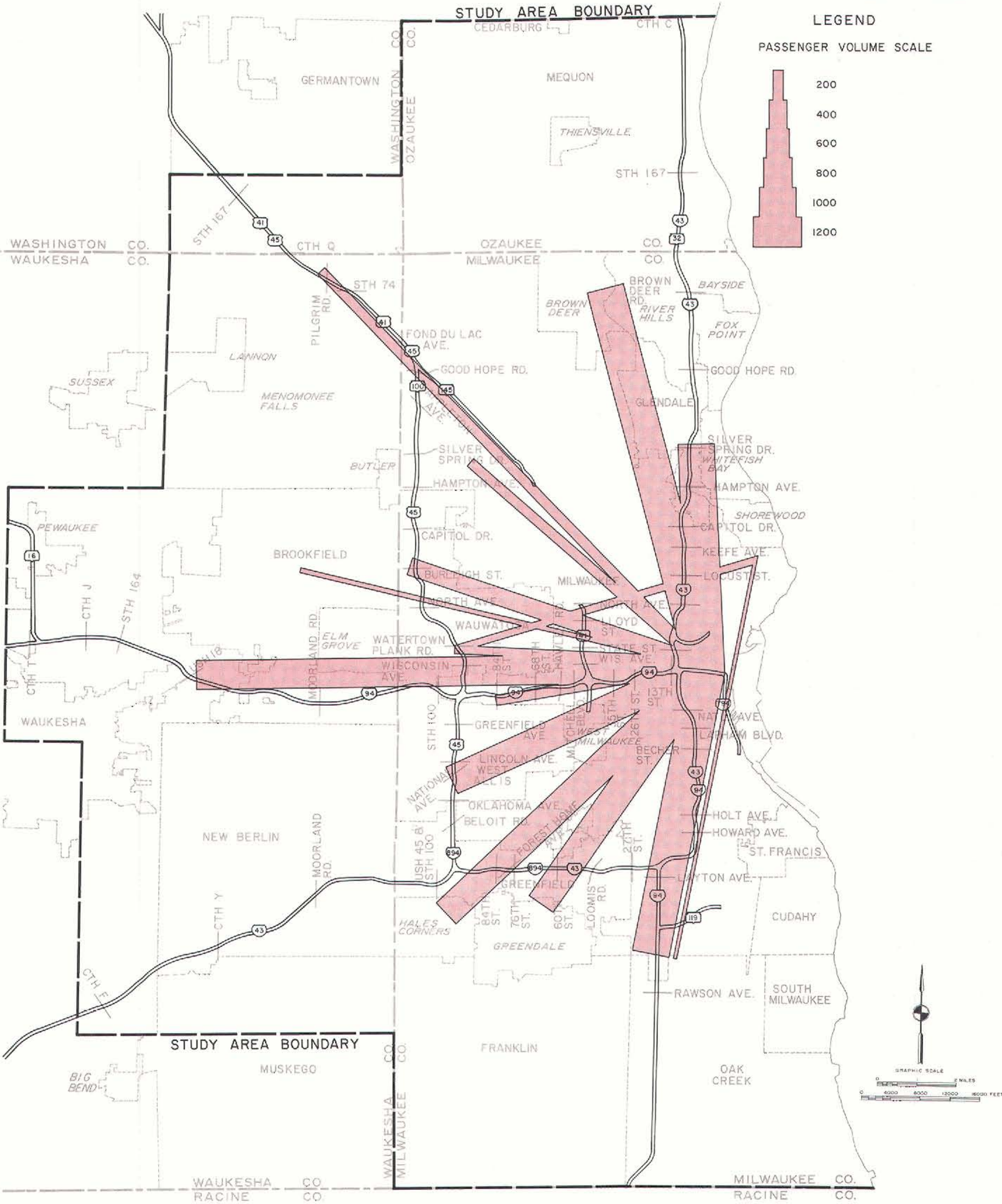
[f] *Trips serve no dedicated park-ride lot.*

[g] *Two trips serve the Watertown Plank Road park-ride lot as well.*

Source: SEWRPC.

Map 23

RAPID TRANSIT TRAVEL DEMAND IN THE MILWAUKEE AREA DURING AN AVERAGE WEEKDAY: 1983



The primary transit system—bus-on-freeway—served approximately 5,000 passengers per average weekday in the Milwaukee area. About 24 percent of this demand was served in the IH 43 (North-South Freeway) corridor, about 36 percent in the IH 94 (North-South Freeway) corridor, and about 40 percent in the IH 94 (East-West Freeway) corridor, as shown on this map. It is estimated that this service removes 2,000 passenger cars per day from the freeway system, with an attendant reduction in parking demand within destination areas.

Source: SEWRPC.

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Chapter V

ALTERNATIVE AND RECOMMENDED FREEWAY TRAFFIC MANAGEMENT SYSTEM PLANS

INTRODUCTION

This chapter presents and evaluates alternative freeway traffic management system plans for the Milwaukee area and presents a recommended plan. Alternatives are presented and evaluated for each element of the freeway traffic management system and system plan. The seven elements are:

1. Incident management—or the identification of freeway incidents, such as accidents, which restrict traffic flow—in order to minimize the effects of incidents.

2. Motorist advisory information, or the provision of information to motorists about current traffic conditions, including incidents.

3. System management, or monitoring and control—the collection and analysis of the freeway operational data essential to the management of the other elements of the freeway traffic management system.

4. Determination of the number and location of freeway on-ramp meters and related control signalization.

5. A freeway operational control strategy, which defines the desired level of operation to be maintained on the freeway system, including the desired operating speeds.

6. A freeway on-ramp meter control strategy, which defines the rate of entry at the various metered freeway on-ramps, distributing the required reduction in freeway volume over the contributing ramps.

7. High-occupancy-vehicle preferential access, or determination of the number and location of exclusive bypasses of the metered on-ramps for use by carpools, vanpools, and buses.

Each of these elements of a freeway traffic management system and system plan is interrelated. However, to make the evaluation of alternatives for each element more understandable, the alternatives for incident management, motorist advisory information, and monitoring and control systems are presented and evaluated separately in this chapter. Two basic alternatives for the remaining freeway traffic management element—the freeway operational control subsystems—are then presented and evaluated. The freeway operational control subsystems include the number and location of ramp meters, the freeway operational control strategy, the ramp-meter control strategy, and high-occupancy-vehicle preferential access.

One of the two alternatives evaluated represents a modest expansion of the existing freeway operational control subsystem. Currently, 21 freeway on-ramps in central Milwaukee County are metered. These metered ramps are located adjacent to the segments of freeway that experience the most severe congestion during morning and evening peak traffic periods. The meters exercise control of freeway traffic volume by restricting, or metering, freeway on-ramp traffic. The principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. Preferential access is provided for buses at six locations. Ramp-meter entrance rates are responsive to the traffic volumes on immediately adjacent "upstream" freeway lanes.

The other freeway operational control subsystem alternative considered represents a major expansion of the existing system. The freeway on-ramps throughout Milwaukee County would be metered, along with selected on-ramps in Ozaukee, Washington, and Waukesha Counties, which carry substantial traffic volumes and contribute to freeway traffic congestion. This subsystem alternative has a broader objective than the existing system—namely, to minimize freeway congestion and provide average operating speeds of 35 to 40 miles per hour (mph) on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters should provide traffic control that is sufficient to prevent freeway capacity from being exceeded. Also under this alternative, preferential access for all high-occupancy-vehicles—buses, carpools, and vanpools—would be provided at an increased number of sites.

ALTERNATIVE AND RECOMMENDED FREEWAY INCIDENT MANAGEMENT ACTIONS

A freeway traffic management system should address the abatement of both recurrent and nonrecurrent traffic congestion. Recurrent traffic congestion is defined as that traffic congestion which may be expected to routinely occur as freeway traffic demand regularly exceeds capacity, such as during the weekday morning and afternoon peak traffic periods. Nonrecurrent traffic congestion is defined as that traffic congestion which occurs as a result of unusual conditions and unpredictable random accidents and incidents. Freeway incident management actions are intended principally to address the abatement of nonrecurrent traffic congestion by providing for the detection, confirmation, and removal of freeway incidents.

In Milwaukee County, the Milwaukee County Expressway Patrol of the Milwaukee County Sheriff's Department provides the first response to all reported freeway incidents. The Expressway Patrol will, as necessary, call for assistance from local police, local fire departments, and ambulance and towing services. Thus, in Milwaukee County, the Expressway Patrol activities are the singularly most important means of identifying freeway incidents. At least one, and usually two, Expressway Patrol squads operate at all times in each of six freeway districts within the County. The length of each district ranges from about 6 miles to about 14 miles of freeway, as shown on Map 24. Typically, each district is patrolled with two one-man squads. These squads typically can drive through their entire districts in 7 to 17 minutes—dependent upon the length—providing the potential to identify any incident within no more than 7 to 17 minutes, unless the Patrol squads are involved in handling a prior incident.

Some incidents are also seen by passing drivers and reported to the County Sheriff's Department by telephone or citizens band radio. Private radio broadcasting stations may also contact the Sheriff's Department based on their own data gathering and analysis. One radio station operates aircraft over-flights during peak traffic periods, and the aircraft maintains radio contact with the Expressway Patrol dispatcher.

Traffic control equipment, and fire and emergency medical services equipment, are typically not dispatched to an incident until an Expressway Patrol squad has arrived at the scene, confirmed the existence of the incident, and called the Sheriff's Department central dispatcher for assistance. The Sheriff's Department dispatcher has direct telephone links to the City of Milwaukee fire and police departments, but must utilize regular telephone lines to suburban fire and police departments. A helicopter based at the Milwaukee County Medical Complex is available for the transfer of trauma cases.

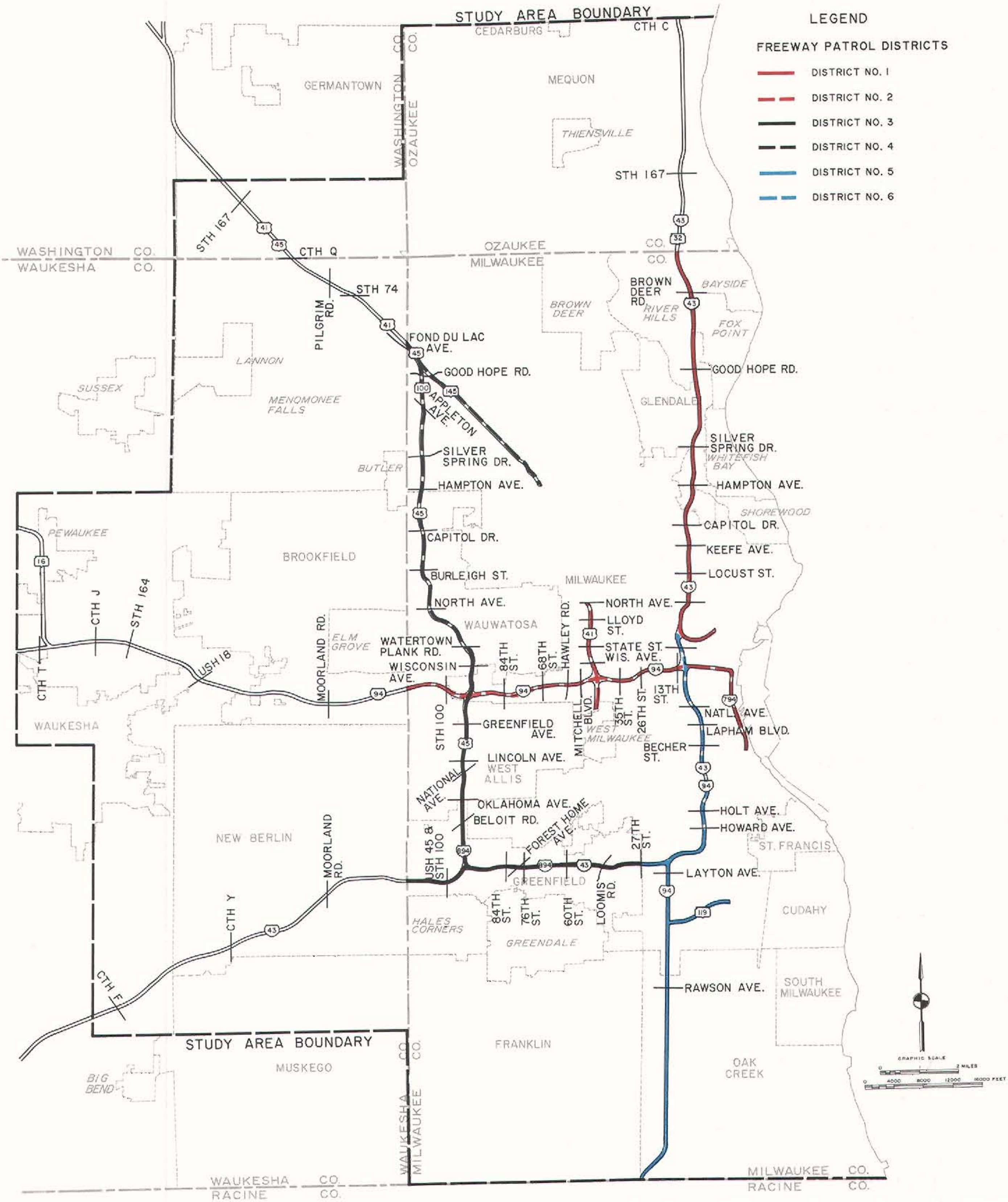
Control of fires and spills of hazardous materials is the responsibility of the fire department of the municipality within which the freeway incident has occurred. All traffic control remains the responsibility of the Sheriff's Department. Any additional needed fire department units are requested by the fire department on the scene of the incident. If a freeway incident involving a fire is reported and there is uncertainty about its precise location—that is, about which municipality the incident has occurred in—the dispatcher may choose to notify and request the assistance of two or more municipal fire departments, and let the arriving fire department units decide responsibility after their arrival at the incident.

If towing services are required to clear the incident, drivers have the opportunity to request the service they desire. If the drivers express no preference, the dispatcher contacts a towing company with which the County contracts for such service.

In other counties in the greater Milwaukee area, incident detection is provided by both the State Patrol and the sheriff's departments of the counties. The State Patrol monitors each sheriff's department radio, as well as the emergency citizen band radio channel. The sheriff's departments are responsible for requesting the appropriate emergency medical or fire department services. Typically, commercial radio broadcasting stations provide no surveillance of the freeways in the outlying counties. As in Milwaukee County, drivers needing mechanical or towing assistance can request the service they

Map 24

EXISTING MILWAUKEE COUNTY EXPRESSWAY PATROL DISTRICTS: 1987



The Milwaukee County Sheriff's Department patrols the freeway system in Milwaukee County 24 hours a day. Two deputy sheriffs are assigned to each of the six patrol districts shown on this map. The districts range from 6 miles to about 14 miles in center line length and take from 7 minutes to 17 minutes to patrol in one direction.

Source: SEWRPC.

desire, or the sheriff's department will select a service for them from a list of contractors.

No formal emergency response agreement exists in the greater Milwaukee area between the Wisconsin Department of Transportation, the sheriff's departments, other county agencies, and local fire and police departments.

Expressway Patrol

The use of expressway patrol is an alternative freeway incident management action. Expressway patrol can be utilized, as it is in Milwaukee County, to perform many of the functions of freeway incident management, including identification of incidents; confirmation of incidents; assessment of the nature and severity of incidents; and management and control of incidents. Expressway patrols do have limitations. It may take up to 17 minutes before, as part of the routine patrol, they may come upon an incident, and confirm and verify the incident. Expressway patrol, however, is essential to the efficient management and control of incidents. In the greater Milwaukee area, regular, scheduled expressway patrol is only provided in Milwaukee County.

Emergency Service Patrols

Freeway incident management action can also be provided by an emergency service patrol. Emergency service patrols would utilize vehicles equipped to provide limited towing assistance, as well as minor services such as fuel, oil, water, and minor mechanical repairs. The emergency service patrol would also assist the expressway patrol in identifying and handling incidents such as accidents, disabled vehicles, and small fires. The Expressway Patrol would maintain responsibility for directing the response to incidents, and managing traffic control at the incident. The emergency service patrol would, at the Expressway Patrol's direction, remove disabled vehicles from the roadway and help other vehicles move away under their own power.

The objective of an emergency service patrol is to assist in maintaining through freeway traffic lanes and in keeping shoulders clear of disabled vehicles. The emergency service patrol permits the Expressway Patrol to handle more incidents and to concentrate on the nonroutine aspects of freeway incident management.

Many freeway traffic incidents are routine. On the Milwaukee County freeway system in 1984, about 37 percent of all the vehicle incidents that did not involve traffic accidents involved disabled vehicles stopped by engine trouble; 18 percent, vehicles stopped by tire trouble; 16 percent, vehicles stopped as a result of running out of fuel; 7 percent, vehicles stopped because they overheated; and 5 percent, vehicles with electrical system problems. The remaining incidents involved drivers who needed information—1 percent—or who had some other type of problem—16 percent.

Such an emergency service patrol has been in operation in the Chicago area since 1961. The service is provided on a 135-mile freeway system 24 hours per day, seven days per week. The emergency service patrol only provides the assistance necessary to remove vehicles from the high-volume and high-speed freeway traffic. For example, towing is provided only to shoulders or to the nearest freeway interchange, where the driver of the disabled vehicle must then arrange for further towing. Also, disabled vehicles are not repaired by the emergency service patrol, but gasoline, water, and air for tires are provided, along with the loan of small tools.

Major Incident Response Teams

Freeway incident management can also be provided by a major incident response team. Major incident response teams have been implemented in Los Angeles, California. The staff of the major incident response team could be a combination of freeway law enforcement staff from the Milwaukee County Sheriff's Department and the Wisconsin State Patrol and traffic engineering staff from the Wisconsin Department of Transportation and the affected counties. When a major incident occurred—which could be defined as a closure of at least two freeway lanes for a period of two hours or more—the team would leave their principal duties to assist in traffic control. The major incident response team would be directed to go to the site of the incident, along with special equipment such as sign trucks and portable signs which would at all times be readily available to the team members. The team members could, for example, have portable signs in the trunks of their cars, or could be responsible for driving portable sign trucks. Upon arrival at the scene of the incident, the team would work with the law enforcement at the scene to expedite the movement of traffic through and around the incident, and take the lead in determining the need to divert traffic and establishing alternative routes.

Citizen Band Radio Monitoring

Freeway incident management can also be provided by monitoring citizen band (CB) radio emergency channel reports of traffic accidents and other traffic incidents. To ensure adequate reception of the emergency reports, a system of remote control CB base stations would need to be installed along the freeway system at about four-mile intervals. Each remote station would receive citizen reports from no farther than two miles, amplify these reports, and relay the report via leased telephone lines or microwave communications system to a traffic management center. Because CB radios are generally used only by drivers of large trucks, which constitute a small proportion of the total vehicle volume, and because any reporting of incidents on CB radio is voluntary and occurs along with other routine conversation, a CB monitoring system could not be used to provide initial identification of incidents. Rather, the CB monitoring system would be used to help verify incidents following the first indication of an incident from an electronic data gathering and analysis system. The traffic management center staff would use the CB monitoring system to verify and gather detailed information about the incident by monitoring only the closest remote CB base station. If the nature and severity of the incident could be determined, emergency medical services, fire, or towing equipment could be dispatched before the Expressway Patrol reached the incident, or was dispatched to the incident. The CB radio monitoring system would rely upon voluntary citizen reports from private vehicles equipped with CB radio at private expense.

Citizen band radio monitoring is in operation along Chicago area freeways and is used in addition to an extensive electronic traffic data gathering and analysis system. That is, the electronic data gathering and analysis system, which includes detectors in the mainline freeway, generates the first indication of a freeway incident. The nearest roadside remote CB base station is then monitored by the traffic management center staff to verify the incident and determine the characteristics of the incident. The Eisenhower Expressway (IH 90) in the Chicago area is equipped with five remote base stations spaced approximately three miles apart.

Cellular Telephones

Freeway incident management can also be provided by motorists with cellular telephones. Such motorists can be encouraged to use their phones to inform the traffic management center of freeway incidents. At the present time, vehicles equipped with cellular telephones constitute a relatively small proportion of the total fleet. Therefore, use of cellular telephones should not be relied upon to provide the initial identification of incidents. However, cellular telephones could be used as one of a number of means to confirm incidents. The use of cellular telephones would rely upon voluntary reports of incidents from private vehicles at private expense. It should be noted that the telephone number for the traffic management center would have to be posted at intervals along the freeway, and that additional manpower may be needed to answer the telephone calls.

Potential disadvantages of the use of cellular telephones are that such use would be dependent upon individual motorists to call at their expense to report an incident; that to make the telephone call, the motorist would either have to have the necessary telephone number committed to memory or be in the immediate vicinity of a sign displaying the number; and that many of the calls received might repeat the same information, or might not be related at all to freeway incidents.

Roadside Call Boxes or Telephones

Freeway incident management can also be provided through the use of telephone call boxes. These boxes provide a means of identifying freeway incidents. Drivers who experience or observe an incident can use a roadside call box to call for assistance. There are several disadvantages attendant to this alternative. Roadside call boxes require drivers to stop along the freeway. Such stops may require otherwise unnecessary lane changes, which can disrupt the mainline freeway traffic flow. The use of roadside telephone call boxes encourages drivers to stop and call for assistance on the freeway rather than at the nearest freeway interchange, and the stopped vehicles may disrupt freeway traffic flow. Roadside telephone call boxes also require operators of disabled vehicles to walk along the freeway, a dangerous practice. Also, roadside telephone call boxes are generally not well used to report incidents, as their use requires motorists to interrupt their trip. Lastly, roadside telephone call boxes are subject to abuses such as false alarms and vandalism.

Electronic Freeway Traffic
Data Gathering and Analysis

Another alternative freeway incident management action is electronic freeway traffic data gathering and analysis. Such data gathering and analysis is provided by loop detectors imbedded in the pavement which measure traffic flow. The loops are installed in each freeway lane at approximately one-half-mile intervals. Electronic data gathering and analysis is considered the best means of initial incident detection, as it provides very quick indication of an incident, particularly during peak traffic periods. When an incident occurs, the traffic flow upstream of the incident will slow, and possibly even stop. The traffic counts measured by the loop detectors will immediately record this disruption of traffic flow. The electronic data gathering and analysis is typically designed to automatically provide visual and/or audio alarms when disruption of traffic flow occurs, or when large differences between actual and typical flow occur. Traffic management center personnel can then quickly examine the traffic flow reported at that loop detector and act to confirm the incident through other means.

As shown on Map 25, part of an electronic traffic data gathering and analysis system is in place in the Milwaukee area, with a total of 243 loop detectors, including loop detectors in all freeway lanes at 25 traffic counting stations, and additional loop detectors generally located adjacent to currently metered ramps and along segments of freeway recently resurfaced or reconstructed. These loop detectors are generally located at approaches to major interchanges and along the most heavily used parts of the freeway system, where incidents are most likely to happen. Additional actions that could be undertaken include: 1) the installation of additional loop detectors in all freeway lanes at about one-half-mile intervals; 2) the linking of the detectors to a central computer to provide automatic and rapid identification of freeway incidents; and 3) the development of a central traffic management center with a manned control room to monitor the electronic traffic data gathering system, to confirm incidents identified through other means, and to dispatch freeway patrol services.

The principal advantage of detector-based electronic data gathering and analysis is that it provides continuous areawide monitoring, with rapid notice upon detection. Such electronically detected incidents, however, still require confirmation through other means, such as the dispatch of freeway patrols.

Closed Circuit Television Monitoring

Closed circuit television (CCTV) is used principally to confirm the presence of freeway incidents, with operators monitoring the CCTV in a traffic management center. Closed circuit television is best used in conjunction with electronic data gathering and analysis as a means to confirm incidents identified by such gathering and analysis.

The principal advantage of CCTV is that it enables operators to focus quickly on freeway segments where electronic data gathering and analysis has indicated that incidents have occurred. Thus, as electronic data gathering and analysis can rapidly detect a possible incident, CCTV has the potential to, within a very short time, confirm an incident and assess its general severity. Also, CCTV can be used to view long stretches of freeway and to monitor freeway segments where incidents most regularly occur.

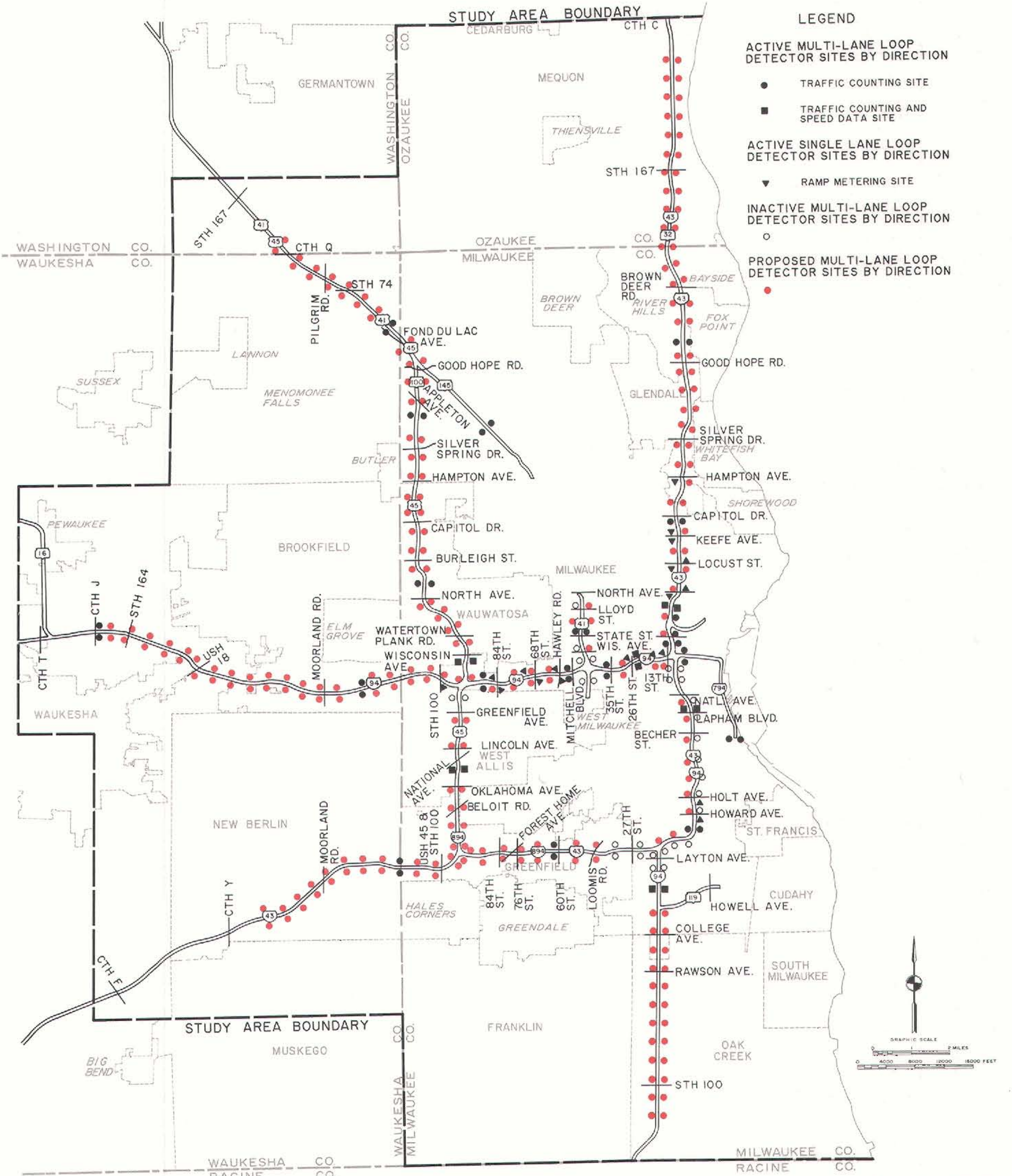
The principal disadvantage of CCTV is that although high mast mounting and zoom lens-equipped cameras can effectively cover a freeway facility for considerable distances, poor images may result due to adverse weather, darkness, or sunlight glare.

Aircraft Surveillance

Another freeway incident management alternative for the detection of freeway incidents is the observation of the freeway from aircraft. Such freeway surveillance by light planes and helicopters, however, is not generally effective for confirming the location, type, and severity of incidents. To confirm incidents and determine the appropriate response, fairly low flight is necessary, but is not always possible. Adverse weather conditions, poor visibility, and fading light can make confirmation of incidents difficult or impossible. Also, atmospheric conditions can inhibit the necessary air-to-ground communications. It should be noted that the poor weather conditions, such as snow and fog, which make safe flight impossible are also those conditions in which there is a greater likelihood of incidents.

Map 25

LOOP DETECTOR SITES ON MILWAUKEE AREA FREEWAYS THAT WOULD BE INCORPORATED INTO THE ELECTRONIC FREEWAY TRAFFIC DATA COLLECTION AND MONITORING SYSTEM: EXISTING (1987) AND PROPOSED



Electronic freeway traffic data gathering and analysis to guide the freeway operational control strategy and enhance freeway incident detection on the Milwaukee area freeway system is proposed to be provided by a total of 996 loop detectors set in the freeway lanes at one-half-mile intervals. This map shows the locations of the 243 existing loop detectors in the Milwaukee area freeway system, as well as the locations of the proposed 753 new loop detectors.

Source: SEWRPC.

The most productive application of aerial traffic surveillance would appear to be to assess the general flow of traffic, and to confirm the presence of particularly serious traffic incidents. However, it clearly is not the best alternative for the timely detection of incidents on an areawide freeway system, or for the determination of the appropriate response to each incident.

Recommendations for
Freeway Incident Management

The recommended freeway incident management system for the greater Milwaukee area consists of: an electronic freeway traffic data gathering and analysis system, a citizen band radio monitoring system, signing with an emergency telephone number for use by motorists with cellular telephones, a closed circuit television monitoring system, an emergency service patrol, continued expressway patrol, and a major incident response team. To provide for the efficient use of these actions, a central freeway traffic management center and staff will be required.

The electronic data gathering and analysis system would be used to initially identify incidents, as it can do so rapidly. It is the most critical element of the freeway incident management system. In-pavement loop detectors would need to be installed approximately every half-mile in every freeway lane. Approximately 750 detectors would be necessary, together with communications conduit for interconnection with ramp meters and with a central traffic management center, at an estimated capital cost of $6.1 million.

Also recommended is a system of remote base station citizen band monitoring. The installation of 12 remote-base CB radio stations at locations throughout the Milwaukee area will provide for a maximum two-mile distance between base station and potential radio calls. The estimated installation cost for the recommended 12 remote stations is $50,000. The recommended locations of the stations are shown on Map 26.

Also recommended is closed circuit television monitoring of freeways to be utilized along with the recommended remote base station citizen band monitoring to quickly confirm freeway incidents. Closed circuit television monitoring would also be used to establish the nature and severity of incidents so that appropriate action could be quickly taken. A system of 20 cameras with high mast mounting is recommended, at a total cost of $850,000, including traffic management center viewing equipment. The recommended locations of the cameras are shown on Map 27.

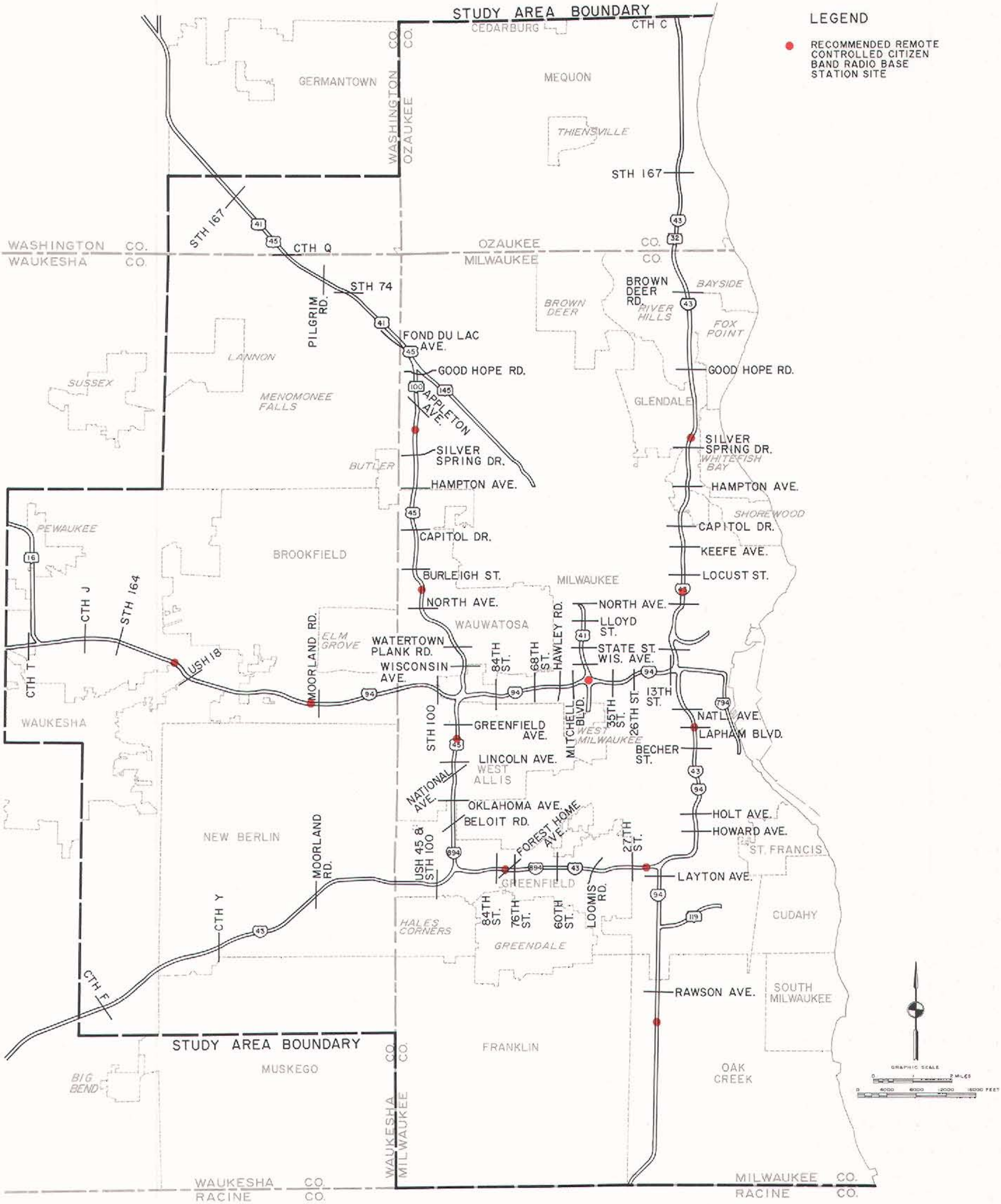
Another recommended incident management action is the continuation of expressway patrol in Milwaukee County. Two patrol squads would continue to be assigned to each of six specific freeway districts. The patrol segments would range from about 6 miles to about 10 miles in length, as is current practice in Milwaukee County. The freeway segments concerned are shown on Map 24. The Expressway Patrol's principal function would be to manage the removal of incidents and, as needed, establish the nature and characteristics of an incident upon arrival at the incident. As traffic increases and begins to exceed freeway design capacity on those segments of the Milwaukee area freeway system in Ozaukee, Washington, and Waukesha Counties, the establishment of expressway patrol will need to be considered in these counties.

Another recommended incident management action for Milwaukee area freeways is the initiation of an emergency service patrol. The emergency service patrol would assist professional law enforcement officers in managing incidents. The emergency service patrol would provide towing to freeway shoulders or interchanges, and would help other disabled vehicles move away under their own power. To provide an emergency service patrol during the hours of heaviest traffic movement—that is, from 6:00 a.m. to 10:00 p.m.—and with a coverage of one service patrol vehicle for about every 20 miles of freeway, as shown on Map 28, a total of six emergency service patrol vehicles would be required, at an estimated cost of $230,000. One service vehicle should be acquired which would be capable of removing heavily loaded tractor-trailer trucks from accident scenes, at an estimated cost of $60,000. The emergency service patrol would require a staff of about 20 persons.

It is also recommended that signs be installed along those freeway segments shown on Map 28 at approximately three-mile intervals outside Milwaukee County and at two-mile intervals within Milwaukee County displaying an emergency telephone number for the freeway traffic management control center and encouraging

Map 26

RECOMMENDED LOCATIONS OF CITIZEN BAND RADIO REMOTE BASE STATIONS FOR INCIDENT MANAGEMENT

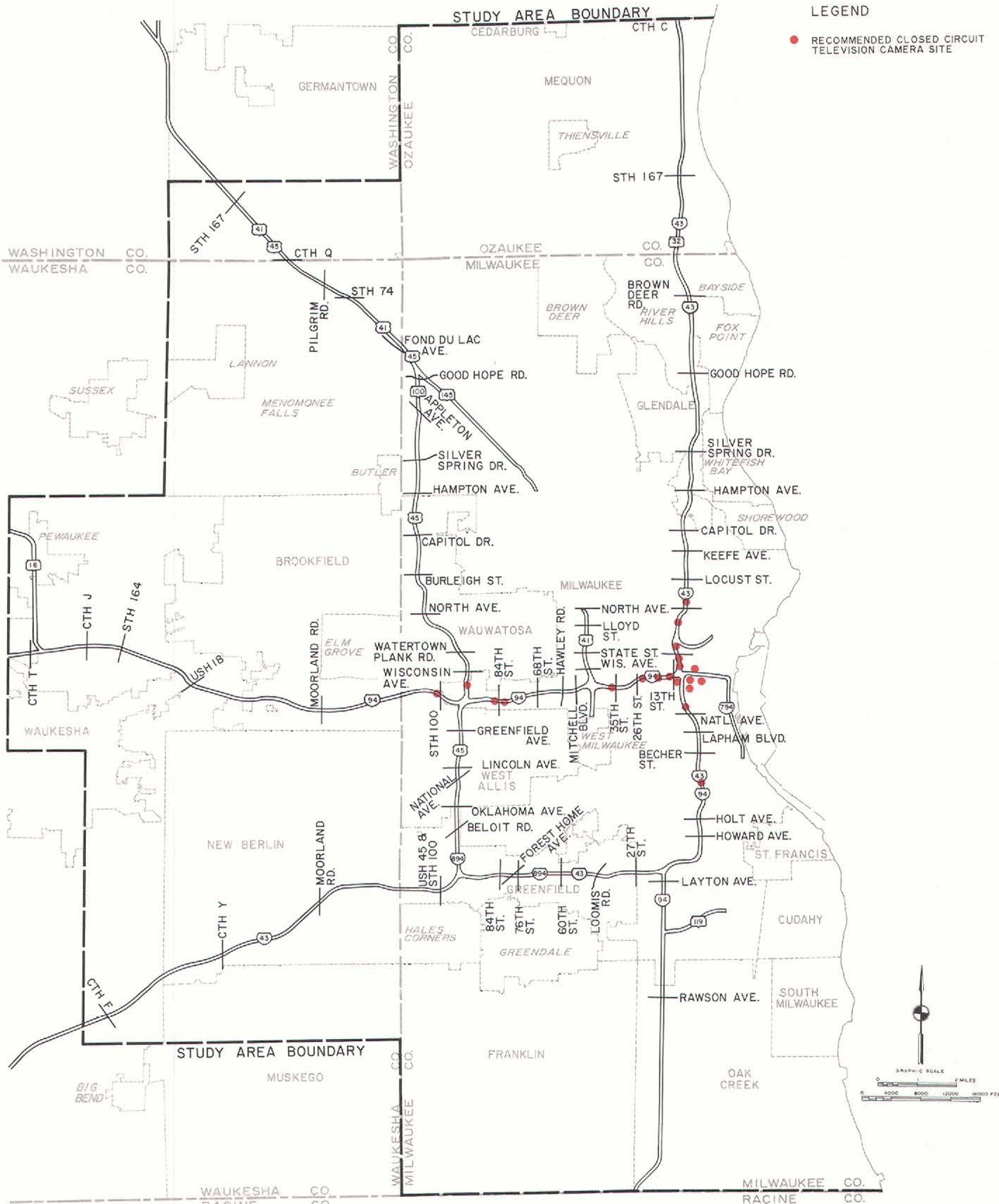


The ability to monitor citizen band radio transmissions via remote base stations would aid in freeway incident verification. This map shows the recommended locations for 12 remote citizen band base stations for the Milwaukee area freeway system.

Source: SEWRPC.

Map 27

RECOMMENDED LOCATIONS OF CLOSED CIRCUIT TELEVISION CAMERAS FOR INCIDENT MANAGEMENT

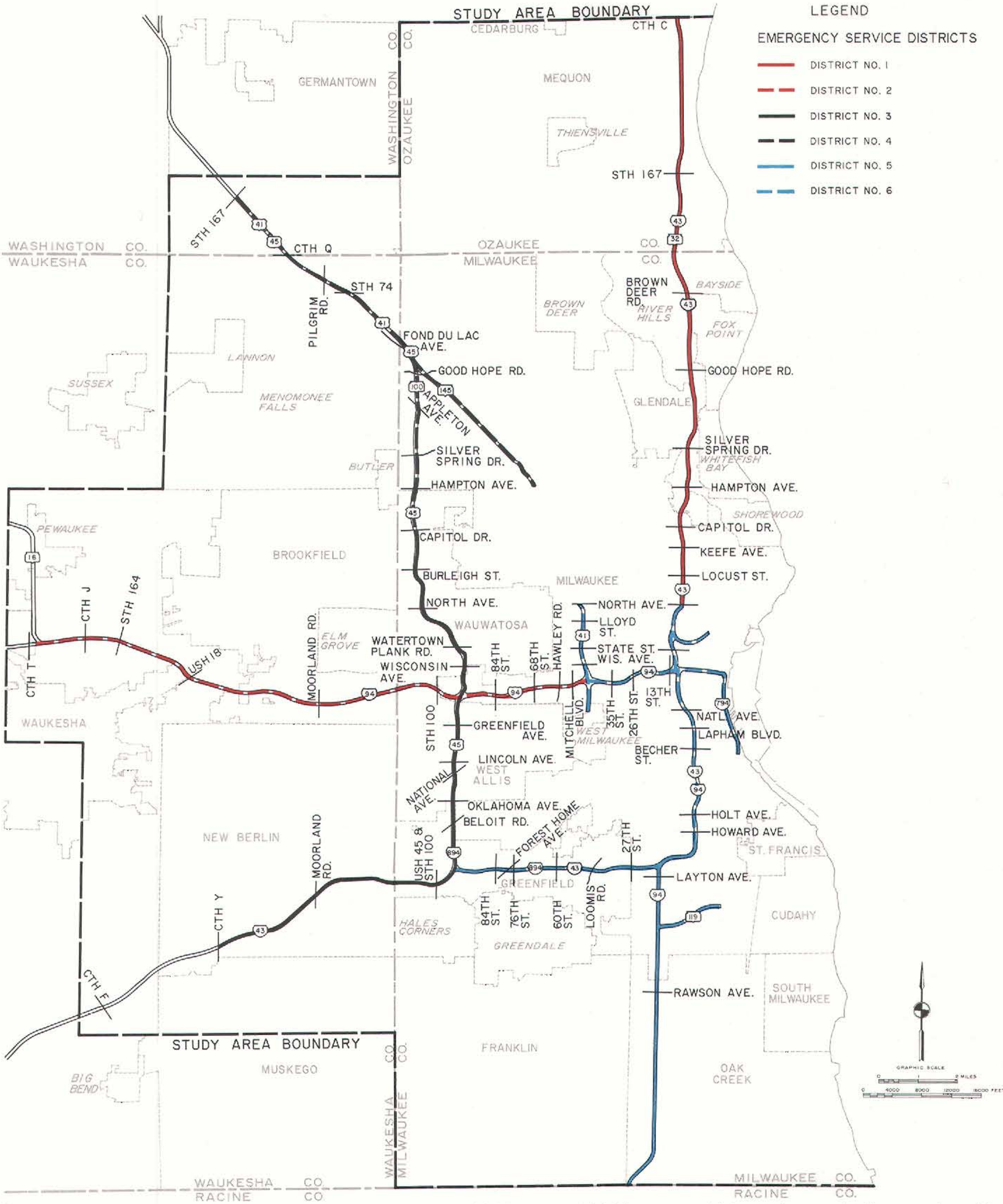


Closed circuit television cameras will aid in freeway incident verification, assessing the nature of the incident, and determining the appropriate response. This map shows recommended locations for 20 closed circuit television cameras on the Milwaukee area freeway system.

Source: SEWRPC.

Map 28

RECOMMENDED AREA TO RECEIVE EMERGENCY SERVICE PATROL FOR INCIDENT MANAGEMENT



Emergency service patrols, operating daily between the hours of 6:00 a.m. and 10:00 p.m., would detect freeway incidents and provide aid to motorists in nonaccident incidents, as well as assist in traffic management at accident locations. One service patrol vehicle would patrol each of the six districts shown on the map. Each district is about 16 miles in center line length, and would take about 19 minutes to patrol in one direction.

Source: SEWRPC.

motorists to call to report an incident. The estimated sign installation cost is $20,000.

It is also recommended that a major incident response team be formed to assist in handling major freeway incidents. The team would leave their principal duties upon a major incident and assist in implementing traffic control and establishing alternative routes.

ALTERNATIVE AND RECOMMENDED MOTORIST ADVISORY INFORMATION ACTIONS

Motorist advisory information assists in abating both recurrent and nonrecurrent traffic congestion and in making more efficient use of the freeway system and total arterial street system. By providing information about freeway incidents and attendant lane closures and alternative freeway and nonfreeway routes during the peak weekday traffic periods, motorist advisory information systems help to abate recurrent traffic congestion problems and promote the more efficient use of freeway and total arterial system capacity. By providing information about incidents, such as identifying lane closures well in advance, motorist advisory information systems can also address nonrecurrent traffic congestion and again assist in making more efficient use of the freeway system.

Existing motorist advisory information in the Milwaukee area is limited to that provided by commercial radio broadcasting stations principally during weekday peak traffic periods, and six portable changeable message signs that are primarily used for freeway construction and maintenance projects. The commercial radio stations obtain their information on traffic conditions from their own surveillance and from the Milwaukee County Sheriff's Department. Also, highway advisory radio transmissions are provided at Milwaukee County Stadium, principally to guide motorists to Stadium freeway exits and parking areas, and to warn motorists of freeway traffic conditions.

Changeable Message Signs

Motorist advisory information systems on freeways are used mainly to inform motorists of traffic conditions ahead and to recommend appropriate actions, such as speed reductions in advance of fog or roadway ice, detours via other freeway segments or surface arterials, or lane changes to avoid a lane closure. Signs with fixed messages cannot be used to provide such unique and continually variable information. Changeable message signs can provide information as traffic conditions warrant. Changeable message signs have been successfully used in several areas of the United States for the last 10 years.

Changeable message signs can be permanently installed, with large display panels spanning the entire directional freeway. Changeable message signs can also be transportable, usually as six- to eight-foot-square signs mounted across the backs of pickup or larger trucks. Transportable signs have the advantage of being able to be positioned precisely where needed. The disadvantages of such signs are that the transporting vehicle may be caught up in the very congestion the sign is intended to address, and that the sign messages provided to traffic are much smaller and less visible, and, as a result, less effective than the larger, fixed changeable message signs.

Because of their cost, major remotely controlled changeable message signs are generally applied only at locations where major traffic diversion either to other freeways or to surface arterials could occur, such as at freeway-to-freeway junctions and at areas of severe congestion and/or frequent traffic incidents.

Radio-Based Driver Information Systems

Information systems can also be provided which rely on commercial radio broadcasts, citizen band radio, or highway advisory radio. These radio-based alternatives to changeable message signs all have shortcomings. Most importantly, vehicles may lack a radio or a citizen band radio. Also, motorists may fail to tune their radio to the commercial radio stations broadcasting traffic information, or to the highway advisory radio station, to obtain the information being transmitted.

Traffic reports provided by commercial radio broadcasting stations have additional shortcomings. Unless traffic reports are based on information provided by a central traffic management center with electronic traffic surveillance and other timely incident detection and confirmation capabilities, the information provided is generally incomplete and not current. Where stations are provided with such information, usually in the form of teletype printouts direct from a traffic management center, the resulting commercial radio announcements are much more useful, and the only limitations are whether motorists have a radio and are listening to the station, and whether the station provides timely broadcast of the information.

Citizen band radio is not a reasonable alternative because of its limited range of three to four miles for broadcasts, and the limited number of motorists with CB radios.

Highway advisory radio is generally considered the best of the three radio-based methods of providing motorist information, as the information provided is the most timely and accurate, and best addresses problems in the affected area. However, it, too, has significant limitations. Typically, highway advisory radio is transmitted at the ends of the normal amplitude modulation (AM) energy band (530 AM or 1610 AM). A major problem is that highway advisory radio cannot be received by all radios, as not all radios are tunable to 530 AM or 1610 AM. Also, highway advisory radio is generally provided by a low-powered AM transmitter with limited range; as a result, it is easily interfered with by commercial radio broadcasting stations on nearby frequencies. In summary, highway advisory radio is dependent upon the motorist seeing and reading the roadside sign advising him or her to tune to the indicated frequency, the motorist having a radio that can receive the highway advisory, the radio being able to receive the transmission clearly, and the motorist tuning the radio to the highway advisory channel.

There are two basic types of highway advisory radio transmission equipment—whip antenna spaced at intervals along the highway and sending a signal in all directions, and cable antenna stretched along the highway and sending only a short lateral signal. Cable antenna is initially more expensive, but possesses a longer useful life. Most highway advisory radio installations have to date, however, been limited to relatively short stretches of freeway or to particular problem areas like tunnels, bridges, or airport terminals. In the Milwaukee area, highway advisory radio has been implemented to assist in handling traffic at Milwaukee County Stadium.

<u>Recommendations for Motorist Advisory Information Systems</u>

The recommended motorist advisory information system for the greater Milwaukee area consists of transportable changeable message signs, fixed changeable message signs, and timely provision of information to commercial radio broadcasting stations. To provide for efficient use of these system components, a central freeway traffic management center will be required.

It is recommended that the motorist advisory information system include two specially equipped trucks capable of carrying and transporting message signs upon which a wide variety of messages can be inserted and displayed. The two trucks, including sign boards and arrays of insertable messages and necessary electrical equipment, have an estimated cost of $100,000. The message signs should be mounted sufficiently high on the trucks to permit the signs to be viewed and read from a distance. The trucks may be used to provide advisory information relative to major special events such as the Fourth of July fireworks display, the Circus Parade, or capacity events at County Stadium; to warn motorists of traffic back ups; or to suggest other exits or routes. The trucks can also be used in response to major incidents.

It is recommended that a system of permanent, remotely controlled, changeable message signs spanning the freeway be installed. These signs should not be installed until the electronic freeway traffic surveillance center is in operation. They should permit the display of any message and not be fixed to provide only a limited number of messages. The cost of the signs will depend on the length and size of message lines that they can provide. The typical message sign includes three lines of 18-inch characters, with between 16 and 32 characters per line, depending upon the number of traffic lanes to be spanned. A 32-character line is usually displayed in a 50- to 60-foot sign enclosure spanning four to five lanes. The cost of the signs would approximate $150,000 each.

The locations of the message signs throughout the Milwaukee area should be selected based upon many considerations. The signs should be located ahead of freeway segments experiencing the most severe traffic congestion, as advisory information about alternative routes and incidents will have the greatest potential in those locations to minimize travel time and delay. The signs should also be located ahead of those segments of the freeway where incidents that typically result in freeway lane blockages are most likely to occur. The signs should also be placed ahead of major freeway interchanges and other connections to alternative routes. The signs should be placed ahead of segments of freeway that may experience unique problems due to their location and design, combined with adverse weather conditions such as fog, snow, or ice. Signs would be used to warn motorists of these conditions and advise them of alternative routes. Signs should also be placed at locations where unusual traffic conditions may occur attendant to special events at County Stadium, State Fair Park, and the lakefront. Based on these considerations, it is recommended that changeable message signs be placed at 14 locations in the greater Milwaukee area, as shown on Map 29. The total cost of this measure should approximate $3.0 million.

It is recommended that upon implementation of the proposed freeway traffic management center and the changeable message signs on the East-West Freeway (IH 94), consideration be given to discontinuing the dedicated highway advisory radio broadcasts from Milwaukee County Stadium. Should continued operation of this station be deemed desirable, the proposed freeway traffic management center should operate it.

It is also recommended that commercial radio broadcasting stations be provided with current traffic reports from the central traffic management center via teleprinter machines. Only stations that would agree to provide a timely broadcast of the information received would be provided with the information.

ALTERNATIVE AND RECOMMENDED MONITORING AND CONTROL SYSTEMS

As already noted, proper implementation of the recommended incident management and advisory information actions would require a central traffic management center. Such a center would also be required for the recommended ramp-meter element of the total freeway traffic management system.

At the traffic management center, all traffic information would be received, analyzed, and evaluated, and decisions made regarding what incident management, advisory information, and ramp metering would be implemented. The control center equipment would include a high-speed, high-capacity computer and related peripheral equipment; a console for providing direction to the computer and for instantaneous review of computer reports; display devices such as CCTV screens; and communications equipment such as radio receivers and transmitters and direct telephone line connections.

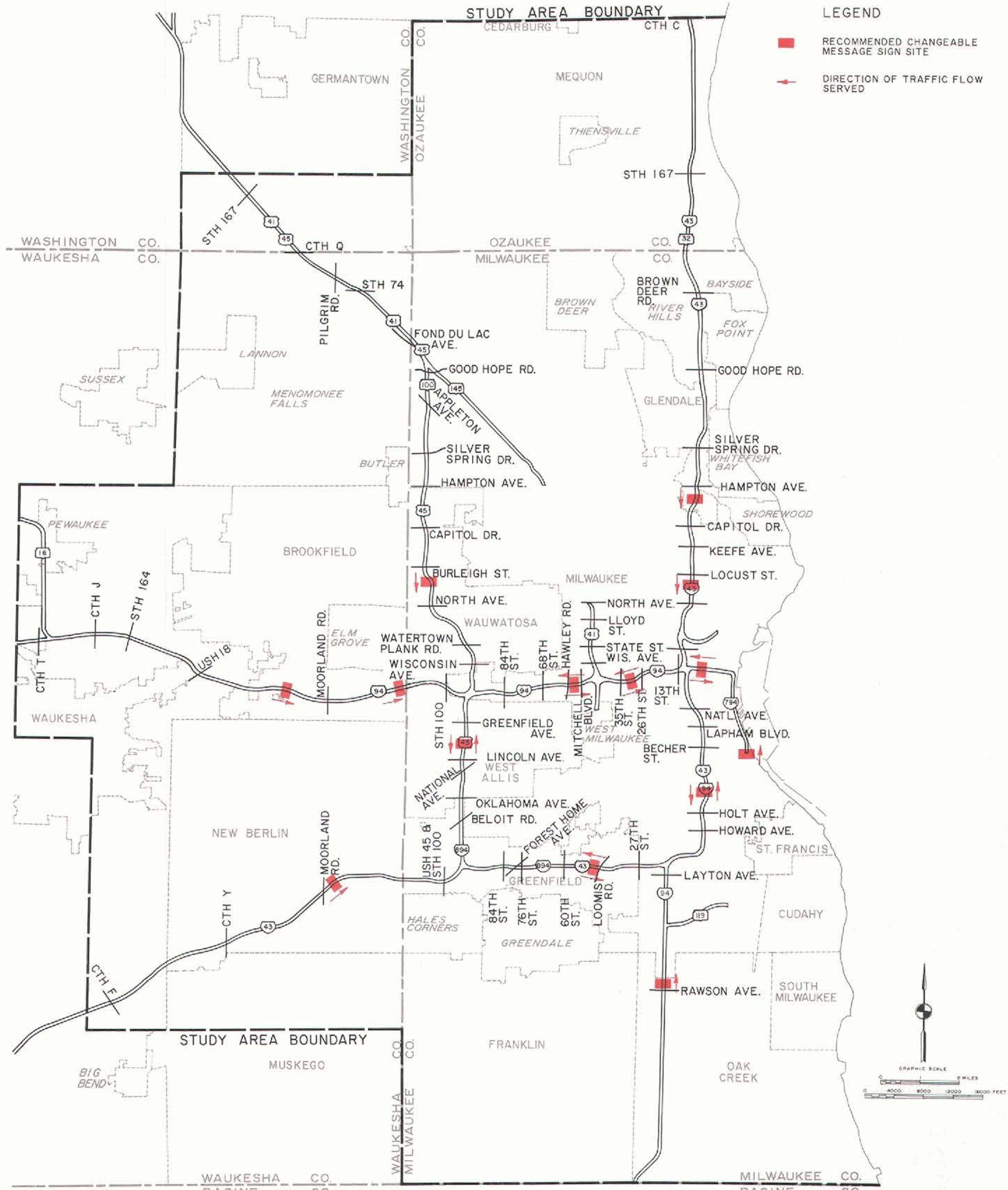
The computer would operate in real time with pre-established programmed control routines. These routines would include turning on and turning off ramp-metering systems; selecting and ordering the display of certain advisory information on remotely controlled, fixed-site, changeable message signs; and monitoring freeway system performance, both printing it for permanent record as well as displaying it to allow operator interaction with the system. Whenever there was a traffic emergency—such as a major incident—routine computer controls could be overridden by the control center staff.

The computer would be used to inform the control center staff of unusual traffic conditions based on computer analysis of the electronically gathered freeway data. Both audio and visual alarms would alert the staff to such incidents. Upon such alarm, the staff would attempt to confirm the incident by reviewing the electronic freeway data at the computer console; reviewing the appropriate closed circuit television screen; monitoring the citizen band radio reports from the nearest remote base station; and contacting expressway patrol squads. Once the problem had been identified, the control center staff would respond, as needed, with changes in ramp metering, and by dispatching expressway patrol squads and emergency service patrols, transmitting messages on changeable message signs, and transmitting information to commercial radio stations.

Control center staff should include both operations and maintenance personnel. The provision of 12-hour weekday and selected special event coverage would require the following staff: a center manager; operations personnel, including two traffic engineers, one electronic systems engineer, four technician operators, and one clerk; and maintenance personnel, including a supervisor, two electronics technicians, and two electricians. Operations personnel must possess extensive knowledge of traffic flow principles, control concepts, and local conditions. There must also be an appreciation of computer-based traffic control systems, along with special knowledge of computer programming. Mainte-

Map 29

RECOMMENDED LOCATIONS OF CHANGEABLE MESSAGE SIGNS ON THE MILWAUKEE AREA FREEWAY SYSTEM



Changeable message signs can provide the motorist with real time information regarding freeway traffic conditions and alternative routes in the event of a major freeway incident. This map shows the recommended locations for 20 changeable message signs on the Milwaukee area freeway system.

Source: SEWRPC.

nance personnel should be capable of maintaining the operating integrity of the system. Traffic control systems must function in a demanding environment, subject to interference by adverse weather conditions, electrical disturbances, and possible damage from vandals and vehicles. The system must provide a highly reliable operation on a continuous basis, 24 hours each day of the year.

The traffic management system required maintenance can be categorized into three types: functional, hardware, and software. Functional maintenance is defined as the ongoing evaluation of how well the traffic management system is achieving its defined objectives. Hardware maintenance is the defined as the monitoring and replacement as necessary of damaged, worn out, or functionally obsolete equipment, either in the field or in the control center. Software maintenance is defined as the development and installation of new computer programs and control procedures as conditions change. All maintenance should be the responsibility of the control center staff, with functional and software maintenance being the responsibility of operations personnel, and hardware maintenance being the responsibility of maintenance personnel.

Based on the estimated staffing needs and the space required for the equipment in a control center, an estimated 7,000 square feet of floor space is needed for the traffic management center. This should provide sufficient space to house the required mechanical and electrical equipment; a storage and maintenance area for the electronic equipment and technicians; offices for law enforcement personnel and the operations supervisor and staff; and a reception area and conference room for meetings and training. Recent construction of control centers in Illinois and Virginia indicate costs approximating $150 per square foot. Construction of a 7,000-square-foot building would cost approximately $1.0 million, exclusive of land and equipment. Necessary equipment would include the computer and its ancillary equipment, including equipment for communications and closed circuit television monitors, at an estimated cost of $650,000, for a total estimated cost of $1,650,000 for the traffic management center. Careful consideration should be given to the location of the center, as it should provide accessibility to the area freeway system.

ALTERNATIVE AND RECOMMENDED FREEWAY OPERATIONAL CONTROL SUBSYSTEMS

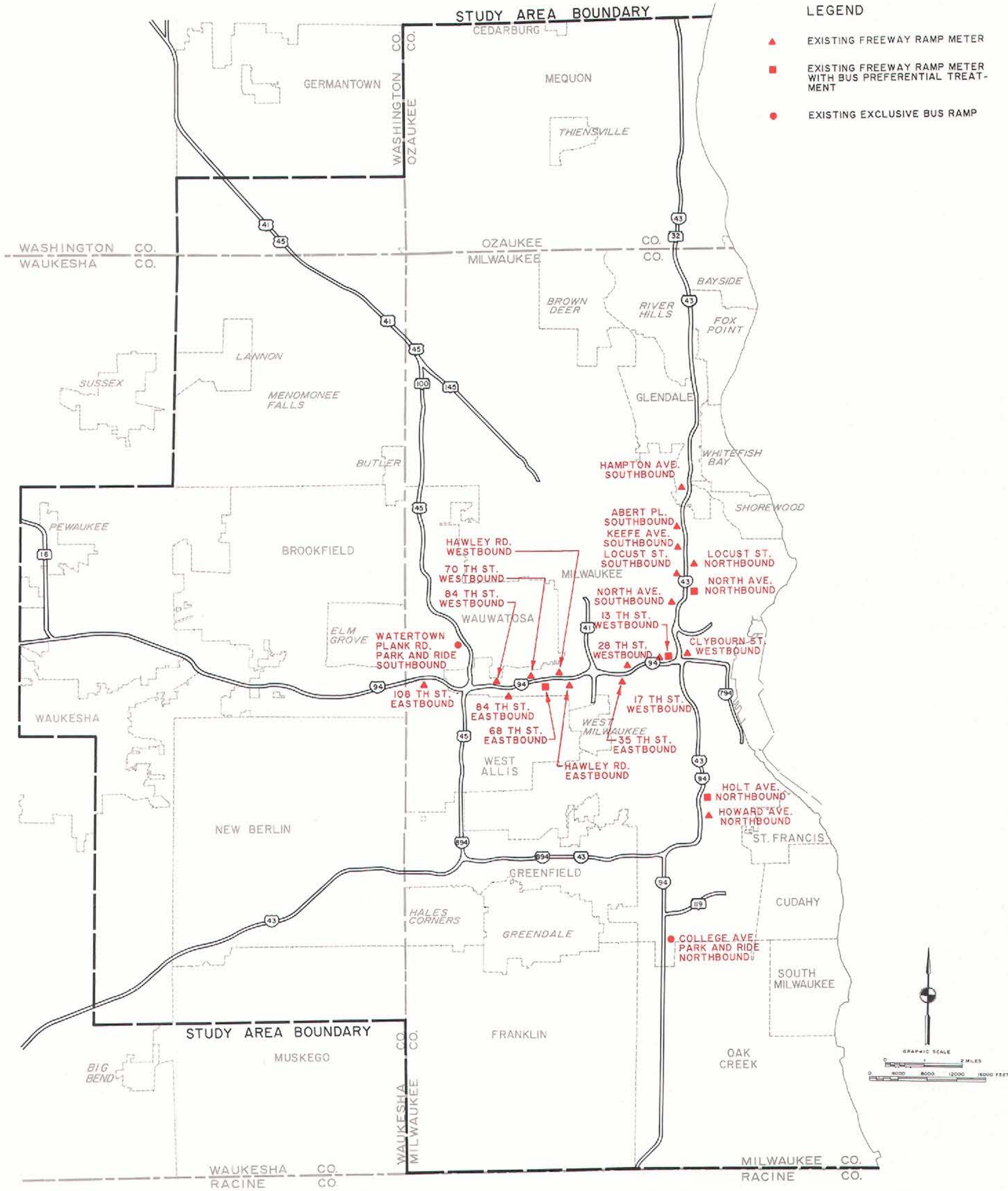
Two basic alternatives for the freeway operational control subsystems which incorporate the remaining freeway traffic management elements are presented and evaluated. The freeway operational control subsystems include the ramp-metering system, or the number and location of ramp meters; the freeway operational control strategy; the ramp-meter control strategy; and high-occupancy-vehicle preferential access.

One of the two alternatives evaluated represents a modest expansion of the existing freeway operational control subsystem. Currently, 21 freeway on-ramps in central Milwaukee County are metered, as shown on Map 30. The meters are located at freeway on-ramps adjacent to the segments of freeway that experience the most severe congestion during morning and evening peak traffic periods. The meters exercise control of freeway traffic volume by restricting, or metering, freeway on-ramp traffic. The principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. Preferential access is provided for buses at six locations, also shown on Map 30. Ramp-meter entrance rates are responsive to the traffic volumes on immediately adjacent freeway lanes. Under this alternative, new freeway ramp meters would be installed at those on-ramps adjacent to congested stretches of freeways that are currently not metered, as shown on Map 31. New preferential access for buses would be provided at those on-ramps that are proposed to be metered and that are used by freeway flyer buses to provide transit service.

The other freeway operational control subsystem alternative considered represents a major expansion of the existing system. The freeway on-ramps throughout Milwaukee County would be metered, along with selected on-ramps in Ozaukee, Washington, and Waukesha Counties which carry substantial traffic volumes and contribute to freeway traffic congestion, as shown on Map 32. This subsystem alternative has a broader objective than the existing system—namely, to minimize freeway congestion and provide average operating speeds of 35 to 40 mph on all

Map 30

EXISTING MILWAUKEE AREA FREEWAY TRAFFIC MANAGEMENT SYSTEM: 1987

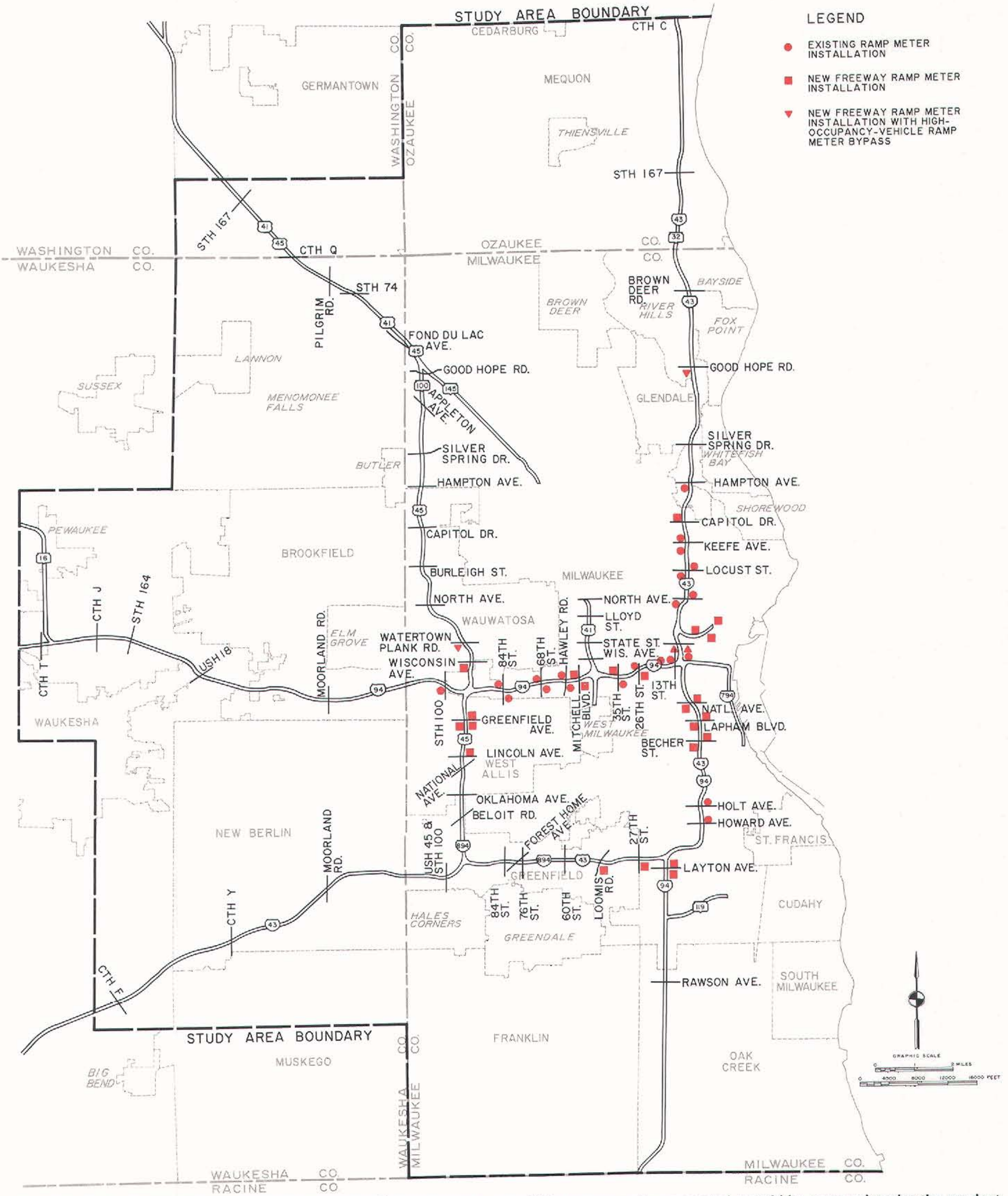


Traffic entering the freeway system at a limited number of freeway on-ramps within the Milwaukee area freeway system is currently metered during the morning or evening peak periods. This map shows the locations of the 21 existing metered ramps, as well as the locations of the four existing ramp meters with bypasses for buses.

Source: Wisconsin Department of Transportation and SEWRPC.

Map 31

PROPOSED METERING OF FREEWAY ON-RAMPS UNDER THE ALTERNATIVE OF MODEST EXPANSION OF FREEWAY OPERATIONAL CONTROL

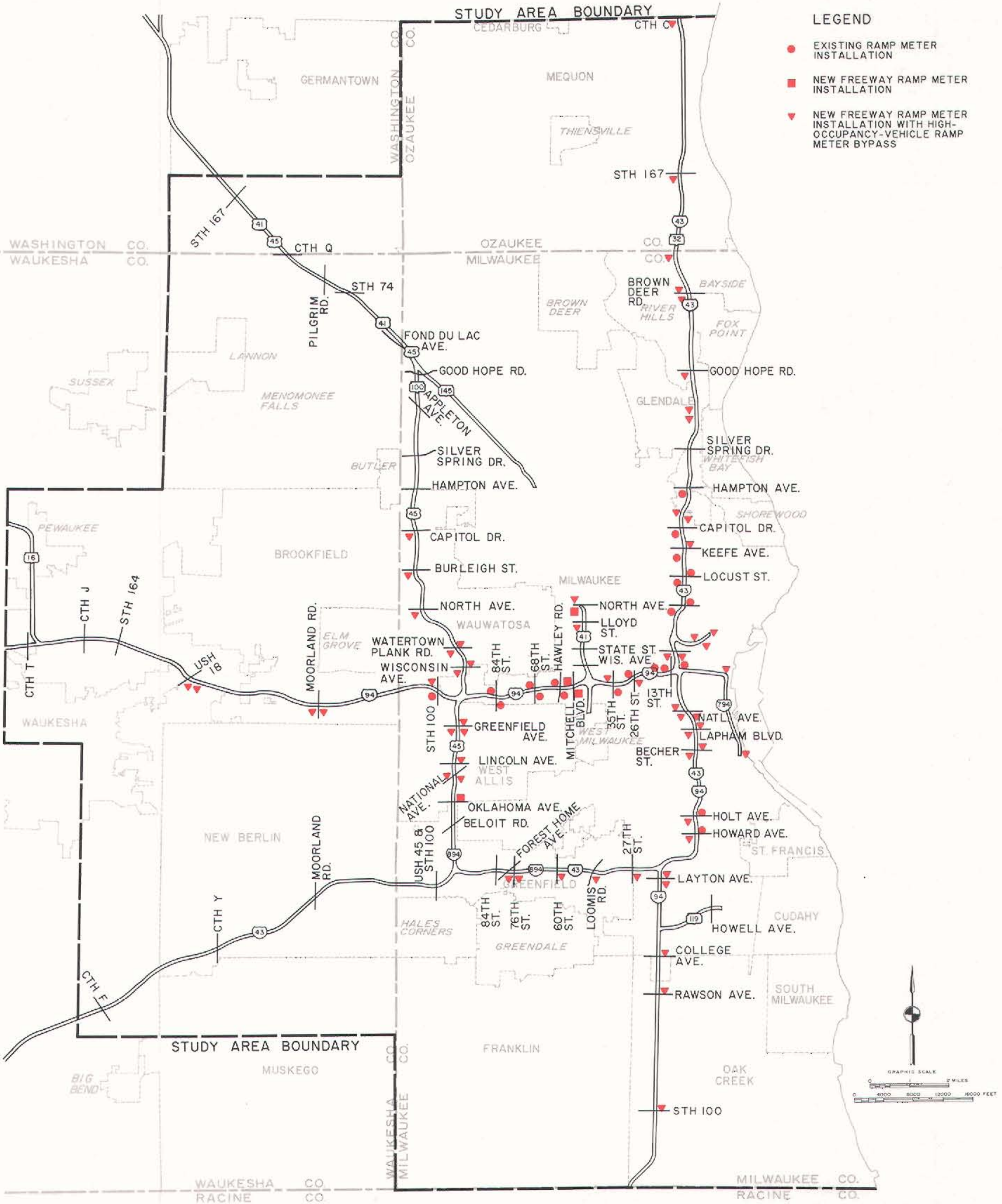


A total of 24 additional ramps, located adjacent to freeway segments which are currently congested, would be metered under the modest freeway operational control expansion alternative. The recommended locations of these additional metered ramps, and of the existing metered ramps, are shown on this map.

Source: SEWRPC.

Map 32

PROPOSED METERING OF FREEWAY ON-RAMPS UNDER THE ALTERNATIVE OF MAJOR EXPANSION OF FREEWAY OPERATIONAL CONTROL



A total of 57 additional ramps, located adjacent to and upstream of freeway segments which are currently congested, would be metered under the major expansion alternative. The locations of these metered ramps, and of the existing metered ramps, are shown on this map.

Source: SEWRPC.

segments of the freeway during peak traffic periods. The areawide expansion of ramp meters should permit sufficient control of traffic demand to prevent demand from exceeding freeway capacity. The necessary restriction of freeway traffic demand to permit peak-hour operation of at least 35 to 40 mph would be attempted to be applied equally at all metered freeway on-ramps. Also under this alternative, preferential access for all high-occupancy vehicles—buses, carpools, and vanpools—would generally be provided at all metered ramps.

The configuration and evaluation of these two freeway operational control subsystem alternatives—modest system expansion and major system expansion—are herein presented by segment of freeway, as well as for the areawide freeway system as a whole. The test and evaluation of the two alternative freeway operational control subsystems was conducted with a micro traffic simulation model, FREQ7PE,[1] which simulated freeway corridor traffic in 15-minute increments during the morning peak traffic hour of 7:00 a.m. to 8:00 a.m. The model was calibrated with the freeway origin and destination survey data collected in 1983 and 1984.

<u>North-South (IH 43) Freeway</u>
<u>Between the Marquette Interchange</u>
<u>and Pioneer Road (CTH C)</u>

The first freeway segment selected for analysis was the North-South Freeway (IH 43) between the Marquette Interchange and Pioneer Road (CTH C), the northern boundary of the greater Milwaukee area. Along this stretch of freeway there are currently 17 southbound freeway on-ramps and 12 northbound freeway on-ramps, as summarized in Table 6. Average weekday peak morning and evening traffic volumes for each on-ramp in 1986 are also presented in Table 6, along with the peak-hour traffic volumes on the freeway adjacent to the on-ramp; the percentage of peak-hour traffic from each on-ramp that travels through congested portions of this freeway segment; and the percentage of peak-hour traffic on these congested freeway portions that is attributable to each on-ramp. Those on-ramps that are proposed to be metered under each freeway operational control subsystem alternative are shown in Table 6 and on Map 33. Under the alternative proposing major expansion of the freeway operational control subsystem, ramp meters were proposed for installation principally at those on-ramps at which 50 percent or more of the peak-hour traffic demand utilized congested freeway segments. Under the modest expansion freeway operational control subsystem alternative, ramp meters were proposed to be installed generally at those on-ramps adjacent to congested freeway segments.

The metering rates under each freeway operational control subsystem alternative during the morning peak traffic hour are shown in Table 7, along with the average and maximum queue of vehicles at each on-ramp, and the average and maximum delay per metered vehicle at the ramp meter at each on-ramp. Also shown is the anticipated diversion of freeway traffic to surface arterials as a result of the ramp metering. Such diversion was generally determined to occur as delays at metered ramps approached one to two minutes and vehicle queues approached 12 vehicles. The potential freeway portion of the trips determined to be diverted was, for the most part, under two miles in length, with the remainder generally between two and five miles in length. The vehicle trips diverted would not, under either alternative, be expected to significantly affect the operation of related surface arterials.

Table 8 compares the two freeway operational control subsystem alternatives to 1983 conditions with respect to efficiency of travel during the morning peak hour. Both alternatives would improve the operation of the North-South Freeway (IH 43), as well as the operation of the total transportation system in the freeway corridor, including the freeway, its ramps, and the traffic diverted to surface arterials. Specifically, both alternatives would represent a reduction of approximately 55 passenger hours of travel in the morning peak hour on this freeway segment itself, or a reduction of over 3 percent, even though major portions of this freeway segment are currently metered and a sizeable portion of the travel during the morning peak hour on the segment does not generally require—and therefore receives little benefit from—freeway operational control, including the early portions of the peak hour during which freeway capacity exceeds travel demand.

[1] *See <u>FREQ7PE: A Freeway Corridor Simulation Model</u>, Institute of Transportation Studies, University of California, 1980.*

Both alternatives may also be expected to improve the operation of the total transportation system of the North-South Freeway corridor, including operation of both personal and mass transit vehicles, by shortening the delays at freeway on-ramps attendant to the expanded ramp-metering system, and by increasing travel times by diverting freeway traffic to surface arterials. The modest expansion alternative may be expected to result in a reduction of approximately five passenger hours, or a reduction of under 1 percent, and the major expansion alternative may be expected to result in a reduction of approximately 25 passenger hours during the morning peak hour, or a reduction of about 1.5 percent. The more substantial improvement in freeway corridor operation under the major expansion alternative may be attributed to its provision of extensive preferential freeway access to high-occupancy vehicles, which does not delay carpools at the metered freeway on-ramps. It should be noted that the estimated improvement in freeway corridor operation attributable to carpools is a result of improved travel conditions provided to carpools under this alternative. Nevertheless, the small average delays of under one minute and expected maximum delays of about two minutes at freeway ramp meters are not expected to result in an increase of more than 1 percent in the number of carpools on the North-South Freeway (IH 43) during the morning peak hour.

Another difference between the major and minor expansion alternatives are their effects on delays at individual on-ramps. Under the major expansion alternative, the average delays at the on-ramps that are currently metered in the central portion of Milwaukee County are expected to be slightly reduced, particularly if it is recognized that carpools at these on-ramps are no longer delayed. Similar delays would occur at seven additional ramps, generally located in northern Milwaukee County and southern Ozaukee County. As shown in Table 7, a substantial portion of the traffic from the additional ramps proposed to be metered—between 55 and 75 percent—travels through congested segments of the North-South Freeway (IH 43). Also, the traffic from the additional on-ramps proposed to be metered generally represents a significant portion—between 3 and 13 percent—of the total traffic utilizing the congested freeway segments of the North-South Freeway (IH 43).

The alternative calling for major expansion of freeway operational control, however, would have an estimated capital cost of $1,300,000, which is substantially greater than the estimated capital cost of $245,000 for the modest expansion alternative. The greater capital cost is attributable to the additional on-ramps which would be metered, and the reconstruction of freeway on-ramps that would be necessary to provide high-occupancy-vehicle preferential freeway access.

North-South Freeway (IH 94)
Between the Marquette Interchange and
the Milwaukee County-Racine County Line

The next freeway segment analyzed was the North-South Freeway (IH 94) between the Marquette Interchange and the Milwaukee County-Racine County line. The analysis of this freeway segment also included analysis of the connecting freeway segment of the Airport Freeway (IH 894) between the Mitchell Interchange and the Hale Interchange. Consideration was also given to the segment of the Rock Freeway (IH 43) between the Hale Interchange and the western limits of the Milwaukee urbanized area; however, no ramp metering was proposed on this freeway segment under either the modest or major expansion alternative. The inventories indicated that no segment of the Rock Freeway—formerly STH 15, designated IH 43 in 1988—adjacent to an on-ramp experiences traffic congestion, and a relatively small portion—generally less than 20 percent—of the total peak-hour traffic demand at any of the Rock Freeway on-ramps utilized congested segments of the greater Milwaukee area freeway system. Under the alternative proposing major expansion of the freeway operational control subsystem, ramp meters were generally proposed for installation at those on-ramps at which 50 percent or more of the peak-hour traffic demand utilized congested freeway segments. Under the modest expansion alternative, ramp meters were proposed to be installed generally at those on-ramps adjacent to congested freeway segments.

Along this stretch of the North-South Freeway (IH 94) and the Airport Freeway (IH 894), there are currently 17 northbound and eastbound freeway on-ramps and 17 southbound and westbound on-ramps, as summarized in Table 9. Average weekday morning and evening peak-hour traffic volumes in 1986 are presented in Table 9 for each on-ramp, along with the peak-

Table 6

FREEWAY ON-RAMPS PROPOSED TO BE METERED UNDER THE FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES ON THE NORTH-SOUTH FREEWAY (IH 43)

	Southbound IH 43—Morning Peak Traffic Hour								
				Morning Peak-Hour Traffic Characteristics					
						Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
Freeway On-Ramps	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	IH 43 at Silver Spring Drive	IH 43 at North Avenue	IH 43 at Silver Spring Drive	IH 43 at North Avenue
CTH C (Pioneer Road)	--	--	X	640	1,910/2	70	55	11	6
STH 167 (Mequon Road)	--	--	X	720	2,550/2	75	58	13	7
County Line Road	--	--	X	360	3,050/2	73	54	6	3
STH 100 Westbound (Brown Deer Road)	--	--	X	320	3,170/2	76	63	6	3
STH 100 Eastbound (Brown Deer Road)	--	--	X	510	3,390/2	83	64	10	6
CTH PP (Good Hope Road)	--	X[d]	X	1,040	3,395/2	98	84	24	15
Silver Spring Drive Westbound	--	--	X	440	4,235/2	100	92	10	7
Silver Spring Drive Eastbound	--	--	X	680	4,145/3	--	98	--	11
Hampton Avenue	X	X	X	590	4,825/3	--	97	--	10
STH 57 (Green Bay Avenue)	--	X	X	490	4,910/3	--	98	--	8
Abert Place	X	X	X	380	5,275/3	--	100	--	7
Keefe Avenue	X	X	X	400	5,655/3	--	100	--	7
Locust Street	X	X	X	340	5,800/3	--	100	--	6
North Avenue	X	X	X	500	5,720/3	--	100	--	6
East-South Ramp—Hillside Interchange	--	--	--	570	4,810/3	--	--	--	--
State Street[b]	--	--	--	370	4,690/3	--	--	--	--

	Northbound IH 43—Afternoon Peak Traffic Hour								
				Afternoon Peak-Hour Traffic Characteristics					
						Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
Freeway On-Ramps	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	IH 43 at Locust Street	IH 43 at Hampton Avenue	IH 43 at Locust Street	IH 43 at Hampton Avenue
CTH C (Pioneer Road)	--	--	--	70	1,270/2	--	--	--	--
STH 167 (Mequon Road)	--	--	--	210	1,600/2	--	--	--	--
STH 100 Westbound (Brown Deer Road)	--	--	--	210	2,320/2	--	--	--	--
STH 100 Eastbound (Brown Deer Road)	--	--	--	200	2,805/2	--	--	--	--
CTH PP (Good Hope Road)	--	--	--	480	3,070/2	--	--	--	--
Silver Spring Drive Westbound	--	--	--	350	3,805/2	--	100	--	--
Silver Spring Drive Eastbound	--	--	--	330	4,110/3	--	100	--	--
Fiebrantz Avenue	--	--	X[d]	420	5,005/3	--	100	--	9
Atkinson Avenue	--	--	X[e]	120	5,800/3	--	75	--	2
Locust Street	X	X	X[d]	340	5,870/3	100	60	6	5
North Avenue	X[c]	X[c]	X[d]	500	5,840/3	100	56	7	6
4th Street (Park Freeway)	--	X[f]	X[d,f]	1,130	N/A	62	40	11	11
Milwaukee Street (Park Freeway)	--	X[f]	X[d,f]	820	N/A	61	33	5	4
Jefferson Street (Park Freeway)	--	X[f]	X[d,f]	690	N/A	61	33	4	4
Kilbourn Avenue	--	X	X[d]	1,000	5,700/3	97	60	17	14

NOTE: N/A indicates data is not applicable because freeway on-ramp does not access IH 43 directly.

[a] *A high-occupancy-vehicle bypass for buses and multi-occupant vehicles is provided at each metered on-ramp under this alternative.*

[b] *Metering at this ramp would be provided under both alternatives during the afternoon peak hour, as 1986 traffic demand at this on-ramp during the afternoon peak hour was an estimated 1,090 vehicles per hour; and 1986 traffic on the adjacent three-lane freeway segment was an estimated 3,960 vehicles per hour.*

[c] *High-occupancy-vehicle ramp-meter bypass currently for buses only.*

[d] *High-occupancy-vehicle bypass to be provided.*

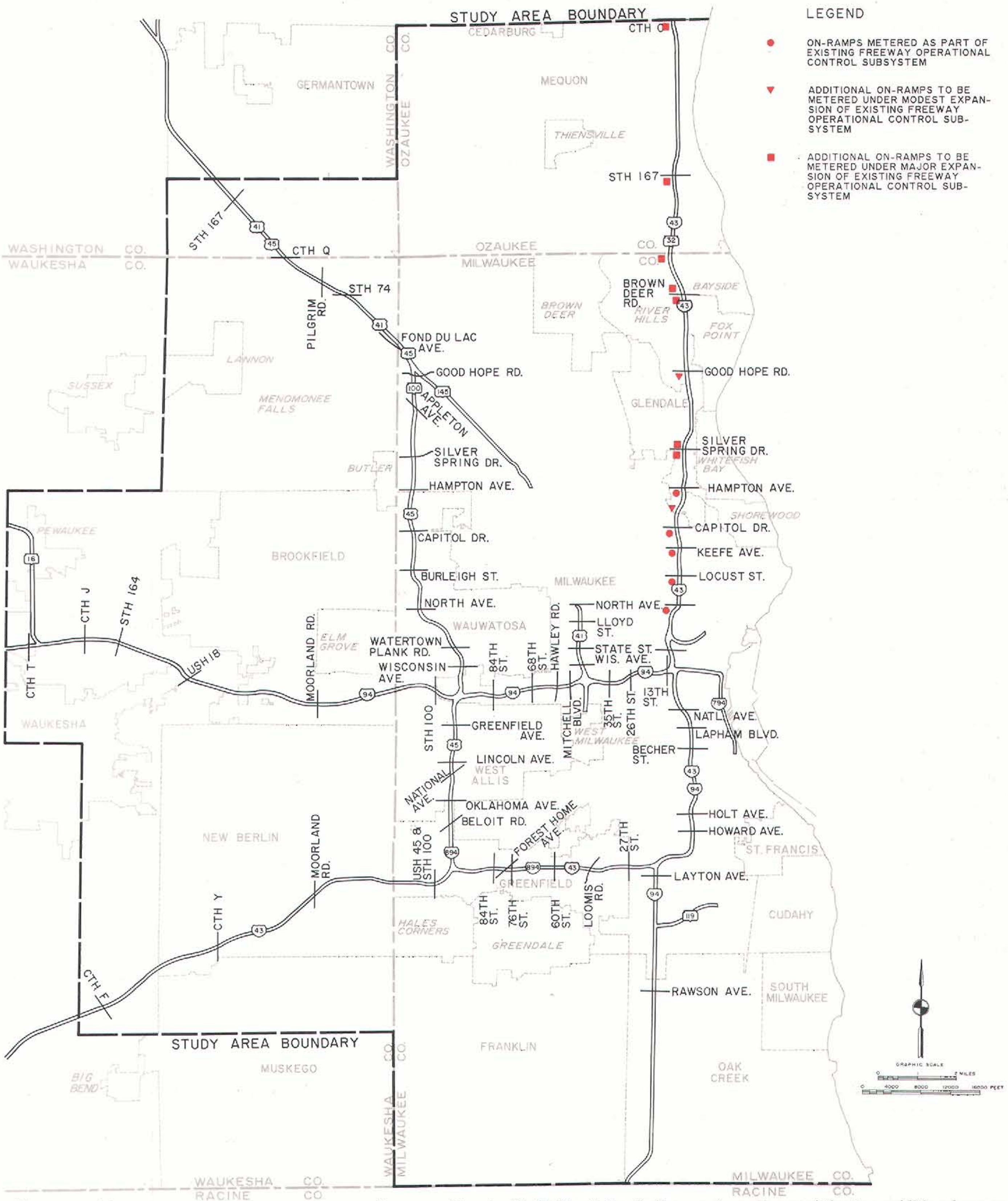
[e] *The volume entering at this ramp is less than the volume generally considered necessary for ramp metering. This ramp should be metered, however, to discourage traffic from bypassing metered ramps upstream.*

[f] *The metering of these three ramps could also be accomplished through metering of the westbound Park Freeway ramp to the northbound North-South Freeway.*

Source: SEWRPC.

Map 33

ON-RAMPS PROPOSED TO BE METERED DURING MORNING PEAK TRAFFIC PERIOD UNDER EACH FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVE ON IH 43 FROM CTH C TO THE MARQUETTE INTERCHANGE



Shown on this map are the five on-ramps currently metered in the IH 43 (North-South Freeway) corridor; and the two additional ramps that would be metered under the modest expansion freeway operational control alternative and the seven additional ramps that would be metered under the major expansion alternative.

Source: SEWRPC.

Table 7

COMPARISON OF ESTIMATED IMPACTS OF FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES AT THE ON-RAMPS ON THE NORTH-SOUTH FREEWAY (IH 43) DURING THE MORNING PEAK TRAFFIC HOUR

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Existing Freeway Operational Control[a]						
				Meter Delay			Meter Queue		
	Single Occupant	Multiple Occupant	Average Peak-Hour Meter Rate	Average per Vehicle (minutes)	Maximum per Vehicle (minutes)	Total (hours)	Average	Maximum	Traffic Diversion to Surface Arterial (vehicles)
CTH C (Pioneer Road)	451	58	--	--	--	--	--	--	--
STH 167 (Mequon Road)	447	123	--	--	--	--	--	--	--
County Line Road	389	46	--	--	--	--	--	--	--
STH 100 Westbound (Brown Deer Road)	359	46	--	--	--	--	--	--	--
STH 100 Eastbound (Brown Deer Road)	446	49	--	--	--	--	--	--	--
CTH PP (Good Hope Road)	976	154	--	--	--	--	--	--	--
Silver Spring Road Westbound	400	65	--	--	--	--	--	--	--
Silver Spring Drive Eastbound	507	88	--	--	--	--	--	--	--
Hampton Avenue	416	68	480	0.5	0.9	3.7	4	6	133
STH 57 (Green Bay Avenue)	322	48	--	--	--	--	--	--	--
Abert Place	404	101	505	0.7	1.7	5.0	5	12	116
Keefe Avenue	284	65	349	0.4	1.2	1.9	2	7	100
Locust Street	281	54	335	0.5	1.0	2.4	3	5	50
North Avenue	258	42	297	1.0	1.2	4.1	5	5	67
East-South Ramp—Hillside Interchange	346	44	--	--	--	--	--	--	--
State Street	342	58	--	--	--	--	--	--	--

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Modest Expansion of Freeway Operational Control[a]						
				Meter Delay			Meter Queue		
	Single Occupant	Multiple Occupant	Average Peak-Hour Meter Rate[b]	Average per Vehicle (minutes)	Maximum per Vehicle (minutes)	Total (hours)	Average	Maximum	Traffic Diversion to Surface Arterial (vehicles)
CTH C (Pioneer Road)	451	58	--	--	--	--	--	--	--
STH 167 (Mequon Road)	447	123	--	--	--	--	--	--	--
County Line Road	389	46	--	--	--	--	--	--	--
STH 100 Westbound (Brown Deer Road)	359	46	--	--	--	--	--	--	--
STH 100 Eastbound (Brown Deer Road)	446	49	--	--	--	--	--	--	--
CTH PP (Good Hope Road)	976	154	884	0.7	0.9	10.7	11	12	90
Silver Spring Road Westbound	400	65	--	--	--	--	--	--	--
Silver Spring Drive Eastbound	507	88	--	--	--	--	--	--	--
Hampton Avenue	416	68	480	0.5	0.9	3.7	4	6	133
STH 57 (Green Bay Avenue)	322	48	514	0.2	0.7	1.6	2	6	--
Abert Place	404	101	505	0.7	1.7	5.0	5	12	116
Keefe Avenue	284	65	349	0.4	1.2	1.9	2	7	100
Locust Street	281	54	335	0.5	1.0	2.4	3	5	50
North Avenue	258	42	295	1.0	1.2	4.1	5	5	67
East-South Ramp—Hillside Interchange	346	44	--	--	--	--	--	--	--
State Street	342	58	--	--	--	--	--	--	--

hour volumes on the freeway segments adjacent to the on-ramps, the percentage of peak-hour traffic from each on-ramp that travels through congested portions of the freeway segment concerned, and the percentage of peak-hour traffic on the congested freeway portions that is attributable to each on-ramp. Those on-ramps that are proposed to be metered under each freeway operational control subsystem alternative are shown in Table 9 and on Map 34.

The metering rates under each freeway operational control subsystem alternative during the morning peak hour are shown in Table 10, along

Table 7 (continued)

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Major Expansion of Freeway Operational Control[a]						
			Average Peak-Hour Meter Rate[b]	Meter Delay			Meter Queue		Traffic Diversion to Surface Arterial (vehicles)
	Single Occupant	Multiple Occupant		Average per Vehicle (minutes)[c]	Maximum per Vehicle (minutes)	Total (hours)	Average	Maximum	
CTH C (Pioneer Road)	451	58	466	0.6	1.0	3.9	4	7	- -
STH 167 (Mequon Road)	447	123	467	0.6	1.0	4.1	4	7	- -
County Line Road	389	46	445	0.5	1.0	3.5	4	6	- -
STH 100 Westbound (Brown Deer Road)	359	46	427	0.6	0.9	3.1	4	6	- -
STH 100 Eastbound (Brown Deer Road)	446	49	510	0.5	1.0	4.1	4	7	- -
CTH PP (Good Hope Road)	976	154	884	0.7	0.9	10.7	11	12	90
Silver Spring Road Westbound	400	65	453	0.9	2.0	6.4	7	12	5
Silver Spring Drive Eastbound	507	88	534	0.6	1.0	4.7	5	8	- -
Hampton Avenue	416	68	470	0.6	1.2	4.1	4	7	133
STH 57 (Green Bay Avenue) . . .	322	48	399	0.5	0.8	2.4	3	4	- -
Abert Place	404	101	431	0.8	1.7	4.4	5	8	116
Keefe Avenue	284	65	352	0.4	1.2	2.2	2	5	100
Locust Street	281	54	364	0.6	1.2	2.7	3	5	50
North Avenue	258	42	346	0.6	1.2	2.2	3	5	67
East-South Ramp—Hillside Interchange	346	44	- -	- -	- -	- -	- -	- -	- -
State Street	342	58	- -	- -	- -	- -	- -	- -	- -

[a]*The average vehicle speeds in the morning peak hour on the freeway under the two freeway operational control subsystem alternatives and existing 1983 conditions are as follows: Brown Deer Road to Silver Spring Drive—under existing conditions, an estimated 49.0 mph, under the modest expansion alternative, 49.0 mph, and under the major expansion alternative, 50.4 mph; Silver Spring Drive to Capitol Drive—under existing conditions, 47.5 mph, under the modest expansion alternative, 48.8 mph, and under the major expansion alternative, 49.6 mph; and Capitol Drive to North Avenue—under existing conditions, 41.9 mph, under the modest expansion alternative, 44.6 mph, and under the major expansion alternative, 46.0 mph. The travel time savings for mass transit vehicles operating between Brown Deer Road and North Avenue under the modest or major expansion of freeway operational control would be about one minute, reducing the time required for the trip from 11 to 10 minutes.*

[b]*Because the peak-hour freeway traffic demand is much heavier during the last 45 minutes of the morning peak hour, the metering rate at each on-ramp during that portion of the peak hour is 75 to 90 percent of the metering rate shown in the table, which is an average over the full morning peak hour.*

[c]*Multi-occupant vehicles may be expected to represent 15 to 20 percent of the total entering volume on the on-ramps in the central portion of Milwaukee County in this North-South Freeway (IH 43) corridor. Implementation of the major expansion alternative would eliminate any delays to multi-occupant vehicles; therefore, the average delay per entering vehicle under the major expansion alternative would be 15 to 20 percent less than the average delay per metered vehicle presented in this table for that alternative.*

Source: SEWRPC.

with the average and maximum number of vehicles in the queues at each on-ramp, and the average and maximum delay per metered vehicle at each ramp meter. Also shown is the anticipated diversion of potential freeway traffic to surface arterials as a result of the ramp metering. Such diversion was generally determined to occur as delays at metered ramps approached one to two minutes and vehicle queues approached 12 vehicles. The potential freeway portion of the trips determined to be diverted was, for the most part, under two miles in length, with the remainder generally between two and five miles in length. The vehicle trips diverted would not, under either alternative, be expected to significantly affect the operation of related surface arterials.

Table 11 compares the two freeway operational control subsystem alternatives to existing 1983 conditions with respect to efficiency of travel during the morning peak hour. Both alternatives would improve somewhat the operation of the North-South Freeway (IH 94) and the Airport Freeway (IH 894); however, neither would improve the operation of the total transportation system in this freeway corridor—including the freeway facilities, the freeway ramps, and the surface arterials—because the additional travel time due to delayed traffic at metered freeway ramps and to traffic diverted to surface arterials would offset the improvements to the operation of the freeway itself. Specifically, with respect to freeway operation, implementation of the major expansion alternative would result in a reduc-

Table 8

COMPARISON OF ALTERNATIVE FREEWAY OPERATIONAL CONTROL SUBSYSTEMS ON THE NORTH-SOUTH FREEWAY (IH 43) WITH RESPECT TO EFFICIENCY OF FREEWAY TRAVEL IN THE MORNING PEAK TRAFFIC HOUR

Subsystem	Vehicle Hours of Travel				Vehicle Miles of Travel		
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Total
Existing (1983)	1,230	20	100	1,350	64,000	2,300	66,300
Modest Expansion of Freeway Operational Control	1,200	30	130	1,360	63,300	3,000	66,300
Major Expansion of Freeway Operational Control	1,200	70	110	1,380	63,600	2,600	66,200

Subsystem	Passenger Hours of Travel					Passenger Miles of Travel			
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total
Existing (1983)	1,575	25	120	85	1,805	81,000	2,700	3,900	87,600
Modest Expansion of Freeway Operational Control	1,520	40	158	82	1,800	80,100	3,600	3,900	87,600
Major Expansion of Freeway Operational Control	1,520	70	110	80	1,780	81,100	2,600	3,900	87,600

Source: SEWRPC.

tion of approximately 40 passenger hours of travel in the morning peak hour on the freeway segment itself—a reduction of about 3 percent. Implementation of the modest expansion alternative would result in a reduction of about 15 passenger hours of travel on the freeway segment, or a reduction of about 1 percent. With respect to the improvement in freeway operation during the morning peak hour that may be expected under these two alternatives, it should be recognized that substantial portions of the existing travel on this freeway segment during the morning peak hour do not generally require—and therefore would receive little benefit from—freeway operational control. Such travel demand includes the travel on the entire freeway segment during the early portions of the peak hour in which freeway capacity exceeds travel demand, and the travel on those portions of the freeway segment located in the far southern and southwestern portions of Milwaukee County where freeway capacity exceeds travel demand throughout the entire morning peak hour.

Neither of the alternative control systems may be expected to significantly improve the operation of the total transportation system in the North-South Freeway (IH 94) and the Airport

Freeway (IH 894) corridors, with the total system encompassing not only the freeways, but also the freeway ramps and surface arterials. Under the modest expansion alternative, the total passenger hours of travel during the morning peak hour in the freeway corridor may be expected to actually increase by approximately 10 passenger hours, or about 0.6 percent. Under the major expansion alternative, total passenger hours may be expected to increase by approximately five passenger hours, or about 0.3 percent. The smaller increase in passenger hours of travel under the major expansion alternative may be attributed to the extensive preferential access provided to high-occupancy vehicles, particularly carpools. Nevertheless, the small average delays of generally under one minute, and maximum delays of about two minutes, at freeway ramp meters are not expected to result in an increase of more than 1 percent in the number of carpools on the North-South Freeway (IH 94) and Airport Freeway (IH 894) during the morning peak hour.

A difference between the major and modest expansion of freeway operational control is their effects on metering delays at individual on-ramps. Under the major expansion alternative, the delays at the on-ramps in the central portion of Milwaukee County would be slightly reduced. However, delays would also occur at 12 additional ramps, which are generally located in southern and southwestern Milwaukee County. As shown in Table 6, a substantial portion of the traffic from the additional ramps proposed to be metered—between 50 and 100 percent—may be expected to travel through congested segments of the North-South Freeway (IH 94). Also, the traffic from the additional on-ramps proposed to be metered represents between 3 and 10 percent of the total traffic utilizing the congested freeway segments of the North-South Freeway (IH 94).

The major expansion alternative would have an estimated capital cost of $2,100,000, substantially greater than the estimated capital cost of $280,000 for the modest expansion alternative. The greater capital cost is attributable to the additional on-ramps that would be metered, and the reconstruction of freeway on-ramps which be necessary to provide high-occupancy-vehicle preferential freeway access.

East-West Freeway (IH 94) West of the Marquette Interchange, Including Connecting Segments of the Stadium (USH 41), Zoo (USH 45), and Airport (IH 894) Freeways

The next freeway analyzed was the East-West Freeway (IH 94) west of the Marquette Interchange, and connecting freeway segments of the Stadium Freeway (USH 41), the Airport Freeway (IH 894), and the Zoo Freeway (USH 45). Under the alternative proposing major expansion of the freeway operational control subsystem, ramp meters were proposed for installation principally at those on-ramps at which 50 percent or more of the peak-hour traffic demand utilized congested freeway segments. Under this alternative, ramp meters were generally proposed along the stretch of the East-West Freeway (IH 94) between the Marquette Interchange and the USH 18 Goerke's Corners Interchange; on the Stadium Freeway (USH 41); on the Airport Freeway (IH 894) between the Zoo Interchange and the Hale Interchange; and on the Zoo Freeway (USH 45) between the Zoo Interchange and Capitol Drive. Under the modest expansion freeway operational control subsystem alternative, ramp meters were proposed to be installed generally at those on-ramps adjacent to congested freeway segments.

Along the East-West Freeway (IH 94) and the above identified connecting freeway segments, there are currently 11 eastbound freeway on-ramps and 16 connecting northbound and southbound freeway on-ramps, as summarized in Table 12. Also, there are currently 14 westbound freeway on-ramps and 10 connecting northbound and southbound freeway on-ramps. Average weekday morning and evening peak-hour traffic volumes in 1986 are presented in Table 12 for each on-ramp, along with the peak-hour traffic volumes on the freeway segments adjacent to the on-ramps; the percentage of peak-hour traffic from each on-ramp that travels through congested portions of the freeway segment concerned; and the percentage of peak-hour traffic on the congested freeway segments that is attributable to each on-ramp. Those on-ramps that are proposed to be metered under each freeway operational control subsystem alternative are shown in Table 12 and on Map 35.

The metering rates under each freeway operational control subsystem alternative during the morning peak hour are shown in Table 13, along

Table 9

FREEWAY ON-RAMPS PROPOSED TO BE METERED UNDER THE FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES ON THE NORTH-SOUTH FREEWAY (IH 94) AND THE AIRPORT FREEWAY (IH 894)

Freeway On-Ramps	Northbound IH 94 and Eastbound IH 894—Morning Peak Traffic Hour								
	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	Morning Peak-Hour Traffic Characteristics					
				On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
						IH 94 at Howard Avenue	IH 94 at at National Avenue	IH 94 at Howard Avenue	IH 94 at National Avenue
IH 94									
Ryan Road	--	--	X	740	1,300/3	60	54	8	6
Rawson Avenue	--	--	X	970	1,975/3	51	40	9	6
College Avenue	--[c]	--[c]	X	810	2,830/3	66	61	10	8
Airport Spur (East-North Ramp)	--	--	--	400	3,540/3	--	--	--	--
Layton Avenue Eastbound	--	X	X	310	2,270/3	100	62	6	3
Layton Avenue Westbound	--	X	X	240	2,270/3	100	77	4	3
West-North Ramp— Mitchell Interchange . . .	--	--	--	2,610	2,270/3	--	--	--	--
Howard Avenue	X	X	X	600	4,845/3	--	92	--	9
Holt/Morgan Avenue . . .	X[d]	X[d]	X	600	4,845/3	--	96	--	9
Becher Street	--	X	X	970	5,080/3	--	100	--	16
Lapham Boulevard	--	X[e]	X[e]	410	5,080/3	--	100	--	7
6th Street/ Mineral Street	--	X[e]	X[e]	120	6,240/3	--	--	--	--
Ninth Street/ Walker Street	--	X[e]	X[e]	190	6,240/3	--	--	--	--
IH 894									
Forest Home Avenue . . .	--	--	X	580	3,160/3	66	53	7	5
76th Street	--	--	X	430	3,740/3	60	49	5	3
60th Street	--	--	X	470	3,990/3	55	49	5	4
Loomis Road	--	X	X	670	4,155/3	87	68	10	7
North-East Ramp— Greendale Interchange[b]	--	--	--	--	4825/3	--	--	--	--
27th Street	--	X	X	280	4,140/3	63	53	3	2

Freeway On-Ramps	Southbound IH 94 and Westbound IH 894—Afternoon Peak Traffic Hour								
	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	Afternoon Peak-Hour Traffic Characteristics					
				On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
						IH 94 at Oklahoma Avenue	IH 94 at Howard Avenue	IH 94 at Oklahoma Avenue	IH 94 at Howard Avenue
IH 43									
State Street	--	X[f]	X	1,090	3,960/3	54	38	9	7
IH 94									
9th Street/ Mineral Street	--	--	X[e]	160	5,840/3	89	75	3	3
Lapham Boulevard	--	X	X	840	4,870/3	100	80	13	12
Becher Street	--	X	X	260	4,870/3	100	85	5	5
Holt Avenue	--	--	X	430	5,335/3	--	99	--	7
Howard Avenue	--	--	X	290	4,990/3	--	100	--	5

[a]A high-occupancy-vehicle bypass for buses and multi-occupancy vehicles is provided at each metered on-ramp under this alternative.

[b]Use of this on-ramp from park-ride lot is limited to buses.

[c]At this on-ramp, an exclusive lane is currently provided for high-occupancy vehicles.

[d]At this currently metered on-ramp, a high-occupancy-vehicle ramp-meter bypass is provided for buses only.

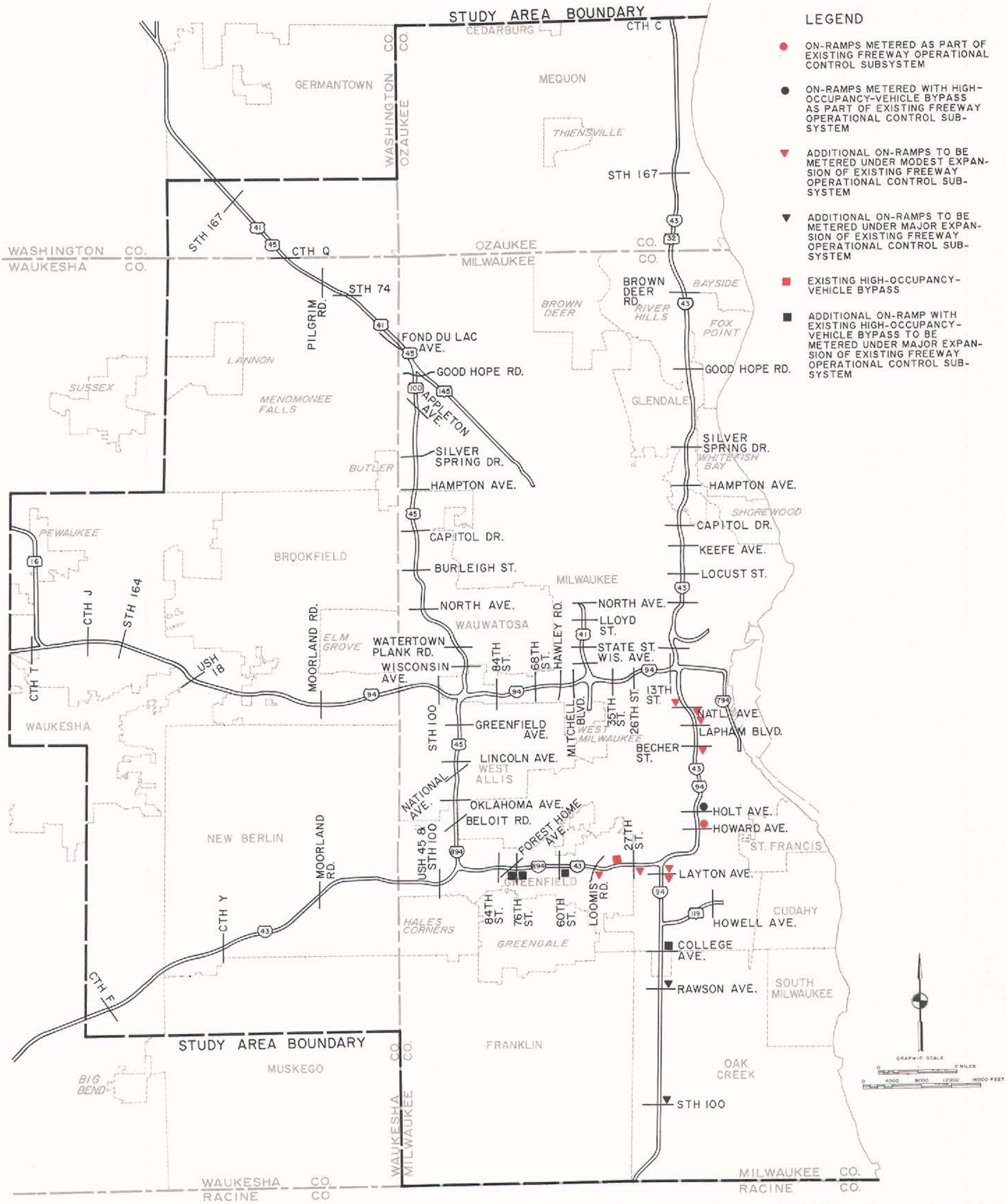
[e]Meter is proposed at this on-ramp only to prevent platoons of merging vehicles and to discourage motorists from bypassing upstream metered on-ramps.

[f]A high-occupancy-vehicle bypass for buses and multi-occupant vehicles is to be provided at this on-ramp under this alternative.

Source: SEWRPC.

Map 34

ON-RAMPS PROPOSED TO BE METERED DURING THE MORNING PEAK TRAFFIC PERIOD UNDER EACH FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVE ON IH 94 AND IH 894 FROM THE MILWAUKEE COUNTY-RACINE COUNTY LINE AND THE HALE INTERCHANGE TO THE MARQUETTE INTERCHANGE



Shown on this map are the two on-ramps currently metered in the IH 94 (North-South Freeway) and IH 894 (Airport Freeway) corridors, and the eight additional ramps that would be metered under the modest expansion of freeway operational control alternative and the six additional ramps that would be metered under the major expansion alternative.

Source: SEWRPC.

Table 10

COMPARISON OF ESTIMATED IMPACTS OF FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES AT THE ON-RAMPS ON THE NORTH-SOUTH FREEWAY (IH 94) AND THE AIRPORT FREEWAY (IH 894) DURING THE MORNING PEAK TRAFFIC HOUR

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Existing Freeway Operational Control[a]						
				Meter Delay			Meter Queue		
	Single Occupant (vehicles)	Multiple Occupant (vehicles)	Average Peak-Hour Meter Rate (vehicles)	Average per Vehicle (minutes)	Maximum per Vehicle (minutes)	Total (hours)	Average (vehicles)	Maximum (vehicles)	Total Traffic Diversion to Surface Arterial (vehicles)
IH 94									
Ryan Road	784	66	- -	- -	- -	- -	- -	- -	- -
Rawson Avenue	806	64	- -	- -	- -	- -	- -	- -	- -
College Avenue	895	30	- -	- -	- -	- -	- -	- -	- -
General Mitchell International Airport	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howell Avenue	- -	- -	- -	- -	- -	- -	- -	- -	- -
Layton Avenue Eastbound	376	114	- -	- -	- -	- -	- -	- -	- -
Layton Avenue Westbound	481	104	- -	- -	- -	- -	- -	- -	- -
West-North Ramp— Mitchell Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howard Avenue	499	91	590	0.7	1.2	9.0	7	12	70
Holt/Morgan Avenue	339	91	430	0.8	1.7	7.8	8	12	52
Becher Street	629	51	- -	- -	- -	- -	- -	- -	- -
Lapham Boulevard	200	45	- -	- -	- -	- -	- -	- -	- -
6th Street/Walker Street	77	13	- -	- -	- -	- -	- -	- -	- -
9th Street/Mineral Street	92	18	- -	- -	- -	- -	- -	- -	- -
IH 894									
Forest Home Avenue	460	70	- -	- -	- -	- -	- -	- -	- -
76th Street	228	47	- -	- -	- -	- -	- -	- -	- -
60th Street	383	67	- -	- -	- -	- -	- -	- -	- -
Loomis Road	520	95	- -	- -	- -	- -	- -	- -	- -
North-East Ramp— Greendale Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
27th Street	229	61	- -	- -	- -	- -	- -	- -	- -

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Modest Expansion of Freeway Operational Control[a]						
				Meter Delay			Meter Queue		
	Single Occupant (vehicles)	Multiple Occupant (vehicles)	Average Peak-Hour Meter Rate (vehicles)[b]	Average per Vehicle (minutes)	Maximum per Vehicle (minutes)	Total (hours)	Average (vehicles)	Maximum (vehicles)	Total Traffic Diversion to Surface Arterial (vehicles)
IH 94									
Ryan Road	784	66	- -	- -	- -	- -	- -	- -	- -
Rawson Avenue	806	64	- -	- -	- -	- -	- -	- -	- -
College Avenue	895	30	- -	- -	- -	- -	- -	- -	- -
General Mitchell International Airport	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howell Avenue	- -	- -	- -	- -	- -	- -	- -	- -	- -
Layton Avenue Eastbound	376	114	600	0.1	- -	0.8	1	1	- -
Layton Avenue Westbound	481	104	600	0.6	1.2	5.5	6	12	2
West-North Ramp— Mitchell Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howard Avenue	499	91	581	1.0	1.2	9.8	10	12	106
Holt/Morgan Avenue	339	91	353	0.9	2.2	5.0	5	12	68
Becher Street	629	51	690	0.5	1.0	5.7	6	12	10
Lapham Boulevard	200	45	600	0.1	- -	0.4	1	1	- -
6th Street/Walker Street	77	13	600	0.1	- -	0.2	1	1	- -
9th Street/Mineral Street	92	18	600	0.1	- -	0.2	1	1	- -
IH 894									
Forest Home Avenue	460	70	- -	- -	- -	- -	- -	- -	- -
76th Street	228	47	- -	- -	- -	- -	- -	- -	- -
60th Street	383	67	- -	- -	- -	- -	- -	- -	- -
Loomis Road	520	95	653	0.2	0.9	2.3	2	9	- -
North-East Ramp— Greendale Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
27th Street	229	61	600	0.1	0.1	0.5	1	1	- -

Table 10 (continued)

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Major Expansion of Freeway Operational Control[a]							
	Single Occupant (vehicles)	Multiple Occupant (vehicles)	Average Peak-Hour Meter Rate (vehicles)[b]	Meter Delay: Average per Vehicle (minutes)[c]	Meter Delay: Maximum per Vehicle (minutes)	Meter Delay: Total (hours)	Meter Queue: Average (vehicles)	Meter Queue: Maximum (vehicles)	Total Traffic Diversion to Surface Arterial (vehicles)
IH 94									
Ryan Road	784	66	721	0.3	1.0	4.6	5	12	32
Rawson Avenue	806	64	753	0.6	1.2	6.1	7	12	32
College Avenue	895	30	823	0.7	1.0	8.8	9	12	46
General Mitchell International Airport	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howell Avenue	- -	- -	- -	- -	- -	- -	- -	- -	- -
Layton Avenue Eastbound	376	114	366	0.8	2.3	4.6	5	12	6
Layton Avenue Westbound	481	104	470	0.6	1.7	4.2	4	12	8
West-North Ramp—Mitchell Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
Howard Avenue	499	91	518	0.5	1.4	4.3	4	12	8
Holt/Morgan Avenue	339	91	356	0.8	2.2	4.3	5	12	4
Becher Street	629	51	625	0.4	1.1	4.3	4	12	16
Lapham Boulevard	200	45	207	0.8	2.6	2.6	3	8	- -
6th Street/Walker Street	77	13	600	0.1	- -	0.2	1	1	- -
9th Street/Mineral Street	92	18	600	0.1	- -	0.2	1	1	- -
IH 894									
Forest Home Avenue	460	70	451	0.8	2.0	5.0	5	12	7
76th Street	228	47	224	0.9	2.4	3.1	3	8	- -
60th Street	383	67	375	0.8	2.2	4.4	5	12	1
Loomis Road	520	95	503	0.7	1.7	4.8	5	12	19
North-East Ramp—Greendale Interchange	- -	- -	- -	- -	- -	- -	- -	- -	- -
27th Street	229	61	223	0.9	2.5	3.1	3	8	- -

[a] *The average vehicle speeds in the morning peak hour on the freeway under the two freeway operational control subsystem alternatives and existing 1983 conditions are as follows: Mitchell Interchange to Holt Avenue—under existing conditions, 48 mph, under the modest expansion alternative, 49 mph, and under the major expansion alternative, 51 mph; and Holt Avenue to Marquette Interchange—under existing conditions, 46 mph, under modest expansion alternative, 46 mph, and under major expansion alternative, 48 mph. The travel time savings for mass transit vehicles operating between the Mitchell and Marquette Interchanges would be about one minute under the modest or major expansion of freeway operational control, reducing the time required for the trip from eight to seven minutes.*

[b] *Because the peak-hour freeway traffic demand is much heavier during the last 45 minutes of the morning peak hour, the metering rate at each on-ramp during that portion of the peak hour is 75 to 90 percent of the metering rate shown in the table, which is an average over the full morning peak hour.*

[c] *Multi-occupant vehicles may be expected to represent 10 to 30 percent of the total entering volume at the on-ramps in the central portion of Milwaukee County in this North-South Freeway (IH 94) corridor. Implementation of the major expansion alternative would eliminate any delays to multi-occupant vehicles; therefore, the average delay per entering vehicle under the major expansion alternative would be 10 to 30 percent less than the average delay per metered vehicle presented in this table for that alternative.*

Source: SEWRPC.

with the estimated average and maximum queue of vehicles at each on-ramp and the estimated average and maximum delay per metered vehicle at the ramp meter at each on-ramp. Also shown is the anticipated diversion of freeway traffic to surface arterials as a result of the ramp metering. Such diversion was generally determined to occur as delays at metered ramps approached one to two minutes, and the vehicle queues approached 12 vehicles. The potential freeway portion of the trips determined to be diverted was, for the most part, under two miles in length, with the remainder generally between two and five miles in length. The vehicle trips diverted would not, under either alternative, be expected to significantly affect the operation of related surface arterials.

Table 14 compares the two freeway operational control subsystem alternatives to existing 1983 conditions with respect to efficiency of travel during the morning peak hour. Both alternatives would improve the operation of the East-West Freeway (IH 94) and connecting freeway segments. The modest expansion alternative may be expected to provide a reduction of about 30

Table 11

COMPARISON OF ALTERNATIVE FREEWAY OPERATIONAL CONTROL SUBSYSTEMS ON THE NORTH-SOUTH FREEWAY (IH 94) AND THE AIRPORT FREEWAY (IH 894) WITH RESPECT TO EFFICIENCY OF FREEWAY TRAVEL IN THE MORNING PEAK TRAFFIC HOUR

Subsystem	Vehicle Hours of Travel				Vehicle Miles of Travel		
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Total
Existing (1983)	1,250	17	18	1,285	63,100	400	63,500
Modest Expansion of Freeway Operational Control	1,240	30	25	1,295	63,000	500	63,500
Major Expansion of Freeway Operational Control	1,210	65	30	1,305	62,500	900	63,400

Subsystem	Passenger Hours of Travel					Passenger Miles of Travel			
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total
Existing (1983)	1,550	21	22	177	1,770	78,500	500	8,700	87,800
Modest Expansion of Freeway Operational Control	1,535	40	30	175	1,780	78,300	800	8,700	87,800
Major Expansion of Freeway Operational Control	1,510	65	30	170	1,775	78,100	1,000	8,700	87,800

Source: SEWRPC.

passenger hours of travel during the morning peak hour on the freeway itself, or about 1 percent. The major expansion alternative may be expected to provide a reduction of about 450 passenger hours, or about 15 percent.

Only the major expansion alternative may be expected to improve the operation of the total transportation system of the East-West Freeway (IH 94) and its connecting freeway segments, including operation of both personal and mass transit vehicles, by shortening delays at freeway on-ramps attendant to the expanded ramp metering system, and by increasing travel times by diverting freeway traffic to surface arterials. This alternative would result in a reduction of about 200 passenger hours of travel during the morning peak hour on the freeway and connecting freeway segments, or a reduction of about 6 percent. The substantial improvement in freeway corridor operation under the major expansion alternative may be attributed in part to its provision of extensive preferential freeway access to high-occupancy vehicles which does not delay carpools or buses at the metered freeway on-ramps. It should be noted that the estimated improvement in freeway corridor operation attributable to carpools and mass transit use is largely a result of improved travel conditions provided to carpools and transit passengers under this alternative. The average delays of two minutes at freeway ramp meters may be expected to result in an increase of about 3 percent in the number of carpools on the East-West Freeway (IH 94) and connecting freeway segments during the morning peak hours of an average weekday.

Table 12

FREEWAY ON-RAMPS PROPOSED TO BE METERED UNDER THE FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES ON THE EAST-WEST FREEWAY (IH 894)

	Eastbound IH 94—Morning Peak Traffic Hour								
				Morning Peak-Hour Traffic Characteristics					
						Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
Freeway On-Ramps	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	IH 94 at 92nd Street	IH 94 at 35th Street	IH 94 at 92nd Street	IH 94 at 35th Street
IH 94									
Moreland Boulevard	- -	- -	X	890	2,130/3	43	23	7	3
Barker Road	- -	- -	X	400	2,130/3	45	28	4	2
Moorland Road Southbound	- -	- -	X	400	2,640/3	50	34	3	2
Moorland Road Northbound	- -	- -	X	660	2,640/3	59	40	6	4
S. 108th Street	X	X	X	330	3,300/3	69	49	5	3
South-East Ramp Zoo Interchange	- -	- -	- -	- -	- - /3	- -	- -	- -	- -
North-East Ramp Zoo Interchange	- -	- -	- -	- -	- - /3	- -	- -	- -	- -
S. 84th Street	X	X	X	280	5,050/3	100	79	6	3
S. 68th Street	X[d]	X	X	420	4,830/3	100	89	6	4
S. Hawley Road	X	X	X	290	4,910/3	100	84	4	3
N. and S. Mitchell Boulevard	- -	X	X	230	4,860/3	100	87	1	0
South-East Ramp Stadium Interchange	- -	- -	- -	- -	- - /3	- -	- -	- -	- -
North-East Ramp Stadium Interchange	- -	- -	- -	- -	- - /3	- -	- -	- -	- -
N. 35th Street	X	X	X	420	6,025/3	- -	100	- -	4
N. 25th Street	- -	X	X	390	5,950/3	- -	100	- -	5
USH 41[b]									
W. Garfield Avenue	- -	- -	X	1,740	- - /2[e]	- -	59	- -	14
W. Lloyd Street	- -	- -	X	1,110	1,710/3	- -	39	- -	7
W. Alois Street	- -	- -	X	550	2,570/3	- -	47	- -	3
W. Wisconsin Avenue	- -	- -	- -	190	2,850/3	- -	48	- -	1
Stadium Entrance (Gate 6)	- -	- -	- -	20	1,230/2	- -	40	- -	0
W. National Avenue	- -	- -	- -	1,260	- - /2[e]	- -	42	- -	7
IH 894									
Oklahoma Avenue	- -	- -	X	850	4,260/3	38	27	6	4
W. National Avenue	- -	- -	X	350	4,620/3	58	41	4	2
Lincoln Avenue	- -	X	X	570	4,970/3	46	31	4	3
Greenfield Avenue Eastbound	- -	X	X	320	5,140/3	65	48	4	2
Greenfield Avenue Westbound	- -	X[f]	X	170	5,460/3	37	28	1	1
USH 45									
W. Capitol Drive	- -	- -	X	750	3,930/3	40	25	4	2
W. Burleigh Street	- -	- -	X	540	4,090/3	35	24	2	1
W. North Avenue	- -	- -	X	530	4,105/3	46	32	4	2
W. Watertown Plank Road	- -[g]	X[g]	X[g]	820	4,180/3	38	29	4	3
W. Wisconsin Avenue	- -	X	X	130	4,320/3	30	26	0	0

	Westbound IH 94—Afternoon Peak Traffic Hour								
				Afternoon Peak-Hour Traffic Characteristics					
						Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
Freeway On-Ramps	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	IH 94 at 92nd Street	IH 94 at 35th Street	IH 94 at 92nd Street	IH 94 at 35th Street
IH 94/IH 794									
S. Carferry Drive	- -	- -	X	580	- - /4[e]	31	50	2	3
N. Lincoln Memorial Drive	- -	- -	- -	660	160/2	N/A	N/A	N/A	N/A
N. Jackson Street[c]	- -	- -	- -	2,380	820/3	31	58	15	23
N. 2nd Street[c]	- -	- -	- -	1,710	3,200/3	21	37	7	11
W. Clybourn Street/ W. Michigan Street	X	X	X	420	1,940/2	48	87	4	6
N. 13th Street	X[h]	X	X	250	5,420/3	52	100	2	3
N. 17th Street	X	X	X	230	5,290/3	56	100	5	6
N. 28th Street	X	X	X	410	5,520/3	57	100	6	8
N. 35th Street	- -	X	X	680	5,590/3	54	100	7	- -
N. and S. Mitchell Boulevard	- -	- -	X[f]	90	5,310/3	91	- -	2	- -
S. Hawley Road	X	X	X	350	5,170/3	85	- -	5	- -
S. 70th Street	X	X	X	280	5,040/3	98	- -	6	- -
S. 84th Street	X	X	X	280	4,880/3	100	- -	6	- -
S. 108th Street	- -	- -	X	540	3,170/3	- -	- -	- -	- -

Table 12 (continued)

Freeway On-Ramps	Westbound IH 94—Afternoon Peak Traffic Hour								
				Afternoon Peak-Hour Traffic Characteristics					
						Percentage of Total On-Ramp Traffic Traveling on Congested Freeway Segment (1983)		Percentage of Traffic on Congested Freeway Segment Attributable to On-Ramp (1983)	
	Existing	Alternative 1 Modest System Expansion	Alternative 2 Major System Expansion[a]	On-Ramp Traffic Demand (vehicles per hour: 1986)	Adjacent Freeway Traffic (vehicles per hour: 1986) and Number of Freeway Lanes	IH 94 at 92nd Street	IH 94 at 35th Street	IH 94 at 92nd Street	IH 94 at 35th Street
USH 41									
W. Garfield Avenue	--	--	--	840	-- /2[e]	18	--	3	--
W. Lloyd Street	--	--	--	750	840/3	18	--	2	--
N. Alois Street	--	--	--	610	1,540/3	18	--	3	--
W. Wisconsin Avenue	--	--	--	250	1,390/3	42	--	2	--
Stadium Entrance (Gate 6)	--	--	--	30	1,160/2	--	--	--	--
W. National Avenue	--	--	--	1,160	-- /2[e]	17	--	3	--
IH 894									
W. Greenfield Avenue	--	X	X	820	4,890/3	--	--	--	--
W. National Avenue	--	--	X	500	4,710/3	--	--	--	--
USH 45									
W. Wisconsin Avenue	--	--	X	840	4,620/3	--	--	--	--
W. Watertown Plank Road	--	--	X	470	4,640/3	--	--	--	--

NOTE: N/A indicates data not available.

[a] *High-occupancy-vehicle bypass to be provided at each metered on-ramp with the following exceptions: 1) northbound on-ramp to IH 894 from Oklahoma Avenue; 2) southbound on-ramp to the Stadium Freeway from Lloyd Street; and 3) the east- and westbound on-ramps to IH 94 from Mitchell Boulevard.*

[b] *As an alternative, the proposed metering could be accomplished with freeway-to-freeway ramp metering at the southbound Stadium Freeway-to-East-West Freeway ramp and the northbound Stadium Freeway-to-East-West Freeway ramp.*

[c] *The entering volume exceeds the upper boundary of demand which can be practically metered.*

[d] *Existing high-occupancy bypass for buses only.*

[e] *Beginning of freeway.*

[f] *Metered only to prevent platoons and to discourage motorists from bypassing ramps upstream.*

[g] *At this on-ramp, an exclusive lane is currently provided for all high-occupancy vehicles.*

[h] *High-occupancy-vehicle ramp-meter bypass currently for buses only.*

Source: SEWRPC.

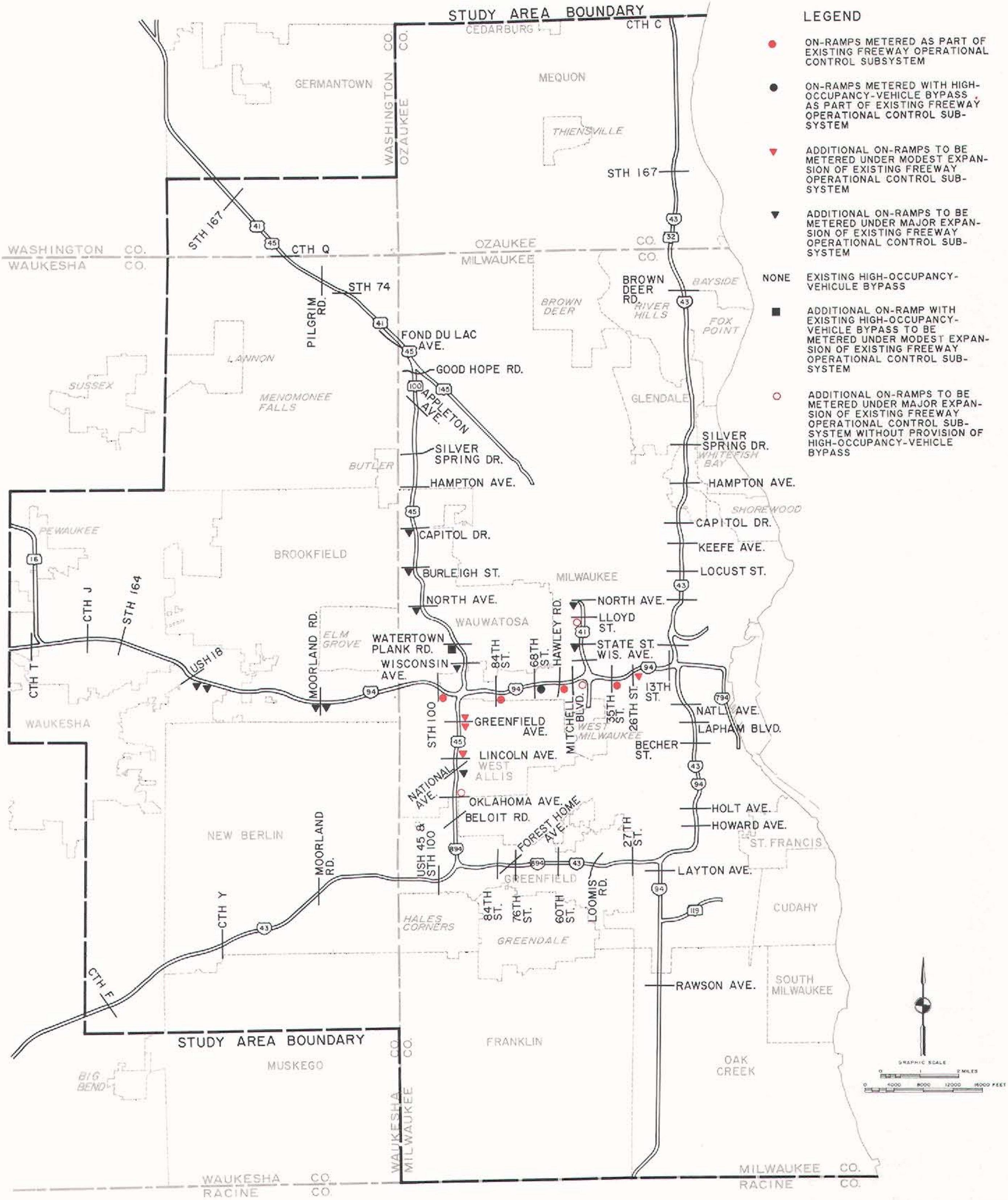
Another difference between the major and modest expansion alternatives is their effect on metering delays at individual on-ramps. Under the major expansion alternative, the average delay at metered freeway on-ramps in central Milwaukee County that are currently metered would be expected to increase somewhat, but generally to remain at one to two minutes. Also, 19 additional freeway on-ramps in Milwaukee and Waukesha Counties—besides those already in place—would be metered under the major expansion alternative.

As shown in Table 12, a substantial portion of the traffic from the additional ramps proposed to be metered—between 40 and 100 percent—may be expected to travel through congested segments of the East-West Freeway (IH 94) and connecting freeway segments. Also, the traffic from the additional on-ramps proposed to be metered generally represents a significant portion—between 2 and 7 percent—of the total travel utilizing the congested freeway segments of the East-West Freeway (IH 94). The average delay at these additional on-ramps would be between one and two minutes. Under the modest expansion alternative, only six additional freeway on-ramps would be metered, and the average delay at these ramps and at on-ramps currently metered would be between one-half minute and two minutes.

The major expansion alternative would have an estimated cost of $2,880,000, which is substantially greater than the estimated capital cost of $180,000 for the modest expansion alternative.

Map 35

ON-RAMPS PROPOSED TO BE METERED UNDER EACH FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVE ON THE EAST-WEST FREEWAY (IH 94) AND CONNECTING SEGMENTS OF THE STADIUM FREEWAY (USH 45), ZOO FREEWAY (USH 45), AND AIRPORT FREEWAY (IH 894)



Shown on this map are the five on-ramps currently metered in the IH 94 (East-West Freeway), IH 894 (Zoo Freeway), and USH 45 (Airport Freeway) corridors, and the six additional ramps that would be metered under the modest expansion of freeway operational control alternative and the 10 additional ramps that would be metered under the major expansion alternative.

Source: SEWRPC.

Table 13

COMPARISON OF ESTIMATED IMPACTS OF FREEWAY OPERATIONAL CONTROL SUBSYSTEM ALTERNATIVES AT THE ON-RAMPS ON THE EAST-WEST FREEWAY (IH 94) DURING THE MORNING PEAK TRAFFIC HOUR

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Existing Freeway Operational Control[a]						
	Single Occupant (vehicles)	Multiple Occupant (vehicles)	Average Peak-Hour Meter Rate (vehicles)	Meter Delay: Average per Vehicle (minutes)	Meter Delay: Maximum per Vehicle (minutes)	Meter Delay: Total (hours)	Meter Queue: Average (vehicles)	Meter Queue: Maximum (vehicles)	Total Traffic Diversion to Surface Arterial (vehicles)
IH 94									
USH 18 (Moreland Boulevard)	881	39	- -	- -	- -	- -	- -	- -	- -
Barker Road	418	57	- -	- -	- -	- -	- -	- -	- -
Moorland Road Southbound	294	26	- -	- -	- -	- -	- -	- -	- -
Moorland Road Northbound	575	45	- -	- -	- -	- -	- -	- -	- -
STH 100 (N. 108th Street)	397	43	435	0.7	1.4	5.0	6	10	62
N. 84th Street	297	63	360	1.0	1.4	5.6	6	8	50
N. 68th Street	327	33	360	0.8	1.2	4.8	5	7	50
N. Hawley Road	212	48	260	1.9	3.1	5.2	6	13	36
Mitchell Boulevard	64	6	- -	- -	- -	- -	- -	- -	- -
N. 35th Street	199	46	245	1.5	2.4	6.0	6	10	34
N. 25th Street	269	32	- -	- -	- -	- -	- -	- -	- -
USH 41									
Garfield Avenue	1,534	211	- -	- -	- -	- -	- -	- -	- -
Lloyd Street[d]	1,088	137	- -	- -	- -	- -	- -	- -	- -
State Street	447	73	- -	- -	- -	- -	- -	- -	- -
Wisconsin Avenue	102	13	- -	- -	- -	- -	- -	- -	- -
Stadium Entrance (Gate 6)	48	2	- -	- -	- -	- -	- -	- -	- -
National Avenue	1,131	124	- -	- -	- -	- -	- -	- -	- -
IH 894									
Oklahoma Avenue	892	98	- -	- -	- -	- -	- -	- -	- -
STH 15 (National Avenue)	306	54	- -	- -	- -	- -	- -	- -	- -
Lincoln Avenue	495	100	- -	- -	- -	- -	- -	- -	- -
STH 59 (Greenfield Avenue eastbound)	311	34	- -	- -	- -	- -	- -	- -	- -
STH 59 (Greenfield Avenue westbound)	140	30	- -	- -	- -	- -	- -	- -	- -
USH 45									
STH 190 (Capitol Drive)	607	63	- -	- -	- -	- -	- -	- -	- -
Burleigh Street	369	36	- -	- -	- -	- -	- -	- -	- -
North Avenue	455	25	- -	- -	- -	- -	- -	- -	- -
Watertown Plank Road	605	75	- -	- -	- -	- -	- -	- -	- -
Wisconsin Avenue	88	12	- -	- -	- -	- -	- -	- -	- -

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Modest Expansion of Freeway Operational Control[a]						
	Single Occupant (vehicles)	Multiple Occupant (vehicles)	Average Peak-Hour Meter Rate (vehicles)	Meter Delay: Average per Vehicle (minutes)	Meter Delay: Maximum per Vehicle (minutes)	Meter Delay: Total (hours)	Meter Queue: Average (vehicles)	Meter Queue: Maximum (vehicles)	Total Traffic Diversion to Surface Arterial (vehicles)
IH 94									
USH 18 (Moreland Boulevard)	881	39	- -	- -	- -	- -	- -	- -	- -
Barker Road	418	57	- -	- -	- -	- -	- -	- -	- -
Moorland Road Southbound	294	26	- -	- -	- -	- -	- -	- -	- -
Moorland Road Northbound	575	45	- -	- -	- -	- -	- -	- -	- -
STH 100 (N. 108th Street)	397	43	435	0.7	1.5	5.0	6	10	62
N. 84th Street	297	63	360	1.0	1.4	5.6	6	8	50
N. 68th Street	327	33	350	1.4	2.2	8.3	8	12	50
N. Hawley Road	212	48	260	1.3	3.1	5.2	6	13	36
Mitchell Boulevard	64	6	180	0.3	0.3	0.4	1	1	- -
N. 35th Street	46	245	245	1.5	2.4	6.0	6	10	34
N. 25th Street	269	32	292	1.2	2.0	5.9	6	9	- -
USH 41									
Garfield Avenue	1,534	211	- -	- -	- -	- -	- -	- -	- -
Lloyd Street[d]	1,088	137	- -	- -	- -	- -	- -	- -	- -
State Street	447	73	- -	- -	- -	- -	- -	- -	- -
Wisconsin Avenue	102	13	- -	- -	- -	- -	- -	- -	- -
Stadium Entrance (Gate 6)	48	2	- -	- -	- -	- -	- -	- -	- -
National Avenue	1,131	124	- -	- -	- -	- -	- -	- -	- -
IH 894									
Oklahoma Avenue	892	98	- -	- -	- -	- -	- -	- -	- -
STH 15 (National Avenue)	306	54	- -	- -	- -	- -	- -	- -	- -
Lincoln Avenue	495	100	660	0.3	1.2	4.8	3	12	8
STH 59 (Greenfield Avenue eastbound)	311	34	360	0.8	2.4	4.3	4	12	2
STH 59 (Greenfield Avenue westbound)	140	30	180	0.3	0.3	0.8	1	3	- -
USH 45									
STH 190 (Capitol Drive)	607	63	- -	- -	- -	- -	- -	- -	- -
Burleigh Street	369	36	- -	- -	- -	- -	- -	- -	- -
North Avenue	455	25	- -	- -	- -	- -	- -	- -	- -
Watertown Plank Road	605	75	660	0.3	1.0	4.4	4	12	14
Wisconsin Avenue	88	12	180	0.3	0.3	0.5	1	1	- -

Table 13 (continued)

Freeway On-Ramps	Existing Freeway Traffic Demand (1983)		Major Expansion of Freeway Operational Control[a]						
			Average Peak-Hour Meter Rate (vehicles)	Meter Delay			Meter Queue		Total Traffic Diversion to Surface Arterial (vehicles)
	Single Occupant (vehicles)	Multiple Occupant (vehicles)		Average per Vehicle (minutes)[b,c]	Maximum per Vehicle (minutes)	Total (hours)	Average (vehicles)	Maximum (vehicles)	
IH 94									
USH 18 (Moreland Boulevard)	881	39	810	0.7	1.0	9.2	10	12	64
Barker Road	418	57	374	1.4	2.1	8.2	9	12	23
Moorland Road Southbound	294	26	268	1.8	2.8	8.0	8	12	13
Moorland Road Northbound	575	45	527	1.0	1.6	8.4	9	12	40
STH 100 (N. 108th Street)	397	43	364	1.5	2.2	8.6	9	12	79
N. 84th Street	297	63	274	1.8	2.7	8.1	8	12	87
N. 68th Street	327	33	275	2.0	2.9	8.8	9	12	95
N. Hawley Road	212	48	203	1.9	3.6	6.3	6	12	37
Mitchell Boulevard	64	6	180	0.3	0.3	0.4	1	1	- -
N. 35th Street	46	245	197	1.9	3.6	6.3	6	12	34
N. 25th Street	269	32	244	2.0	3.0	7.4	8	12	16
USH 41									
Garfield Avenue	1,534	211	1,646	0.2	0.5	4.7	6	12	134
Lloyd Street[d]	1,088	137	1,266	0.3	0.6	4.9	6	12	60
State Street	447	73	408	0.9	2.2	4.9	6	12	28
Wisconsin Avenue	102	13	- -	- -	- -	- -	- -	- -	- -
Stadium Entrance (Gate 6)	48	2	- -	- -	- -	- -	- -	- -	- -
National Avenue	1,131	124	- -	- -	- -	- -	- -	- -	- -
IH 894									
Oklahoma Avenue	892	98	856	0.7	0.9	10.9	11	12	125
STH 15 (National Avenue)	306	54	277	2.0	3.0	8.2	9	12	17
Lincoln Avenue	495	100	478	1.2	1.9	8.9	9	12	65
STH 59 (Greenfield Avenue eastbound)	311	34	271	2.0	3.0	8.4	9	12	37
STH 59 (Greenfield Avenue westbound)	140	30	180	0.3	0.3	0.9	1	3	- -
USH 45									
STH 190 (Capitol Drive)	607	63	502	1.3	1.7	10.3	11	12	103
Burleigh Street	369	36	328	2.0	2.3	10.3	11	12	48
North Avenue	455	25	368	1.5	1.9	9.2	10	12	80
Watertown Plank Road	605	75	477	1.4	1.6	10.8	11	13	129
Wisconsin Avenue	88	12	180	0.3	0.3	0.5	1	1	

[a] *The estimated average vehicle speeds in the morning peak hour on the eastbound East-West Freeway (IH 94) are 30 to 37 mph under existing 1983 conditions, 31 to 39 mph under the modest expansion alternative, and 38 to 48 mph under the major expansion alternative. The travel time savings for mass transit vehicles operating between the Zoo and Marquette Interchanges would be about one minute under the modest expansion alternative, and about three minutes under the major expansion alternative, reducing the time required for the trip from 10 minutes to 9 minutes under the modest expansion alternative to 7 minutes under the major expansion alternative.*

[b] *Multi-occupant vehicles may be expected to represent 10 to 25 percent of the total entering volume at the on-ramps in the central portion of Milwaukee County in this East-West Freeway (IH 94) corridor. Implementation of the major expansion alternative would eliminate any delays to multi-occupant vehicles; therefore, the average delay per entering vehicle under the major expansion alternative is 10 to 30 percent less than the average delay per metered vehicle presented in this table for that alternative.*

[c] *The average delay per metered vehicle at each metered on-ramp as indicated in this table for the major expansion alternative is intended to be approximately equal for those ramp meters located in central Milwaukee County, outlying Milwaukee County, and the outlying counties. The average delays indicated in this table are approximately equal, being within the range of one-half minute to two minutes; however, the delays within central Milwaukee County are generally within one to two minutes and the delays in outlying Milwaukee County and in outlying counties are generally within one-half minute to one and one-half minutes. Upon implementation of the major expansion alternative as recommended, it will be necessary to achieve more equal average delays per metered vehicle between those meters located in central Milwaukee County, outlying Milwaukee County, and the outlying counties. It should be possible to do this without any great difficulty, thereby ensuring an equitable freeway operational control subsystem, modifying the major expansion alternative ramp-metering rates slightly—including slightly increasing rates of freeway entry in central Milwaukee County and reducing rates of freeway entry in outlying Milwaukee County and outlying counties.*

[d] *This on-ramp will have two lanes and will not provide a ramp-meter bypass for high-occupancy vehicles.*

Source: SEWRPC.

The greater capital cost is the result of the additional on-ramps that would be metered and the reconstruction of freeway on-ramps which would be necessary to provide high-occupancy-vehicle preferential access.

Recommended Freeway Operational Control Subsystem

Two basic alternatives for the freeway operational control subsystems were evaluated. The freeway operational control subsystems include the number and location of ramp meters, the freeway operational control strategy, the ramp-meter control strategy, and high-occupancy-vehicle preferential access.

One of the two alternatives evaluated proposed the modest expansion of the existing freeway operational control subsystem. Currently 21 freeway on-ramps in central Milwaukee County are metered. The metered ramps are located adjacent to the segments of freeway which experience the most severe congestion during morning and evening peak traffic periods. The

Table 14

COMPARISON OF ALTERNATIVE FREEWAY OPERATIONAL CONTROL SUBSYSTEMS ON THE EAST-WEST FREEWAY (IH 94) AND THE CONTRIBUTING IH 894, USH 45, AND USH 41 FREEWAYS WITH RESPECT TO EFFICIENCY OF FREEWAY TRAVEL IN THE MORNING PEAK TRAFFIC HOUR

Subsystem	Vehicle Hours of Travel				Vehicle Miles of Travel		
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Total
Existing (1983)	2,510	30	30	2,570	111,700	700	112,400
Modest Expansion of Freeway Operational Control	2,480	55	35	2,570	111,600	800	112,400
Major Expansion of Freeway Operational Control	2,110	200	130	2,440	108,600	3,500	112,100

Subsystem	Passenger Hours of Travel					Passenger Miles of Travel			
	Freeway Main Line	Freeway Ramps (delay)	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total	Freeway Main Line	Surface Arterials (diverted traffic)	Freeway Flyer Mass Transit	Total
Existing (1983)	2,940	35	40	200	3,215	130,600	800	7,900	139,300
Modest Expansion of Freeway Operational Control	2,910	65	40	195	3,210	130,500	900	7,900	139,300
Major Expansion of Freeway Operational Control	2,485	200	135	165	2,985	127,800	3,600	7,900	139,300

Source: SEWRPC.

principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. Preferential access is provided for buses at six locations. Ramp-meter entrance rates are responsive to the traffic volumes on immediately adjacent freeway lanes.

Under the modest expansion alternative, 24 new freeway ramp meters would be installed at those on-ramps that are currently not metered and are located adjacent to congested stretches of freeways, as shown on Map 31. New preferential access for buses would be provided at two on-ramps which are proposed to be metered and which are used by freeway flyer buses to provide transit service.

The other freeway operational control subsystem alternative represents a major expansion of the existing system. An additional 57 freeway on-ramps would be metered, including ramps in Milwaukee County and in Ozaukee, Washington, and Waukesha Counties, as shown on Map 32. The on-ramps proposed to be metered carry substantial traffic volumes and contribute to freeway traffic congestion. This alternative freeway operational control subsystem has a broader objective than the existing system—namely, to eliminate freeway congestion and provide average operating speeds of 35 to 40 mph on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters would permit sufficient control to prevent traffic demand from exceeding available freeway capacity. The restriction of freeway traffic demand to permit peak-hour operation of at least 35 to 40 mph would be attempted to be equally

Table 15

EVALUATION AND COMPARISON OF ALTERNATIVE FREEWAY OPERATIONAL CONTROL SUBSYSTEMS

Control Subsystem Alternatives	Reduction in Freeway Corridor Passenger Hours of Travel on Average Weekday During Morning Peak Traffic Hour (passenger hours)	Average Freeway Speed on Average Weekday During Morning Peak Traffic Hour (mph)	Average Freeway Metered On-Ramp Delay at Ramp Meter During Morning Peak Traffic Hour (minutes)				Capital Cost
			Total Passenger Hours	Typical Ramp Central Milwaukee County (minutes)	Typical Ramp Outlying Milwaukee County (minutes)	Typical Ramp Outlying Counties (minutes)	
East-West Freeway (IH 94)							
Existing	- -	30-37	35	0.7-1.9	1.1	- -	$ - -
Modest Expansion	5	32-39	65	1.0-1.5	0.3-0.8	- -	180,000
Major Expansion	230	38-48	200	1.5-2.0	1.2-2.0	0.7-1.4	2,880,000
North-South Freeway (IH 43)							
Existing	- -	42-49	25	0.4-1.0	- -	- -	$ - -
Modest Expansion	5	45-49	40	0.2-1.0	0.7	- -	245,000
Major Expansion	20	46-50	70	0.4-0.8	0.5-0.9	0.6	1,300,000
North-South Freeway (IH 94)							
Existing	- -	46-48	21	0.7-0.8	- -	- -	$ - -
Modest Expansion	None	46-49	40	0.1-1.0	- -	- -	280,000
Major Expansion	None	48-51	65	0.4-0.9	0.3-0.8	- -	2,100,000

Source: SEWRPC.

applied at all metered freeway on-ramps. That is, the necessary percentage reduction in freeway traffic demand would generally be equally applied, with the average delay at each metered on-ramp on each freeway segment being within the same range. Also, preferential access for all high-occupancy vehicles—buses, carpools, and vanpools—would generally be provided at all metered ramps under this alternative.

The evaluation of the two freeway operational control subsystem alternatives, and of the existing system, is summarized in Table 15. The major expansion alternative has the highest capital cost of all the alternatives in each of the freeway corridors, ranging from $1.3 million in the North-South Freeway (IH-43) corridor to $2.88 million in the East-West Freeway (IH 94) corridor. The estimated capital cost of the modest expansion alternative is one-tenth the cost of the major expansion alternative, ranging from $180,000 in the East-West Freeway (IH 94) corridor to $280,000 in the North-South Freeway (IH 94) corridor. However, only the major expansion alternative provides substantial benefits in the East-West Freeway (IH 94) corridor, including connecting segments of the Stadium Freeway (USH 41), the Airport Freeway (IH 894), and the Zoo Freeway (USH 45). The major expansion alternative may be expected to result in a savings of about 230 passenger hours in the East-West Freeway (IH 94) corridor during the morning peak hour of an average weekday. Assuming a value of $8.00[2] per passenger hour,

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[2] *The monetary value of time used in economic evaluation of transportation improvements is difficult to establish and subject to controversy and challenge. The value used in this study reflects a traffic composition of about 90 percent automobiles and 10 percent trucks, and is the value used by the U. S. Department of Transportation, Federal Highway Administration, and Wisconsin Department of Transportation in the evaluation of major highway improvements; and is the value of travel time recommended by the American Association for State Highway and Transportation Officials, adjusted for inflation to reflect differences in base year. It is comparable to the rates of $1.55 and $4.15 used in the Commission's 1963 and 1972 comprehensive transportation planning efforts, when the values are adjusted for general price inflation. It is slightly less than the average hourly wage paid to the southeastern Wisconsin labor force in 1986 of $9.30.*

this would result in a savings during the morning peak hour on an average weekday of approximately $1,800, or an annual savings of approximately $450,000. This savings represents approximately one-sixth the capital cost of the major expansion freeway operational control alternative, and indicates that the travel time savings under the system may be expected to exceed the system capital costs in six years. The benefits may actually exceed the costs in less time, as the freeway operational control subsystem would generate benefits, as well, during the hour preceding and following the morning peak hour, during the afternoon peak hour and period, and when incidents and special events result in severe congestion. Therefore, it is recommended that the major expansion alternative be implemented in the East-West Freeway (IH 94) corridor, including connecting segments of the Stadium Freeway (USH 41), the Zoo Freeway (USH 45), and the Airport Freeway (IH 894), and that the modest expansion alternative be implemented in the North-South Freeway corridors (IH 43 and IH 94).

Comparison of the data in Table 15 indicates that in the East-West Freeway (IH 94) corridor, a substantial reduction in passenger hours of travel may be expected to result from implementation of the major expansion alternative. This is due to the substantial increase in average freeway speeds expected upon implementation of the major expansion alternative. However, implementation of the major expansion alternative in the North-South Freeway (IH 43 and IH 94) corridors may be expected to result in only a marginal reduction in passenger hours of travel and in only marginal increases in average freeway speeds. This is because the North-South Freeway is less congested than the East-West Freeway, in terms of both duration and areal extent of congestion. Therefore, the major expansion of freeway operational control alternative is recommended to be implemented at this time only on the East-West Freeway (IH 94). However, as freeway volumes continue to increase on the North-South Freeway (IH 43 and IH 94)—as may be expected—additional ramp meters will be warranted and can be installed beyond those currently recommended; and eventually, the major expansion alternative may be expected to be fully implemented on the North-South Freeway as well.

SUMMARY

This chapter evaluates alternative freeway traffic management system plans for the Milwaukee area and presents a recommended plan. Alternatives are presented and evaluated for each element of the freeway traffic management system and system plan. The seven elements are:

1. Incident management—or the identification of freeway incidents, such as accidents, which restrict traffic flow—in order the minimize the effects of incidents.

2. Motorist advisory information, or the provision of information to motorists about current traffic conditions, including incidents.

3. System management, or monitoring and control—the collection and analysis of the freeway operational data essential to the management of the other elements of the freeway management system.

4. Determination of the number and location of freeway on-ramp meters and related control signalization.

5. A freeway operational control strategy, which defines the desired level of operation to be maintained on the freeway system, including the desired operating speeds.

6. A freeway on-ramp meter control strategy, which defines the rate of entry at the various metered freeway on-ramps, distributing the required reduction in freeway volume over the contributing ramps.

7. High-occupancy-vehicle preferential access, or determination of the number and location of exclusive bypasses of the metered on-ramps for use by carpools, vanpools, and buses.

All of these elements are interrelated. However, to make the evaluation of alternatives for each element more understandable, the alternatives for incident management, motorist advisory information, and monitoring and control systems were separately presented and evaluated in this chapter. Two basic alternatives for the remaining freeway traffic management elements—the freeway operational control subsystems—were then presented and evaluated. The freeway operational control subsystems include the number and location of ramp meters, the freeway operational control strategy, the ramp-meter control strategy, and high-occupancy-vehicle preferential access. One of the two alternatives considered represents a modest expansion of the existing freeway operational control subsystem. The other alternative represents a major expansion of the existing system.

Freeway incident management actions are intended principally to address the abatement of nonrecurrent traffic congestion by providing for the prompt detection, confirmation, and removal of freeway incidents. Existing freeway incident management in the Milwaukee area is basically limited to the Expressway Patrol provided by the Milwaukee County Sheriff's Department and the Wisconsin State Highway Patrol. Among the incident management actions considered were expressway patrol, emergency service patrol, citizen band radio monitoring, cellular telephones, roadside call boxes, electronic freeway surveillance, closed circuit monitoring, and aircraft surveillance.

The recommended freeway incident management system for the greater Milwaukee area consists of: an electronic freeway traffic surveillance system; a citizen band radio monitoring system; signing with an emergency telephone number for use by motorists with cellular telephones; a closed circuit television monitoring system; an emergency service patrol; continued expressway patrol; and a major incident response team. To provide for the efficient use of these actions, a central freeway traffic management center and staff will be required.

Motorist advisory information assists in abating both recurrent and nonrecurrent traffic congestion and in making more efficient use of the freeway system and total arterial street system. By providing information about alternative routes during the peak weekday traffic periods, motorist advisory information systems help to abate recurrent traffic congestion problems and promote the more efficient use of freeway and total arterial system capacity. By providing information about incidents, such as identifying lane closures well in advance, motorist advisory information systems can also address nonrecurrent traffic congestion. Existing motorist advisory information in the Milwaukee area is limited to information provided by commercial radio broadcasting stations principally during weekday peak traffic periods, and six portable changeable message signs which are principally used for freeway construction and maintenance projects. The commercial radio broadcasting stations obtain their information on traffic conditions from their own surveillance and from the Milwaukee County Sheriff's Department.

Among the alternatives considered for expanded motorist advisory information were changeable message signs and radio-based driver information systems. The recommended motorist advisory information system for the greater Milwaukee area consists of transportable changeable message signs, a system of fixed changeable message signs, and timely provision of information to commercial radio broadcasting stations. To provide for efficient use of these system components, a central freeway traffic management center will be required.

With respect to the monitoring and control element of a freeway traffic management system, as already noted, proper implementation of the recommended incident management and advisory information actions would require a central traffic management center. Such a center would also be required for the recommended ramp-meter element of the total freeway traffic management system.

At the traffic management center, all traffic information would be received, analyzed, and evaluated, and decisions made regarding what incident management, advisory information, and ramp metering would be implemented. The control center equipment would include a high-speed, high-capacity computer and its related peripheral equipment; a console for providing direction to the computer and for instantaneous review of computer reports; display devices such as closed circuit television (CCTV) screens; and communications equipment such as radio receivers and transmitters and direct telephone line connections.

The computer would operate in real time with pre-established programmed control routines. These would include turning on and turning off ramp-metering systems; selecting and ordering the display of certain advisories on fixed-site, remotely controlled changeable message signs; and monitoring freeway system performance, both printing it for permanent record as well as displaying it to allow operator interaction with the system. Whenever there was a traffic emergency—such as a major incident—routine computer controls could be overridden by the control center staff.

The computer would be used to inform the control center staff of unusual traffic conditions based on computer analysis of electronic surveillance data. Both audio and visual alarms would alert the staff to such incidents. Upon such alarm, the staff would attempt to confirm the incident by reviewing the electronic surveillance data at the computer console; reviewing the appropriate closed circuit television screen; monitoring the citizen band radio reports from the nearest remote base station; and contacting expressway patrol squads. Once the problem had been identified, the control center staff would respond, as needed, with changes in ramp metering, and by dispatching expressway patrol squads and emergency service patrols, transmitting messages on changeable message signs, and transmitting information to commercial radio stations.

Two basic alternatives for the freeway operational control subsystems which incorporate the remaining freeway traffic management elements were presented and evaluated.

One of the two alternatives considered represents a modest expansion of the existing freeway operational control subsystem. Currently, 21 freeway on-ramps in central Milwaukee County are metered, as shown on Map 30. The metered ramps are located adjacent to the segments of freeway which experience the most severe congestion during morning and evening peak traffic periods. The principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. Preferential access is provided for buses at six locations, also shown on Map 30. Ramp-meter entrance rates are responsive to the traffic volumes on immediately adjacent freeway lanes. Under this alternative, new freeway ramp meters would be installed at 24 on-ramps that are currently not metered and are adjacent to congested stretches of freeways, as shown on Map 31. Preferential access for buses would be provided at two of those 24 on-ramps.

The other freeway operational control subsystem alternative considered represents a major expansion of the existing system. An additional 57 freeway on-ramps throughout Milwaukee County would be metered, along with six on-ramps in Ozaukee and Waukesha Counties which carry substantial traffic volumes and contribute to freeway traffic congestion, as shown on Map 32. This freeway operational control subsystem alternative has a broader objective than the existing system—namely, to minimize freeway congestion and provide average operating speeds of 35 to 40 miles per hour (mph) on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters should permit sufficient control of traffic demand to prevent demand from exceeding available freeway capacity. The restriction of freeway traffic demand to permit peak-hour operation of at least 35 to 40 mph would generally be equally applied at all metered freeway on-ramps. That is, generally, the restriction of freeway traffic demand—expressed as a percentage of total on-ramp demand—would be applied equally at each on-ramp concerned, and would keep the average delays at each on-ramp comparable—that is, within a range of about one minute. Also under this alternative, preferential access for all high-occupancy vehicles—buses, carpools, and vanpools—would generally be provided at all metered ramps.

It is recommended that the major expansion alternative for freeway operational control be implemented in the East-West Freeway corridor (IH 94), as the benefits of such an alternative in terms of savings in passenger hours in the freeway corridor would exceed the estimated costs. Such implementation results in savings in passenger hours because the major expansion alternative provides improved travel to existing carpool and transit passengers; it encourages an increase in the use of carpools of approximately 3 percent; it limits any delay to single-occupant automobiles; and it encourages some short trips on congested freeway segments to use surface arterials.

It is recommended that the modest expansion alternative be implemented in the North-South

Freeway corridors (IH 43 and IH 94), as traffic congestion is not as severe as in the East-West Freeway corridor (IH 94) with respect to the length of congestion occurring throughout the morning peak hour and the extent of the freeway corridor experiencing congestion. It may be noted that this analysis of freeway operational control benefits was conducted from surveys conducted in 1983; since 1983, morning peak-hour traffic has increased in these freeway corridors by about 20 percent. As freeway traffic continues to increase, the benefits of the major expansion alternative in the North-South Freeway corridors will increase. The freeway operational control system in the North-South Freeway corridors may be readily expanded as warranted by increasing freeway traffic volume and congestion.

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Chapter VI

RECOMMENDED PLAN

INTRODUCTION

This chapter presents a recommended plan for freeway traffic management in the greater Milwaukee area. Implementation of the recommended plan would provide for the more efficient movement of traffic on the Milwaukee area freeway system and the Milwaukee area arterial street and highway system as a whole. Traffic congestion on the freeways and on the related surface arterials would be reduced, including traffic congestion resulting from freeway demand exceeding capacity during weekday peak traffic periods, and congestion resulting from incidents and special events on weekday nonpeak periods and on weekends.

Under the recommended plan, traffic flow on the Milwaukee area freeway system would be improved in five ways. The plan recommends preferential access to freeways for buses and car- and vanpools in order to encourage increased use of such high-occupancy vehicles. The plan also recommends improvements in the detection, confirmation, and removal of accidents and other incidents from the freeway to reduce congestion that occurs as a result of incidents. The plan also recommends improvement and expansion of the information provided to motorists, particularly upon the occurrence of incidents and during special events. The information would better guide motorists to the use of alternative freeway and nonfreeway routes, making better use of total arterial street and highway system capacity. Motorists would also be informed of temporary freeway lane closures to minimize unnecessary lane changing. The plan also recommends development of an electronic system of freeway traffic data gathering based upon loop detectors located every one-half mile in all freeway lanes throughout the greater Milwaukee area, and a traffic management center and staff to analyze and utilize these data in the implementation of freeway incident management actions, freeway advisory information actions, and freeway operational control actions. The plan also recommends a major expansion of freeway operational control along the East-West Freeway (IH 94) and connecting segments of the Stadium Freeway (USH 41), the Zoo Freeway (USH 45), and the Airport Freeway (IH 894), and modest expansion of freeway operational control along the North-South Freeway (IH 94 and IH 43), including metering additional freeway on-ramps and providing preferential high-occupancy-vehicle access. The expansion of freeway operational control, particularly along the East-West Freeway (IH 94) and connecting freeway segments, may be expected to improve freeway and total transportation system traffic flow.

Freeway congestion entails reduced travel speed, increased and unpredictable travel times, and stop-and-go driving, which result in increased operating costs, accidents, energy consumption, and air pollutant emissions. Freeway congestion can be classified into recurrent congestion and nonrecurrent congestion. Recurrent freeway congestion is congestion that occurs regularly as a result of freeway traffic demand exceeding the traffic-carrying capacity of the freeway, principally during weekday morning and afternoon peak traffic periods. Nonrecurrent freeway traffic congestion is congestion that occurs as a result of a freeway incident, such as an accident or disabled vehicle. The accident or disabled vehicle can affect freeway traffic flow whether it is located within freeway lanes or on freeway shoulders. Nonrecurrent congestion can also occur as a result of inclement weather. About 50 percent of the traffic congestion that occurs on urban area freeway systems is due to incidents, and is defined as nonrecurrent congestion. The other 50 percent is due to recurrent freeway traffic congestion. This indicates the need to address the abatement of both nonrecurrent and recurrent congestion on the Milwaukee area freeway.

The recommended freeway traffic management system plan is based upon extensive study. Inventories were conducted of the existing peak-period freeway traffic volume and pattern—that is, of the number of vehicles during peak periods which entered at each freeway on-ramp and then exited at each freeway off-ramp and the path taken by those vehicles on the freeway system from on-ramp to off-ramp. Inventories were also conducted of existing freeway traffic management systems in operation in other major urban areas of North America. Alternative plans were developed, quantitatively tested as applicable, and evaluated for each potential element of a freeway traffic management system and system plan. These seven elements are:

1. Incident management—or the identification and removal of freeway incidents, such as accidents, which restrict traffic flow—in order to minimize the effects of incidents.

2. Motorist advisory information, or the provision of information to motorists about current traffic conditions, including incidents.

3. System management, or monitoring and control—the collection and analysis of the freeway operational data essential to the management of the other elements of the freeway management system.

4. Determination of the number and location of freeway on-ramps and related control signalization.

5. A freeway operational control strategy, which defines the desired level of operation to be maintained on the freeway system, including the desired operating speeds.

6. A freeway on-ramp meter control strategy, which defines the rate of entry at the various metered freeway on-ramps, distributing the required metering of freeway volume over the contributing on-ramps.

7. High-occupancy-vehicle preferential access, or determination of the number and location of exclusive bypasses to the metered on-ramps for use by carpools, vanpools, and buses.

All these elements of a freeway traffic management system plan are interrelated. However, to make the presentation and evaluation of the alternatives considered for each element more understandable, the findings and evaluations of alternatives for incident management, motorist advisory information, and monitoring and control systems were presented separately. Two basic alternatives for the remaining freeway traffic management elements—the freeway operational control subsystem—were presented and evaluated. The freeway operational control subsystem includes the number and location of ramp meters, the freeway operational control strategy, the ramp-meter control strategy, and high-occupancy-vehicle preferential access. One of the two subsystem alternatives considered represented a modest expansion of the existing Milwaukee area freeway operational control subsystem. The other alternative represented a major expansion of the existing system.

RECOMMENDED FREEWAY INCIDENT MANAGEMENT ELEMENT

Freeway incident management actions are intended primarily to address the abatement of nonrecurrent traffic congestion by minimizing the impacts of incidents on freeway traffic flow through the provision of the prompt detection, confirmation, and management of freeway incidents. Existing freeway incident management in the Milwaukee area is basically limited to the Expressway Patrol provided by the Milwaukee County Sheriff's Department and the Wisconsin State Highway Patrol. Among the alternative incident management actions considered were expressway patrol, emergency service patrol, a major incident response team, citizen band radio monitoring, radio call boxes, electronic freeway data gathering and analysis, closed circuit television monitoring, and aircraft surveillance.

The recommended freeway incident management system for the greater Milwaukee area consists of: an electronic freeway traffic data gathering and analysis system; signing to provide an emergency telephone number that can be used by motorists having cellular telephones to contact the freeway traffic management center; a citizen band radio monitoring system; a closed circuit television monitoring system; an emergency service patrol; a major incident response team; and continued expressway patrol. To provide for the efficient application of these measures, a central freeway traffic management center and staff will be required.

The electronic freeway traffic data gathering system would be used to initially identify incidents, as it can quickly provide such identification. It is the most critical element of the freeway incident management system, and is essential to efficient operation of every other freeway traffic management element. In-pavement loop detectors would need to be installed approximately every half-mile in every freeway lane throughout the 95 miles of freeway within the greater Milwaukee area as that area is shown on Map 36.[1] The approximately 750 necessary detectors, together with communications conduit for interconnection with ramp meters and with a central traffic management center, would have an estimated capital cost of $6.1 million. The operating costs of the electronic freeway traffic data gathering system are part of the estimated annual cost of $800,000 that would be required to operate the traffic management center of the recommended freeway traffic management system.

Also recommended is a system of remote base station citizen band monitoring. The installation of 12 remote-base CB radio stations at strategic locations throughout the Milwaukee area would provide for a maximum two-mile distance between base station and potential radio calls. The remote-base CB radio stations would be used to confirm the presence of an incident identified by the electronic freeway traffic data gathering system. The estimated capital cost of the recommended 12 remote stations is $50,000. The operating costs are part of the estimated annual $800,000 operating costs of the traffic management center of the freeway traffic management system. The recommended locations of the 12 stations are shown on Map 36.

It is also recommended that signs displaying a telephone number for the freeway traffic management control center be installed along those freeway segments shown on Map 36 at approximately three-mile intervals outside Milwaukee County, and two-mile intervals within Milwaukee County. The estimated cost of installation of the signs is $20,000.

Also recommended is closed circuit television monitoring of freeways to be utilized with the recommended remote base station citizen band monitoring to quickly confirm the presence of freeway accidents. The closed circuit television monitoring would also be used to establish the nature and severity of incidents so that appropriate action could be quickly taken. A system of 20 cameras with high mast mounting is recommended, at a capital cost of $850,000, including traffic management center viewing equipment. The operating costs are part of the estimated annual $800,000 operating costs of the traffic management center of the total freeway traffic management system. The recommended locations of the camera stations are shown on Map 36.

Another recommended incident management action is the initiation of an emergency service patrol on the freeway system serving the greater Milwaukee area. The emergency service patrol would assist professional law enforcement officers in managing freeway incidents. The emergency patrols would provide towing to freeway shoulders or interchanges, and would help disabled vehicles move away under their own power. To provide an emergency service patrol during the hours of heaviest traffic movement—that is, from 6:00 a.m. to 10:00 p.m.—and with a coverage of one service patrol vehicle for approximately every 20 miles of area freeway, a total of six emergency service patrol vehicles would be required, at an estimated capital cost of $230,000. One service vehicle should be acquired which would be capable of removing heavily loaded tractor-trailer trucks from accident scenes, at an estimated capital cost of $60,000. Operating costs would approximate $400,000 per year, and vehicles would need to be replaced about every five years.

Another recommended incident management action is the continuation of expressway patrol in Milwaukee County. Two patrol squads would continue to be assigned to each freeway segment. The segments range from about 6 miles to about 14 miles in length, as shown on Map 36. The principal function of the expressway patrol would be to manage the removal of incidents and, as needed, establish the nature and characteristics of the incident. The estimated annual cost of continuing to provide expressway patrol on the Milwaukee County freeway system on a 24-hour basis is $4.0 million, including acquisition and replacement of patrol vehicles. As traffic on the areawide freeway system increases

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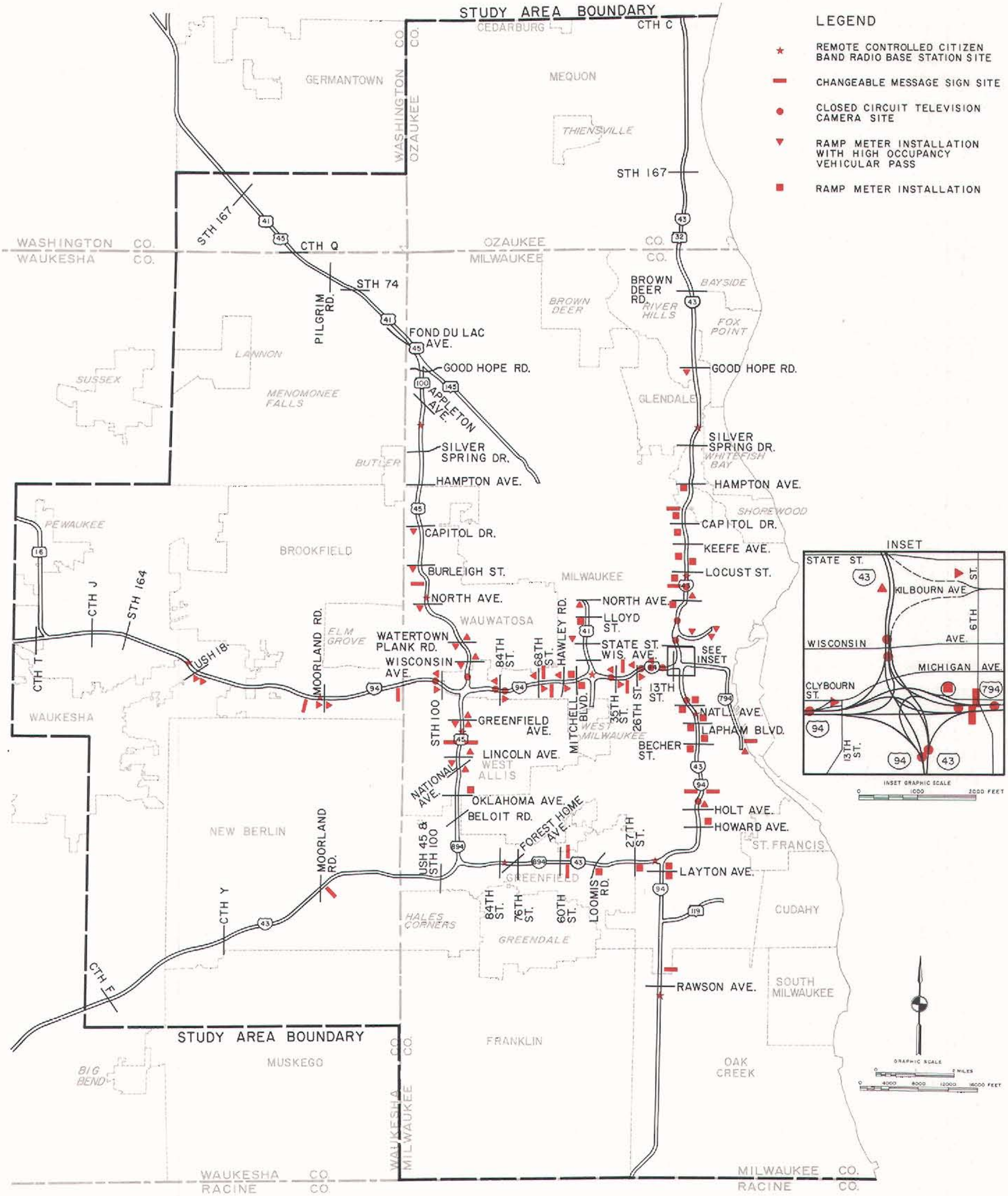
[1] *It is recommended that installation of loop detectors on IH 794, which includes four miles of the 95-mile area freeway system, be undertaken as part of its future resurfacing or reconstruction, as this segment of freeway is on structure. It is also recommended that the four-mile segment of STH 145 have loop detectors installed only as part of its resurfacing or reconstruction, as this segment of freeway carries relatively low traffic volumes.*

Map 36

RECOMMENDED FREEWAY TRAFFIC MANAGEMENT SYSTEM FOR THE GREATER MILWAUKEE AREA



Shown on this map are the proposed locations of the various elements of the recommended freeway traffic management system plan, including the freeway incident management, motorist advisory, and freeway operational control elements. Notably, under the recommended plan, expansion of the freeway operational control element in the IH 43 and IH 94 (North-South Freeway) and the IH 894 (Airport Freeway) corridors would be modest, with additional ramp meters at those on-ramps adjacent to congested freeway segments. However, the freeway operational control element would undergo major expansion in the IH 94 (East-West Freeway) corridor and the freeways entering that corridor, with ramp metering at on-ramps upstream of, as well as adjacent to, congested freeway segments.

Source: SEWRPC.

and begins to exceed freeway design capacity on those segments of the system in Ozaukee, Washington, and Waukesha Counties, the operation of the expressway patrol will need to be expanded into the urban portions of those counties. This may require a change in the institutional structure involved.

Another recommended incident management action is the formation of incident response teams to assist in handling major freeway incidents. The teams would consist of freeway law enforcement staff and staff of the Wisconsin Department of Transportation and affected counties. The teams would leave their principal duties to assist in traffic control upon the occurrence of major incidents. It is assumed that no staff expansion would be necessary to implement this action, and the action would have minimal capital and operating costs.

RECOMMENDED MOTORIST ADVISORY INFORMATION ELEMENT

Motorist advisory information assists in abating both recurrent and nonrecurrent traffic congestion and in making more efficient use of the freeway system and total transportation system. By providing information about alternative freeway and nonfreeway routes during the peak weekday traffic periods, motorist advisory information systems help to abate recurrent traffic congestion problems and promote the more efficient use of freeway and total transportation system capacity. By providing information about incidents, such as identifying lane closures well in advance, motorist advisory information systems can also address nonrecurrent traffic congestion.

Existing motorist advisory information in the Milwaukee area is limited to that provided by commercial radio broadcasting stations principally during weekday peak traffic periods, and six portable changeable message signs used primarily for freeway construction and maintenance projects. The commercial radio broadcasting stations obtain their information on traffic conditions from their own surveillance and from the Milwaukee County Sheriff's Department.

The alternatives considered for expanded motorist advisory information were changeable message signs and radio-based driver information systems. The recommended motorist advisory information system for the greater Milwaukee area consists of transportable changeable message signs, a system of fixed changeable message signs, and timely provision of information to commercial radio broadcasting stations. To provide for efficient use of these system components, a central freeway traffic management center and an electronic freeway traffic data gathering and analysis system will be required.

It is recommended that the motorist advisory information system include two specially equipped trucks capable of carrying and transporting message signs upon which a wide variety of messages can be inserted and displayed. The two trucks, including sign boards, insertable messages, and necessary electrical equipment, have an estimated capital cost of $100,000. Operating costs are included in the estimated annual $800,000 operating costs of the traffic management center. The message signs should be mounted sufficiently high on the trucks to be viewed and read from a distance. The trucks may be used to provide advisory information during major special events, such as the Fourth of July fireworks, the Circus Parade, or capacity events at County Stadium; to warn motorists of traffic backups; and to suggest alternate exits or routes. The trucks may also be used in response to major incidents.

It is recommended that a system of permanent remotely controlled changeable message signs spanning the freeway be installed. These signs should not be installed until the electronic freeway traffic data gathering and analysis system and the traffic management center are in operation. The signs should permit the display of any message and not be fixed to provide only a limited number of messages. The cost of the signs will depend on the length and size of message lines they can provide. The typical message sign includes three lines of 18-inch characters, with between 16 and 32 characters per line, depending upon the number of traffic lanes to be spanned. A 32-character line is usually displayed in a 50- to 60-foot sign enclosure spanning four to five lanes. The signs would have a capital cost of approximately $150,000 each.

The message signs should be located based on a number of considerations. The signs should be located ahead of freeway segments experiencing the most severe traffic congestion, as advisory information will have the greatest potential in those locations to minimize travel time and delay. The signs should also be located ahead of those segments of the freeway where incidents that typically result in freeway lane blockages are most likely to occur. The signs should also be placed ahead of major freeway interchanges and other connections to alternative routes, where motorists could be advised to avoid particular routes and utilize other routes. The signs should be placed ahead of segments of freeway that may experience unique problems due to their location and design, combined with adverse weather conditions such as fog, snow, or ice. Signs would be used to warn motorists of these conditions and advise them of alternative routes. A final consideration in sign location should be the provision of alternative route and exit information during special events at, for example, County Stadium, State Fair Park, and the lakefront. Based upon these considerations, it is recommended that changeable message signs be placed at 14 locations in the greater Milwaukee area, as shown on Map 36. The message signs would have a capital cost of approximately $3.0 million. Operating costs are included in the estimated annual $800,000 operating cost of the traffic management center.

It is also recommended that commercial radio broadcasting stations be provided with current traffic condition reports from the central traffic management center via teleprinter machines. Only radio broadcasting stations that would agree to provide a timely broadcast of the information received would be provided with the information. No significant capital or operating costs are attendant to this measure, assuming creation of a central traffic management center within the area.

RECOMMENDED SYSTEM MONITORING AND CONTROL ELEMENT

As already noted, proper implementation of the recommended incident management and advisory information actions will require a central traffic management center. Such a center would also be required for the recommended freeway operational control and ramp-meter elements of the total freeway traffic management system.

At the traffic management center, all traffic information would be received, analyzed, and evaluated, and decisions made regarding what incident management, advisory information, and ramp metering would be implemented. The control center equipment would include a high-speed, high-capacity computer and peripheral equipment; a console for providing direction to the computer and for instantaneous review of computer reports; display devices such as closed circuit television screens; and communications equipment such as radio receivers and transmitters and direct telephone line connections.

The computer would operate in real time with pre-established programmed control routines. These would include turning on and turning off ramp-metering systems; selecting and ordering the display of certain advisory changeable message signs; and monitoring freeway system performance, both printing it for permanent record as well as displaying it to allow operator interaction with the system. Whenever there was any traffic emergency—such as a major incident—routine computer controls could be overridden by the control center staff.

The computer would be used to inform the control center staff of unusual traffic conditions based on computer analysis of electronic freeway traffic data. Both audio and visual alarms would alert the staff to such incidents. Upon such alarm, the staff would attempt to confirm the incident by reviewing the electronic freeway traffic data at the computer console, reviewing the appropriate closed circuit television screen, monitoring the citizen band radio reports from the nearest remote base station, and contacting expressway patrol squads. Once the problem had been identified, the control center staff would respond, as needed, including changing on-ramp metering, dispatching expressway patrol squads and emergency service patrols, transmitting messages on changeable message signs, and transmitting information to commercial radio stations.

Control center staff should include both operations and maintenance personnel. To provide 12-hour weekday and selected special event coverage, the following staff would be required: a center manager; operations personnel, including two traffic engineers, one electronic systems engineer, four technician operators, and one clerk; and maintenance personnel, including a supervisor, two electronics technicians, and two electricians. Operations personnel must possess extensive knowledge of traffic flow principles, control concepts, local conditions, and computer programming. Maintenance personnel must be capable of maintaining system operations. Traffic control systems must function in a demanding environment, subject to interference by adverse weather conditions, electrical disturbances, and possible damage from vandals and vehicles. The system must provide a highly reliable operation on a continuous basis, 24 hours each day of the year.

Based on the estimated staffing needs and the necessary space for the equipment in a control center, about 7,000 square feet of floor space would be needed for the traffic management center. This should provide sufficient space to house the required mechanical and electrical equipment; a storage and maintenance area for the electronic equipment and technicians; offices for staff; and a reception area and conference room for meetings and training. Recent construction of control centers in Illinois and Virginia indicate capital costs approximating $150 per square foot. A 7,000-square-foot building would thus have a capital cost of about $1.0 million, exclusive of land and equipment. Necessary equipment would include the computer and its ancillary equipment, including equipment for communications and closed circuit television monitors. The capital cost of this equipment may be expected to approximate $650,000, for a total estimated capital cost of $1,650,000 for the traffic management center. Operating costs would approximate $800,000 per year.

Careful consideration should be given to accessibility to the freeway system in locating the traffic management center. Possible locations include the Milwaukee central business district and the former Wisconsin Department of Transportation sign shop along the Stadium Freeway (USH 41) at State Street.

RECOMMENDED FREEWAY OPERATIONAL CONTROL SUBSYSTEM

Two basic alternatives for the freeway operational control subsystem which incorporate the remaining freeway traffic management elements were evaluated. The recommended freeway operational control subsystem plan provides recommendations concerning the following freeway traffic management elements: the number and location of ramp meters; a freeway operational control strategy; a ramp-meter control strategy; and a high-occupancy-vehicle preferential access policy. Essential to the operation of an expanded freeway operational control subsystem is an expanded monitoring and control system with a freeway traffic management center and an attendant electronic freeway traffic data gathering and analysis system.

One of the two subsystem alternatives evaluated represented a modest expansion of the existing freeway operational control subsystem. Currently, 21 freeway on-ramps located in central Milwaukee County are metered, as shown on Map 36. The ramp meters are located at freeway on-ramps adjacent to the segments of freeway which experience the most severe congestion during morning and evening peak traffic periods. The meters exercise control of freeway traffic volume by restricting freeway on-ramp traffic. The principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion. This is accomplished by preventing entire platoons, or groups, of vehicles from attempting to merge into congested freeway segments, thus smoothing traffic flow. Freeway traffic demand is also reduced at areas of freeway congestion. Preferential access is provided for buses at six locations, also shown on Map 36. Ramp-meter entrance rates are responsive to the traffic volumes on immediately adjacent "upstream" freeway lanes.

Under the modest expansion alternative, new freeway ramp meters would be installed at 24 on-ramps in the greater Milwaukee area which are currently not metered, but are adjacent to congested stretches of freeways, as shown on Map 31 in Chapter V. New preferential access for buses and other high-occupancy vehicles would be provided at two of the on-ramps which are proposed to be metered and which are used by freeway flyer buses to provide transit service. Thus, a total of 45 on-ramps would be metered within the greater Milwaukee area, and eight of these ramps would provide preferential access for buses and other high-occupancy vehicles.

The other freeway operational control subsystem alternative evaluated represented a major expansion of the existing system. A total of 77 freeway on-ramps within Milwaukee County would be metered, along with six on-ramps located in Ozaukee and Waukesha Counties, as shown on Map 32 in Chapter V. Of these 83 ramps, 79 would provide preferential access for buses and other high-occupancy vehicles, all as shown on

Map 32 in Chapter V. All on-ramps that carry substantial traffic volumes and contribute to freeway traffic congestion are intended to be metered under this alternative. This freeway operational control subsystem alternative would have a broader objective than the existing system—namely, to minimize freeway congestion—particularly, stop-and-go traffic upstream of freeway capacity bottlenecks—and provide average operating speeds of 35 to 40 miles per hour (mph) on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters is intended to provide sufficient control of traffic demand to prevent demand from exceeding available freeway capacity, and will not require significantly more restrictive ramp metering in central Milwaukee County. The restriction of freeway traffic demand to permit peak-hour freeway operation of 35 to 40 mph was equally applied at all existing metered and proposed newly metered freeway on-ramps.

The major expansion alternative may be expected to reduce recurrent freeway traffic congestion and improve freeway traffic flow in a number of ways. It should improve freeway travel for, and thereby encourage greater use of, public transit, carpools, and vanpools. Freeway travel times for public transit, carpools, and vanpools should be improved not only because freeway traffic congestion would be minimized during peak traffic periods, but because buses and other high-occupancy vehicles would not be delayed at the ramp meters, being provided preferential freeway access. As some of the freeway traffic shifts to more efficient bus and carpool and vanpool use, improvement of other automobile and truck peak-period travel may be expected. The freeway operational control subsystem may also be expected to encourage some very short trips now using the freeway to utilize surface arterial streets instead. The resultant modest reduction in freeway traffic demand may be expected to contribute to a reduction in freeway traffic congestion, while not significantly affecting surface arterial streets. A freeway operational control subsystem may also be expected to reduce freeway traffic congestion by reducing the peaks in freeway traffic demand through ramp metering. Thus, freeway operational control may be expected to reduce freeway travel time even for single-occupant automobiles and trucks, as the delay these vehicles experience at freeway on-ramps may be expected to be offset by reductions in travel time along the freeway.

It is recommended that the major expansion alternative for the freeway operational control subsystem be implemented in the East-West Freeway (IH 94) corridor, including connecting segments of the Stadium Freeway (USH 41), the Zoo Freeway (USH 45), and the Airport Freeway (IH 894), and that the modest expansion alternative be implemented in the North-South Freeway (IH 43 and IH 94) corridors. Evaluation of the two alternatives—including simulation modeling of the operation of the freeways and related surface arterials—in each of these freeway corridors during the morning peak traffic hour indicated that the major expansion alternative would generate substantial benefits in the East-West Freeway (IH 94) corridor. The benefits would be a result of the reduction in the peaking of freeway traffic demand, the provision of preferential treatment to buses and carpools and vanpools, and the diversion of some freeway traffic making short trips to surface arterials.

Under the major expansion alternative in the East-West Freeway corridor (IH 94), average speed on the East-West Freeway and connecting freeway segments during the morning peak travel hour may be expected to increase from 30 to 37 mph to 38 to 48 mph. The average delay at the five eastbound on-ramps currently metered along the East-West Freeway (IH 94) may be expected to remain at one to two minutes, and an additional 20 on-ramps will be metered and experience similar delay. The delay at the ramp meters may be expected to be offset by improved speeds on the freeway within two to four miles of travel on the freeway. The capital cost of the proposed freeway operational control subsystem with the major expansion alternative in the East-West Freeway (IH 94) corridor and the modest expansion alternative in the North-South Freeway (IH 43 and IH 94) corridors is $3.4 million. Operating costs are included in the estimated annual $800,000 operating cost of the traffic management center of the recommended freeway traffic management system.

The major expansion alternative is recommended only in the East-West Freeway corridor because the analyses indicated that only in this corridor would the benefits of major expansion exceed the costs. This is because peak-period freeway traffic congestion in the East-West

Freeway corridor is much more severe, it occurs over nearly all segments of the freeway corridor, and it occurs throughout the entire peak traffic hour. As freeway traffic continues to increase during the peak hours on the area freeway system, the major expansion of the freeway operational control system in the North-South Freeway corridors may become warranted. The modest expansion alternative recommended for the North-South Freeway corridors can be readily expanded as needed into a system similar to that recommended for the East-West Freeway. It is recommended that preferential treatment for buses, carpools, and vanpools be provided at two on-ramps in the North-South Freeway corridors, including the southbound Good Hope Road on-ramp and the southbound State Street on-ramp, as shown on Map 36.

RECOMMENDED FREEWAY TRAFFIC MANAGEMENT SYSTEM

The actions recommended under the proposed freeway traffic management system plan are presented in Table 16, along with the estimated capital costs and annual operating costs. The estimated total capital costs of the recommended freeway traffic management system are $15,060,000; and the estimated total annual operating costs are $1,200,000.[2] It is recommended that the Wisconsin Department of Transportation assume responsibility for implementation of the freeway traffic management system and its operation. This would include full funding by the State of Wisconsin of the existing Milwaukee County Expressway Patrol provided by the Milwaukee County Sheriff's Department.[3] The Milwaukee area freeway system consists of Federal Aid Interstate and Federal Aid Primary highways, which are under the jurisdiction of the State of Wisconsin. The recommended freeway traffic management system may be expected to significantly improve the operation of the freeway system and, potentially, reduce the need for the physical expansion of the system. The Wisconsin Department of Transportation should implement and operate the freeway traffic management system in close cooperation with affected units of government, particularly Milwaukee County.

It is anticipated that the implementation of the freeway traffic management system would be staged over a period of approximately five years. Identification of the staging of each element would be one of the necessary objectives of a preliminary engineering plan for the freeway traffic management system. Certain elements, such as loop detector installation, may be implemented in conjunction with freeway reconstruction and resurfacing to minimize capital costs and freeway traffic disruption. It is recommended that the Wisconsin Department of Transportation proceed as quickly as possible with preparation of the preliminary engineering plan, including the staging of the implementation of the various elements of the freeway traffic management system plan.

The benefit-cost ratio of the recommended freeway traffic management system is conservatively estimated to be 1.27. This ratio was calculated over a 20-year period, using a 6 percent rate of interest. The present worth of the costs of the freeway traffic management system was estimated to be $30.7 million, of which $16.9 million was capital costs and $13.8 million was operating costs. These estimated costs do not include the capital and operating costs attendant to the Expressway Patrol. Expressway patrol is currently provided in Milwaukee County and is recommended to be continued within the County. The estimated annual cost of the Expressway Patrol is $4.0 million.

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[2]*In addition, continuation of expressway patrol in Milwaukee County would have an estimated cost of $4.0 million annually, including vehicle acquisition and replacement.*

[3]*Of the estimated $4.0 million annual cost of the Milwaukee County Expressway Patrol, approximately 30 percent, or $1.2 million, is funded by state transportation operations and maintenance aids to Milwaukee County; 12 percent, or $0.5 million, is funded by the State pursuant to specific action of the Wisconsin State Legislature; 25 percent, or $1.0 million, is funded by fines collected by the Expressway Patrol; and the remaining 33 percent, or $1.3 million, is funded by Milwaukee County. It is recommended that the $1.3 million currently being funded by Milwaukee County be financed by the Wisconsin Department of Transportation.*

Table 16

SUMMARY OF FREEWAY TRAFFIC MANAGEMENT RECOMMENDATIONS

Recommended Freeway Traffic Management Action	Capital Cost[a]
<u>Incident Management</u>	
• Electronic Freeway Traffic Data Gathering and Analysis	$ 6,100,000
• Remote Base CB Radio Stations	50,000
• Signing with an Emergency Telephone Number for Use with Cellular Telephones	20,000
• Closed Circuit Television	850,000
• Emergency Service Patrol	290,000[b]
• Expressway Patrol	- -[c]
• Major Incident Response Team	- -
<u>Advisory Information</u>	
• Trucks with Portable Message Signs	$ 100,000
• Permanent Changeable Message Signs	3,000,000
• Teleprinter Equipment for Information Provision to Commercial Radio	110,000
<u>Monitoring and Control</u>	
• Traffic Management Center	$ 1,650,000
<u>Freeway Operational Control</u>	
• Ramp Meters	$ 1,120,000
• Preferential Access Treatment for High-Occupancy Vehicles	1,770,000
Total	$15,060,000

[a]*The estimated annual operating and maintenance cost of the freeway traffic management system, including monitoring and control, traffic management center, system operation, and enforcement, is $800,000. This cost includes the costs of operation and maintenance for all freeway traffic management system elements except expressway patrol and emergency service patrol.*

[b]*The emergency service patrol has an estimated operating cost of $400,000 annually.*

[c]*The continuation of the Expressway Patrol would entail an annual cost of about $4.0 million, including patrol vehicle acquisition and replacement.*

Source: SEWRPC.

The benefits incorporated in the calculation of the benefit-cost ratio include only those which are direct and readily quantifiable. Specifically, the benefits include the savings of 175,000 passenger hours of travel annually during weekday peak traffic periods attributable to the major expansion of operational control in the East-West Freeway (IH 94) corridor, and assume an average value of $8.00[4] per passenger hour. The travel simulation modeling conducted under the study indicated that the major expansion of freeway operational control may be expected to result in a savings of about 50,000 passenger hours of travel annually during the morning peak hours on average weekdays. The total annual savings of 175,000 hours, valued at about $1.4 million, is based on the assumption that a similar reduction in passenger hours of travel may be expected during the afternoon peak hour, and that some savings will, as well, occur during other hours of the morning and afternoon peak periods.

The other benefit included in the benefit-cost ratio is the savings attributable to a reduction in nonrecurrent congestion on the freeway system. It is estimated that on the Milwaukee area freeway system over an average year, there are 500,000 passenger hours of delay which may be attributable to nonrecurrent congestion, principally as a result of freeway incidents. This estimate is based on Federal Highway Administration estimates that approximately 50 percent of the congestion on an area freeway system is due to recurrent congestion, and the other 50 percent to nonrecurrent congestion. The estimated monetary value of the total annual delay attendant to nonrecurrent congestion on the area freeway system assumes an average value of $8.00 per passenger hour. The recommended freeway traffic management system proposes actions which will substantially improve the detection, confirmation, and removal of incidents on the freeway system, as well as provide information to motorists in order to minimize the impacts of those incidents. Given these actions to minimize nonrecurrent congestion with the implementation of the recommended freeway traffic management system, and estimating conservatively that the recommended system will reduce nonrecurrent congestion on the area freeway system by 50 percent, the estimated annual monetary benefit of freeway traffic management with respect to reduction of nonrecurrent congestion is $2.0 million.

It should be noted that the recommended freeway traffic management system would have many other benefits, such as a reduction of accidents owing to the reduction of recurrent and nonrecurrent congestion, reduced motor vehicle operating costs as a result of reduced recurrent and nonrecurrent congestion, and reduced parking costs as a result of increased use of buses and carpools. Also, it may be noted that the freeway traffic management system, by minimizing freeway traffic congestion through ramp metering and providing preferential freeway access to public transit, carpools, and vanpools, will essentially provide a system of high-speed guideways for high-occupancy vehicles in the Milwaukee area. By comparison, the total capital cost of one mile of guideway—busway or railway—exclusively constructed for high-occupancy vehicles may be expected to range from $2 to $10 million. The recommended freeway traffic management system, in effect, provides a system of exclusive high-occupancy-vehicle guideways on the Milwaukee urbanized area freeway system at an estimated capital cost of $15 million. Such guideways are warranted on about 40 miles of the 95-mile area freeway system which carry traffic volumes that equal or exceed design capacity, including, in Milwaukee County, segments of the East-West Freeway (IH 94), the North-South Freeway (IH 43 and IH 94), the Airport Freeway (IH 894), and the Zoo Freeway (USH 45 and IH 894).

SUMMARY

This chapter presents a recommended plan for freeway traffic management in the Milwaukee area. Implementation of the recommended plan may be expected to provide for the more efficient movement of traffic on the freeway and related arterial street and highway system of the greater Milwaukee area. Traffic congestion on the freeway and street and highway system would be reduced, including recurrent traffic congestion resulting from freeway demand exceeding capacity during weekday peak traffic periods, and nonrecurrent traffic congestion resulting from incidents and special events on weekday nonpeak periods and weekends.

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[4] *A discussion is provided in Chapter V of the reasons for using $8.00 per passenger hour as the monetary value of travel.*

The seven elements of the freeway traffic management system plan are:

1. Incident management—or the identification and removal of freeway incidents, such as accidents, which restrict traffic flow—in order to minimize the effects of incidents.

2. Motorist advisory information, or the provision of information to motorists about current traffic conditions, including incidents.

3. System management, or monitoring and control—the collection and analysis of the freeway operational data essential to the management of the other elements of the freeway management system.

4. Determination of the number and location of freeway on-ramp meters and related control signalization.

5. A freeway operational control strategy, which defines the desired level of operation to be maintained on the freeway system, including the desired operating speeds.

6. A freeway on-ramp meter control strategy, which defines the rate of entry at the various metered freeway on-ramps, distributing the required metering of freeway volume over the contributing on-ramps.

7. High-occupancy-vehicle preferential access, or determination of the number and location of exclusive bypasses to the metered on-ramps for carpools, vanpools, and buses.

The recommended freeway incident management system element for the greater Milwaukee area consists of: an electronic freeway traffic data gathering and analysis system; signing to provide an emergency telephone number that can be used by motorists having cellular telephones to contact the freeway traffic management; a citizen band radio monitoring system; a closed circuit television monitoring system; an emergency service patrol; a major incident response team; and continued expressway patrol. To provide for the efficient use of these actions, a central freeway traffic management center and staff will be required.

The recommended motorist advisory information system element for the greater Milwaukee area consists of truck-mounted transportable changeable message signs, a system of fixed changeable message signs, and timely provision of information to commercial radio broadcasting stations. To provide for efficient use of these system components, a central freeway traffic management center and an electronic freeway traffic data gathering and analysis system will be required.

With respect to the monitoring and control element of the recommended freeway traffic management system, as already noted, proper implementation of the recommended incident management and advisory information elements will require a central traffic management center. Such a center would also be required for the recommended freeway operational control and ramp-meter elements of the total freeway traffic management system. At the traffic management center, all traffic information would be received, analyzed, and evaluated, and decisions made regarding what incident management, advisory information, and ramp metering would be implemented. The control center equipment would include a high-speed, high-capacity computer and related peripheral equipment, display devices such as closed circuit television screens, and communications equipment such as radio receivers and transmitters and direct telephone line connections. Control center staff should include both operations and maintenance personnel.

The remaining freeway traffic management system elements include the number and location of ramp meters, the freeway operational control strategy, the ramp-meter control strategy, and high-occupancy-vehicle preferential access. These elements may be considered to be a freeway operational control subsystem. Two freeway operational control subsystem alternatives were considered. One of the two alternatives represented a modest expansion of the existing freeway operational control subsystem. Under this alternative, a limited number of new freeway ramp meters would be installed at those on-ramps that are currently not metered and are adjacent to congested stretches of freeways. New preferential access for buses would be provided at those on-ramps that are proposed to be metered and that are used by freeway flyer buses to provide transit service.

The other freeway operational control subsystem alternative considered represented a major expansion of the existing system. All freeway on-ramps that carry substantial traffic volumes and contribute to freeway traffic congestion would be metered under this alternative, including ramps in outlying counties. This alternative freeway operational control subsystem would have a broader objective than the existing system and the modest expansion alternative—namely, to minimize freeway congestion—particularly, stop-and-go traffic upstream of freeway capacity bottlenecks—and to provide average operating speeds of 35 to 40 miles per hour (mph) on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters should permit sufficient control of traffic demand to prevent demand from exceeding available freeway capacity, and will not require significantly more restrictive ramp metering at existing metered ramps in central Milwaukee County. The necessary restriction of freeway traffic demand to permit peak-hour freeway operation of at least 35 to 40 mph was equally applied at all existing metered and proposed newly metered freeway on-ramps. Also under this alternative, preferential access for all high-occupancy vehicles—buses, carpools, and vanpools—would generally be provided at all metered ramps.

It is recommended that the major expansion alternative for the freeway operational control subsystem be implemented in the East-West Freeway (IH 94) corridor, including connecting segments of the Stadium Freeway (USH 41), the Zoo Freeway (USH 45), and the Airport Freeway (IH 894); and that the modest expansion alternative be implemented in the North-South Freeway (IH 43 and IH 94) corridors. The major expansion alternative is recommended only in the East-West Freeway corridor because only in this corridor will the benefits of major expansion exceed its costs. This is because peak-period freeway traffic congestion in the East-West Freeway corridor is much more severe, it occurs over nearly all segments of the freeway corridor, and it occurs throughout the entire peak traffic hour. As freeway traffic continues to increase during the peak hours on the area freeway system, the major expansion of freeway operational control in the North-South Freeway corridors may become warranted. The modest expansion alternative recommended to be implemented in the North-South Freeway corridors can be readily expanded as needed.

The estimated capital costs of the recommended freeway traffic management system are $15,060,000, and the estimated annual operating costs are $1.2 million. In addition, the continued operation of the Expressway Patrol in Milwaukee County would entail an annual cost of $4.0 million, including vehicle acquisition and replacement.

It is recommended that the Wisconsin Department of Transportation assume responsibility for implementation of the freeway traffic management system and its operation, including all capital and operating costs. This would include full funding by the State of Wisconsin for the existing Milwaukee County Expressway Patrol provided by the Milwaukee County Sheriff's Department. The Milwaukee area freeway system consists of Federal Aid Interstate and Federal Aid Primary highways, which are under the jurisdiction of the State of Wisconsin. The recommended freeway traffic management system will improve the operation of the freeway system and, potentially, reduce the need for the State of Wisconsin to fund the physical expansion of the freeway system, which would have a much greater cost. The Wisconsin Department of Transportation, however, should implement and operate the freeway traffic management system in close cooperation with affected units of government, particularly Milwaukee County, as Milwaukee County will be the most affected.

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Chapter VII

SUMMARY AND CONCLUSIONS

This report presents a recommended plan for freeway traffic management in the Milwaukee area. Implementation of the plan may be expected to provide for the more efficient movement of traffic on the freeway and related arterial street and highway system of the greater Milwaukee area. Traffic congestion on the freeway and related arterial street and highway system would be reduced, including recurrent traffic congestion resulting from freeway demand exceeding capacity during weekday peak traffic periods, and nonrecurrent congestion resulting from incidents and special events on weekday nonpeak periods and weekends.

Freeway congestion entails reduced travel speed, increased and unpredictable travel times, and stop-and-go driving, which result in increased operating costs, accidents, energy consumption, and air pollutant emissions. Freeway congestion can be classified into recurrent congestion and nonrecurrent congestion. Recurrent congestion is that freeway congestion that occurs regularly as a result of freeway traffic demand exceeding the traffic-carrying capacity of the freeway, principally during weekday morning and afternoon peak traffic periods. Nonrecurrent traffic congestion is congestion that occurs as a result of a freeway incident, such as an accident or disabled vehicle. It is estimated that 50 percent of the traffic congestion that occurs on the freeway system is due to incidents, and would be considered nonrecurrent congestion, while the other 50 percent is due to recurrent traffic congestion.

The recommended freeway traffic management system plan is based upon extensive study. Inventories were conducted of the existing peak-period freeway traffic volume and pattern—that is, the number of vehicles during peak periods which entered at each freeway on-ramp and then exited at each freeway off-ramp, and the path taken by those vehicles on the freeway system from on-ramp to off-ramp. Inventories were also conducted of existing freeway traffic management systems in operation in other major urban areas of North America. Alternative plans were developed, quantitatively tested as applicable, and evaluated for each of the following seven potential elements of a freeway traffic management system and system plan:

1. Incident management—or the identification and removal of freeway incidents, such as accidents, which restrict traffic flow—in order to minimize the effects of incidents.

2. Motorist advisory information, or the provision of information to motorists about current traffic conditions, including incidents.

3. System management, or monitoring and control—the collection and analysis of the freeway operational data essential to the management of the other elements of the freeway management system.

4. Determination of the number and location of freeway on-ramps and related control signalization.

5. A freeway operational control strategy, which defines the desired level of operation to be maintained on the freeway system, including the desired operating speeds.

6. A freeway on-ramp meter control strategy, which defines the rate of entry at the various metered freeway on-ramps, distributing the required metering of freeway volume over the contributing on-ramps.

7. High-occupancy-vehicle preferential access, or the number and location of exclusive bypasses of the metered on-ramps for use by carpools, vanpools, and buses.

Freeway incident management actions are intended primarily to address the abatement of nonrecurrent traffic congestion by minimizing the impacts of incidents on freeway traffic flow through prompt detection, confirmation, and removal. Existing freeway incident management in the Milwaukee area is basically limited to the Expressway Patrol provided by the Milwaukee County Sheriff's Department and the Wisconsin State Highway Patrol. The recommended freeway incident management system for the greater Milwaukee area would consist of: an electronic freeway traffic data gathering and analysis system; a citizen band radio monitoring system; signing to provide an emergency telephone number that could be used by motorists having cellular telephones to contact the freeway traffic management center; a closed circuit television monitoring system; an emergency service patrol; a major incident response team; and continued expressway patrol in Milwaukee County. To provide for the efficient use of these actions, a central freeway traffic management center and staff will be required. The electronic freeway traffic data gathering system would be based upon loop detectors installed at one-half-mile intervals in all lanes of the Milwaukee area freeway system. This system would be used to initially identify incidents, as it can provide such identification rapidly. It is the most critical element of the freeway incident management system, and is essential to efficient operation of every other element of freeway traffic management. Closed circuit television monitoring of freeways, the recommended remote base station citizen band radio monitoring, and the calls received at the traffic management center from motorists having cellular telephones would all be used to quickly confirm the presence of freeway incidents and to establish their nature and severity so that appropriate action could be taken. The emergency service patrol would assist the Expressway Patrol of professional law enforcement officers in managing the removal of incidents.

Motorist advisory information assists in abating both recurrent and nonrecurrent traffic congestion. By providing information about the traffic conditions on the freeway system and on alternative freeway and nonfreeway routes during the peak weekday traffic periods, motorist advisory information systems help to abate traffic congestion problems. By providing information about incidents, such as identifying lane closures well in advance, motorist advisory information systems can also address nonrecurrent traffic congestion.

Existing motorist advisory information in the Milwaukee area is limited to that provided by commercial radio broadcasting stations, principally during weekday peak traffic periods, and six portable changeable message signs which are used primarily for freeway construction and maintenance projects. The commercial radio broadcasting stations obtain their information on traffic conditions from their own surveillance and from the Milwaukee County Sheriff's Department. The recommended motorist advisory information system for the greater Milwaukee area would consist of truck-mounted transportable changeable message signs, a system of fixed changeable message signs, and timely provision of information to commercial radio broadcasting stations. To provide for efficient use of these system components, a central freeway traffic management center and an electronic freeway traffic data gathering and analysis system will be required.

With respect to the monitoring and control element of the recommended freeway traffic management system, as already noted, proper implementation of the recommended incident management and advisory information actions will require a central traffic management center. Such a center would also be required for the recommended freeway operational control and ramp-meter elements of the total freeway traffic management system. At the traffic management center, all traffic information would be received, analyzed, and evaluated, and decisions made regarding what incident management, advisory information, and ramp metering would be implemented. The control center equipment would include a high-speed, high-capacity computer and peripheral equipment; display devices such as closed circuit television (CCTV) screens; and communications equipment such as radio receivers and transmitters and direct telephone line connections.

Control center staff would include both operations and maintenance personnel. To provide 12-hour weekday and selected special event coverage, the following staff would be required: a center manager; operations personnel, including two traffic engineers, one electronic systems engineer, four technician operators, and one clerk; and maintenance personnel, including a supervisor, two electronics technicians, and two electricians.

Based on the estimated staffing needs and the necessary space for the equipment in a control center, an estimated 7,000 square feet of floor space would be needed for the traffic management center. This should provide sufficient space to house the required mechanical and electrical equipment, a storage and maintenance area for the electronic equipment and technicians, offices for staff, and a reception area and conference room for meetings and training.

Two basic freeway operational control subsystem alternatives were developed and evaluated. The freeway operational control subsystems consist of the number and location of ramp meters; the freeway operational control strategy; the ramp-meter control strategy; and high-occupancy-vehicle preferential access. Essential to the operation of an expanded freeway operational control subsystem is an expanded monitoring and control system with a freeway traffic management center, as well as an electronic freeway traffic data gathering and analysis system.

One of the two subsystem alternatives considered represented a modest expansion of the existing freeway operational control subsystem. Currently, 21 freeway on-ramps in central Milwaukee County are metered, as shown on Map 30 in Chapter V. The meters are located at freeway on-ramps adjacent to the segments of freeway which experience the most severe congestion during morning and evening peak traffic periods. The meters exercise control of freeway traffic volume by restricting, or metering, freeway on-ramp traffic. The principal objective of the existing freeway operational control subsystem is to reduce the severity and duration of freeway traffic congestion by preventing platoons, or groups, of vehicles from attempting to merge into congested freeway segments simultaneously, thus smoothing traffic flow. Freeway traffic demand is also reduced at areas of freeway congestion.

Under the modest expansion alternative, a limited number of freeway ramp meters would be installed at those on-ramps that are currently not metered, but are adjacent to congested stretches of freeways. New preferential access for buses and other high-occupancy vehicles would be provided at those on-ramps that are proposed to be metered and that are used by freeway flyer buses to provide transit service.

The other freeway operational control subsystem alternative considered represented a major expansion of the existing system. All freeway on-ramps throughout Milwaukee County which carry substantial traffic volumes and contribute to freeway traffic congestion would be metered, along with selected on-ramps in Ozaukee and Waukesha Counties. This freeway operational control subsystem alternative would have a broader objective than the existing system and the modest expansion alternative—namely, to minimize freeway congestion—particularly stop-and-go traffic upstream of freeway capacity bottlenecks—and to provide average operating speeds of 35 to 40 miles per hour (mph) on all segments of the freeway during peak traffic periods. The areawide expansion of ramp meters may be expected to permit sufficient control of traffic demand to prevent demand from exceeding available freeway capacity, and will not require significantly more restrictive ramp metering at the existing metered ramps in central Milwaukee County. The necessary restriction of traffic demand to permit peak-hour freeway operation of at least 35 to 40 mph was equally applied at all existing metered and proposed newly metered freeway on-ramps. Also under this alternative, preferential access for all high-occupancy vehicles—buses, carpools, and vanpools—would generally be provided at all metered ramps.

The major expansion alternative may be expected to reduce recurrent freeway traffic congestion and improve freeway traffic flow in a number of ways. The major expansion freeway operational control subsystem will improve freeway travel for public transit, carpools, and vanpools, and thereby encourage greater use of such modes. As more freeway traffic shifts to more efficient high-occupancy vehicles, improvement of other automobile and truck peak-period travel may be expected, as total demand for limited freeway capacity will be reduced through more efficient use of the freeway. Also, the freeway operational control subsystem may be expected to encourage some very short trips now using the freeway to utilize surface arterial streets instead. The resultant modest reduction in freeway traffic demand may be expected to contribute to a reduction in freeway traffic congestion, while not substantially affecting surface arterial streets. Also, a freeway operational control subsystem may be expected to reduce freeway traffic congestion by reducing the peaks in freeway traffic demand through the use of ramp metering. Thus, freeway operational control may be expected to reduce freeway travel time even for single-occupant automobiles and trucks, as the delay these vehicles experience at freeway on-ramps may be expected to be offset by attendant reductions in travel time along the freeway.

It is recommended that the major expansion alternative for the freeway operational control subsystem be implemented in the East-West Freeway (IH 94) corridor, including connecting segments of the Stadium Freeway (USH 41), the Zoo Freeway (USH 45), and the Airport Freeway (IH 894), and that the modest expansion alternative be implemented in the North-South Freeway (IH 43 and IH 94) corridors. Evaluation of the two alternatives in each of these freeway corridors during the morning peak traffic hour indicated that the major expansion alternative would generate substantial benefits in the East-West Freeway (IH 94) corridor. Under the major expansion alternative in that corridor, average speed on the East-West Freeway and connecting freeway segments during the morning peak travel hour may be expected to increase from 30 to 37 mph to 38 to 48 mph. The average delay at the five on-ramps currently metered along the eastbound East-West Freeway (IH 94) may be expected to remain at about one to two minutes, and an additional 19 on-ramps would be metered and experience similar delay.

The major expansion alternative is recommended only in the East-West Freeway corridor because only in this corridor may the benefits of major expansion be expected to exceed its costs. This is because peak-period freeway traffic congestion in the East-West Freeway corridor is much more severe, it occurs over nearly all segments of the freeway corridor, and it occurs throughout the entire peak traffic hour. As freeway traffic continues to increase during the peak hours on the area freeway system, the major expansion of freeway operational control in the North-South Freeway corridors may become warranted. The modest expansion alternative recommended to be implemented in the North-South Freeway corridors can be readily expanded as needed.

The estimated total capital costs of the recommended freeway traffic management system are $15,060,000; and the estimated total annual operating costs are $1.2 million, including $800,000 for the freeway traffic management system and $400,000 for the emergency service patrol. The continuation of the Expressway Patrol in Milwaukee County has an estimated annual cost of $4.0 million, including vehicle acquisition and replacement. It is recommended that the Wisconsin Department of Transportation assume responsibility for implementation of the freeway traffic management system and its operation. This would include full funding by the State of Wisconsin of the existing Milwaukee County Expressway Patrol provided by the Milwaukee County Sheriff's Department. The Milwaukee area freeway system consists of Federal Aid Interstate and Federal Aid Primary highways, which are under the jurisdiction of the State of Wisconsin. The recommended freeway traffic management system may be expected to significantly improve the operation of the freeway system and, potentially, reduce the need for the physical expansion of the system. The Wisconsin Department of Transportation should implement and operate the freeway traffic management system in close cooperation with affected units of government, particularly Milwaukee County.

The benefit-cost ratio of the recommended freeway traffic management system is conservatively estimated to be 1.27. This ratio was calculated over a 20-year period, using a 6 percent rate of interest. The present worth of the costs of the freeway traffic management system was estimated to be $30.7 million, of which $16.9 million is capital costs and $13.8 million is operating costs. These estimated costs do not include the capital and operating costs attendant to the Expressway Patrol. It is recommended that the Expressway Patrol currently provided in Milwaukee County be continued. This Expressway Patrol is provided for law enforcement purposes, as well as freeway traffic management purposes. As previously mentioned, the estimated annual cost of the Expressway Patrol is $4.0 million.

The benefits incorporated in the calculation of the benefit-cost ratio include only those that are direct and readily quantifiable. Specifically, the benefits include the estimated savings of 175,000 passenger hours of travel annually during weekday peak traffic periods attributable to the major expansion of freeway operational control in the East-West Freeway (IH 94) corridor, and assume an average value of $8.00[1] per passenger hour. Thus, the monetary value of the travel time savings entailed is estimated at $1.4 million. The travel simulation modeling conducted under the study indicated that major expansion of freeway operational control would result in a savings of about 50,000 passenger

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[1] *The rationale for the use of this value is set forth in Chapter V.*

hours annually in average weekday morning peak-hour travel. The total annual savings of 175,000 hours assumes that a similar reduction in passenger hours of travel may be expected during the afternoon peak hour, as well as during other hours of the morning and afternoon peak periods.

The other benefit included in the benefit-cost ratio is the savings attributable to a reduction in nonrecurrent congestion on the freeway system. It is estimated that on the Milwaukee area freeway system over an average year, there are 500,000 vehicle passenger hours of delay which may be attributable to nonrecurrent congestion, principally as a result of freeway incidents. The estimated monetary value of the total annual delay attendant to nonrecurrent congestion on the area freeway system also assumes an average value of $8.00 per passenger hour. The recommended freeway traffic management system proposes actions which will substantially improve the detection, confirmation, and removal of incidents on the freeway system. Given such actions to minimize nonrecurrent congestion with the implementation of the recommended freeway traffic management system, and estimating conservatively that the recommended system will reduce nonrecurrent congestion on the area freeway system by 50 percent, the estimated monetary benefit of freeway traffic management with respect to reduction of nonrecurrent congestion is $2.0 million.

It should be noted that certain direct benefits of the recommended freeway traffic management system were not included in the benefit-cost analysis, such as a reduction in accident costs due to a reduction of recurrent and nonrecurrent congestion, a reduction in motor vehicle operating costs due to a reduction in recurrent and nonrecurrent congestion, and a reduction in parking costs in the central business district of Milwaukee as a result of increased use of high-occupancy vehicles. Also, it may be noted that the freeway traffic management system, by minimizing freeway traffic congestion through ramp metering and providing preferential freeway access to public transit, carpools, and vanpools, will essentially provide a system of high-speed guideways for high-occupancy vehicles in the Milwaukee area. By comparison, the total capital cost of one mile of guideway—busway or railway—exclusively constructed for high-occupancy vehicles may be expected to range from $2 to $10 million per mile. The recommended freeway traffic management system, in effect, provides a system of exclusive high-occupancy-vehicle guideways on the Milwaukee area freeway system at an estimated total capital cost of $15 million. Such guideways are warranted on about 40 miles of the 95-mile area freeway system which carry traffic volumes that equal or exceed design capacity, including in Milwaukee County segments of the East-West Freeway (IH 94), the North-South Freeway (IH 43 and IH 94), the Airport Freeway (IH 894), and the Zoo Freeway (USH 45 and IH 894).

PUBLIC REACTION TO THE PLAN

The findings and recommendations of the freeway traffic management system plan for the Milwaukee area were presented at a public hearing held on October 27, 1988, at the Milwaukee County Courthouse Annex in Milwaukee, Wisconsin. The purpose of the hearing was to provide public officials and interested citizens an opportunity to ask questions about, and provide comments on, the proposed freeway traffic management system plan. The Commission prepared and widely distributed an issue of the SEWRPC Newsletter, Vol. 28, No. 5 (Sept.-Oct. 1988), which presented in summary form the findings and recommendations of the planning effort. This issue of the newsletter also announced the public hearing. The newsletter was distributed to Milwaukee area daily and weekly newspapers, radio stations, and television stations. Two announcements of the public hearing appeared in the business section of the Milwaukee Journal, one on October 20, 1988, and one on October 25, 1988.

The minutes of the public hearing were published by the Commission for distribution to the Advisory Committee members and are available for review at the Commission offices. The minutes, along with the attendance records, meeting announcements, written comments, and pertinent newspaper articles, are documented in Minutes of Public Hearing: A Freeway Traffic Management System Plan for the Milwaukee Area.

Three statements were submitted at the public hearing: one by the Wisconsin Department of Transportation; another by the U. S. Department of Transportation, Federal Highway Administration; and the third by the Milwaukee County Department of Public Works.

The Wisconsin Department of Transportation statement generally endorsed the recommendations of the freeway traffic management system plan, and indicated that the Department is developing a schedule to implement the recommendations of the plan beginning in 1992. The Department indicated, however, that its general endorsement of the plan specifically did not include endorsement of the plan recommendation that would provide for full state funding of the costs of the Milwaukee County Sheriff's Expressway Patrol. The Department noted that this particular matter involved policy to be determined by the State Legislature, and that the Legislature to date has determined not to provide for full funding of the Expressway Patrol. If, then, this particular element of the plan is to be implemented, Milwaukee County will need to seek approval of the Legislature. This issue was considered by the Advisory Committee at its meeting of July 26, 1988, during plan preparation, and the Committee determined that it would be inequitable for the property owners of Milwaukee County to bear the cost of an action recommended to improve an areawide system. The need to seek legislative action to implement this recommendation is hereby specifically recognized.

The comment made by the Federal Highway Administration Research Engineer suggested that consideration be given to the inclusion in the plan of promoting the conduct of freeway accident investigation at locations removed from the freeway system. This strategy encourages motorists involved in property damage accidents on the freeway to quickly remove their vehicles from the freeway and freeway shoulders after a brief exchange of names and addresses; and encourages the motorists involved to travel to a designated accident investigation area located off the freeway. The benefit of the action would be a reduction in freeway congestion, as vehicles involved in incidents would block freeway lanes or be located on freeway shoulders for a shorter time. "Gapers" blocks would also be shortened by the quick removal from the site of vehicles involved in accidents. The technique would require that off-site accident investigation sites be marked along streets spaced every few miles along the freeway, that appropriate signing along the freeway be developed to identify the location of such sites, and that automobile insurance providers and freeway law enforcement personnel endorse off-site accident investigation and encourage motorists to use such sites when necessary. Also, a motorist education program would need to be conducted to encourage motorists to utilize these accident investigation sites. In response to this comment, it should be noted that the freeway traffic management system plan specifically recommends actions which would attempt to remove incidents from the freeway as quickly as possible, including an emergency service patrol and a continued expressway patrol in Milwaukee County. It is recommended that, upon implementation of the emergency service patrol, the Wisconsin Department of Transportation consider the implementation of an off-site accident investigation strategy.

The comment made by the Milwaukee County Department of Public Works endorsed the recommendations of the freeway traffic management plan. The Milwaukee County Department of Public Works indicated that the potential reduction in traffic congestion and attendant decrease in energy consumption, accidents, and air pollutant emissions are all desirable impacts of the proposed freeway traffic management system. In particular, support for the plan elements encouraging the use of buses, carpools, and vanpools was expressed. Lastly, it was noted by the Milwaukee County Department of Public Works that a key element of the proposed freeway traffic management system was an electronic freeway traffic data gathering element, and that it was proposed that pavement loop detectors be the technology used to implement that element. The Milwaukee County Department of Public Works suggested consideration of a technology being evaluated by the Minnesota Department of Transportation at this time, which is the use of visual image detectors rather than pavement loop detectors. In response to this comment, it should be noted that visual image detectors require further research and development, and are not yet available for practical application. The Wisconsin Department of Transportation, should, however, at the time of implementation of the recommended electronic traffic data gathering system, recognize that the technology concerned is evolving; carefully review the then-current state-of-the-art of such technology; and based upon that review select the most cost-effective technology available at that time.

APPENDICES

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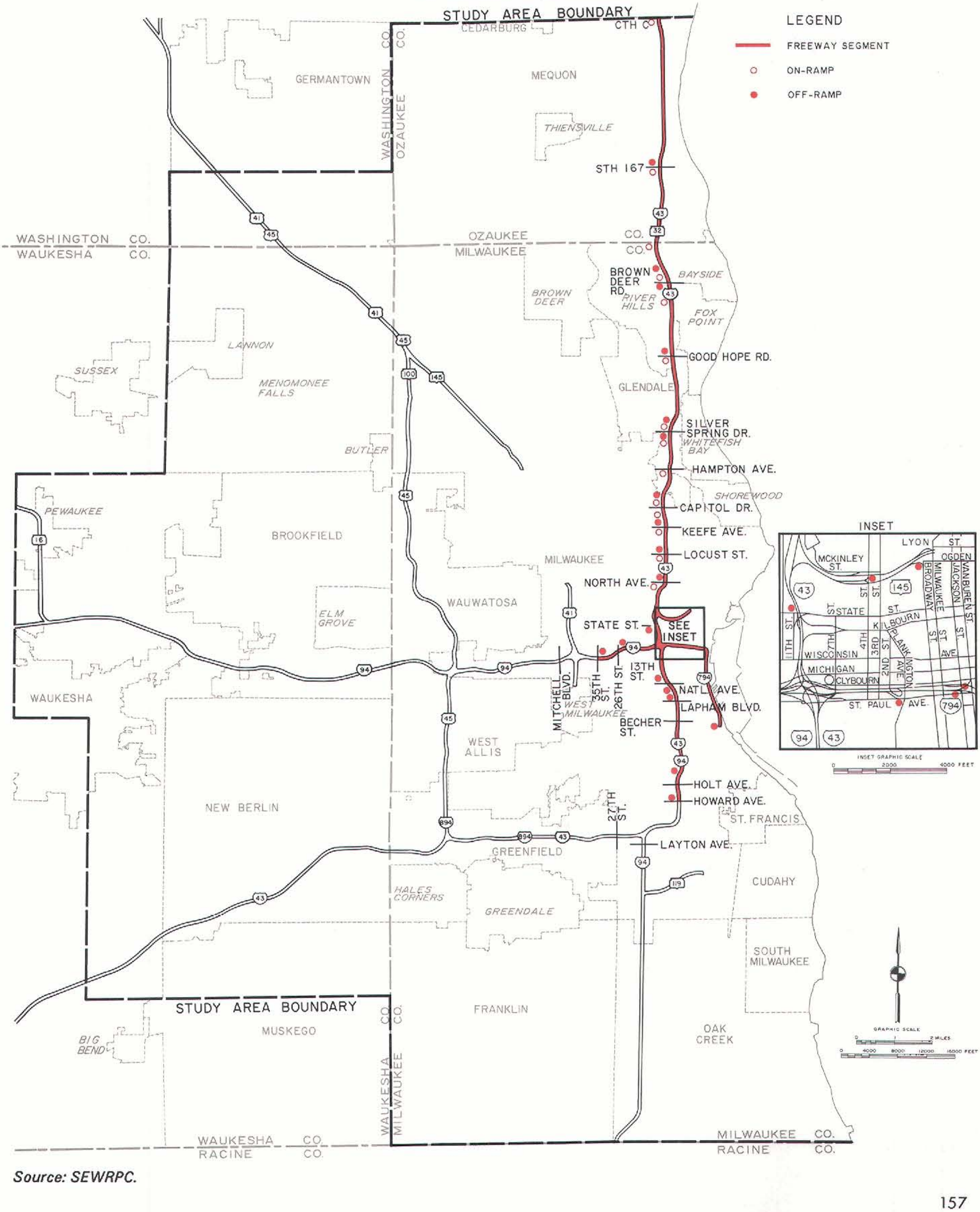
Appendix A

FREEWAY SEGMENTS AS DEFINED FOR FREEWAY TRAVEL PATTERN SURVEY

Map A-1

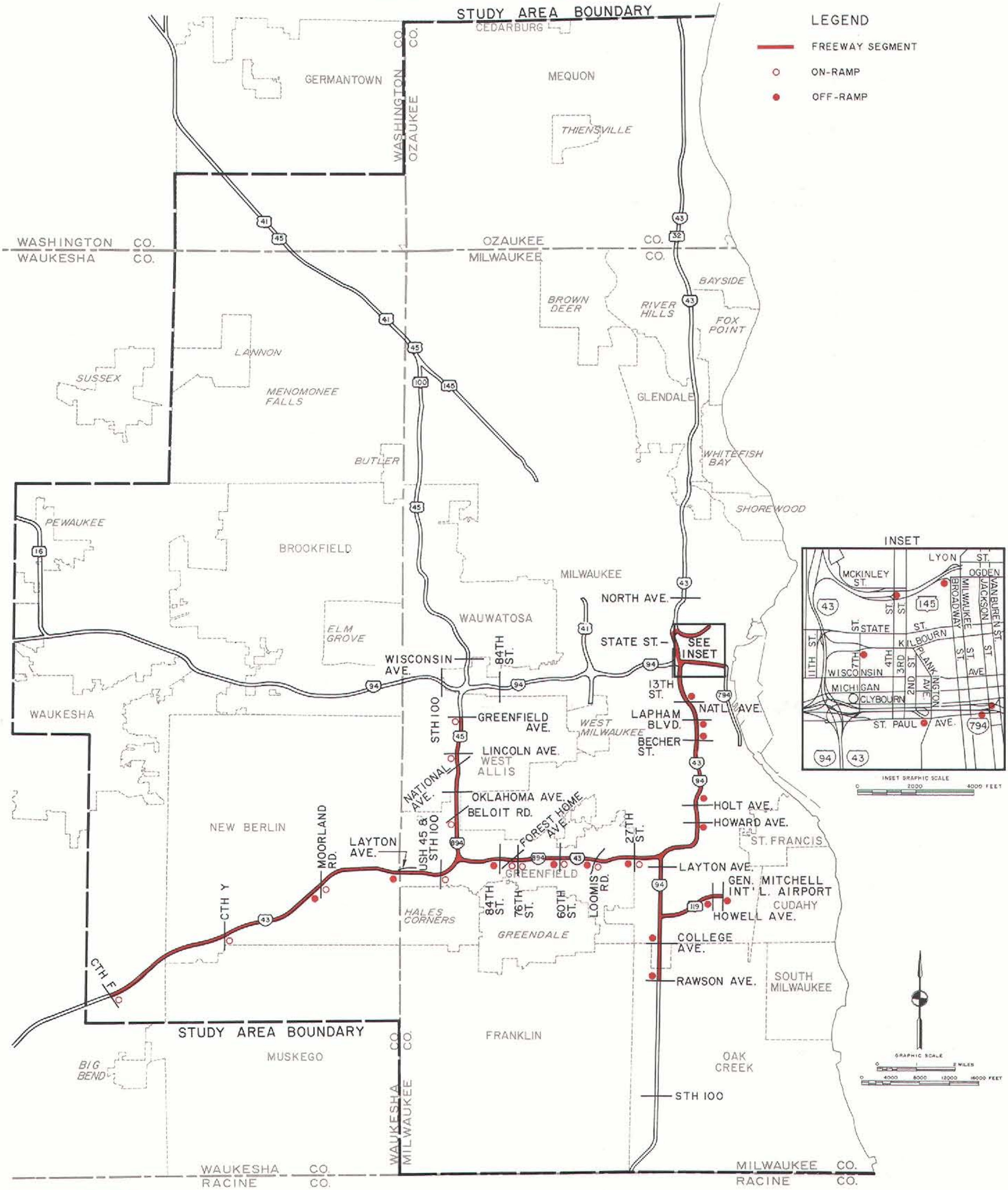
IH 43-MORNING



Source: SEWRPC.

Map A-2

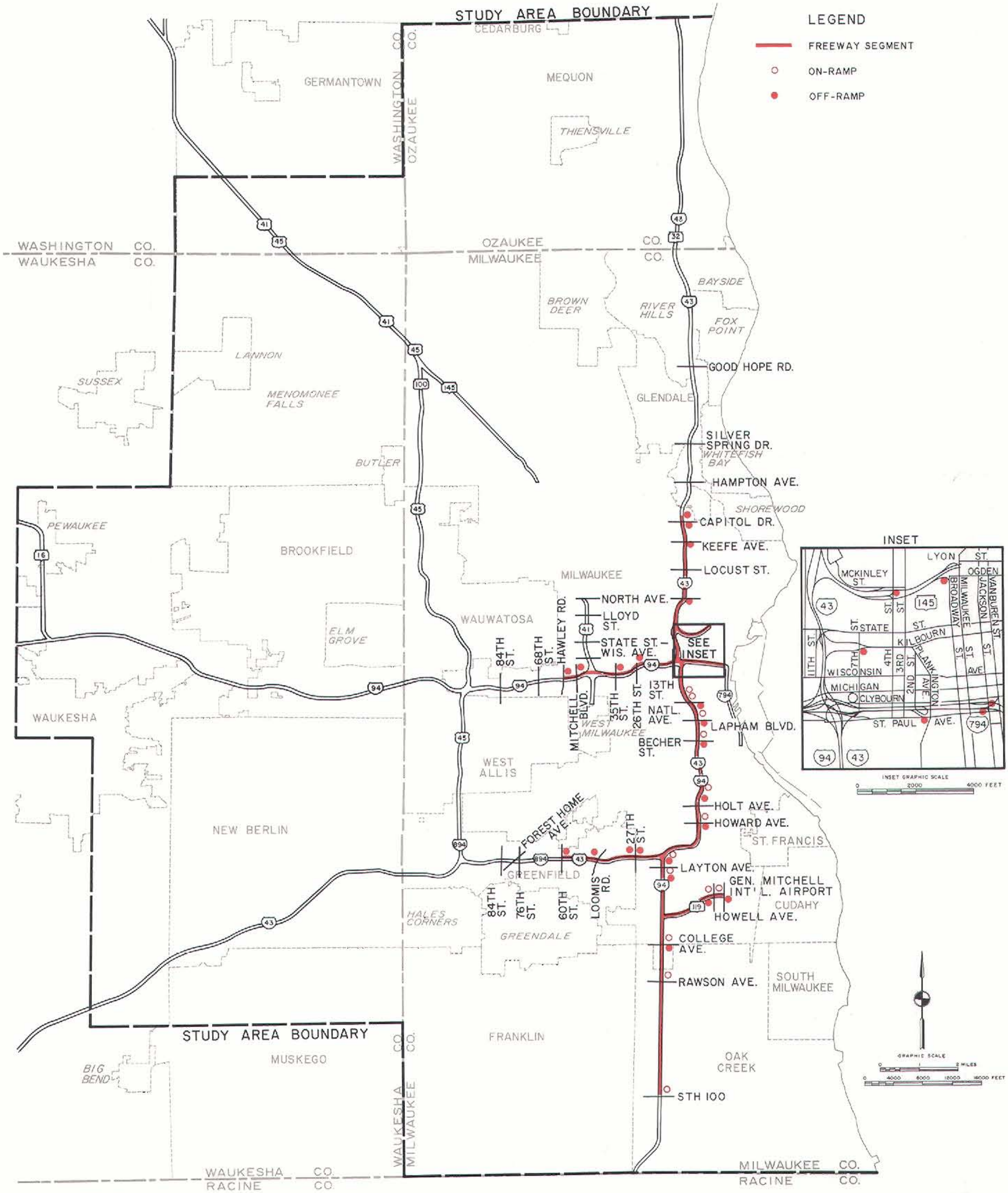
IH 894 AND IH 43-MORNING



Source: SEWRPC.

Map A-3

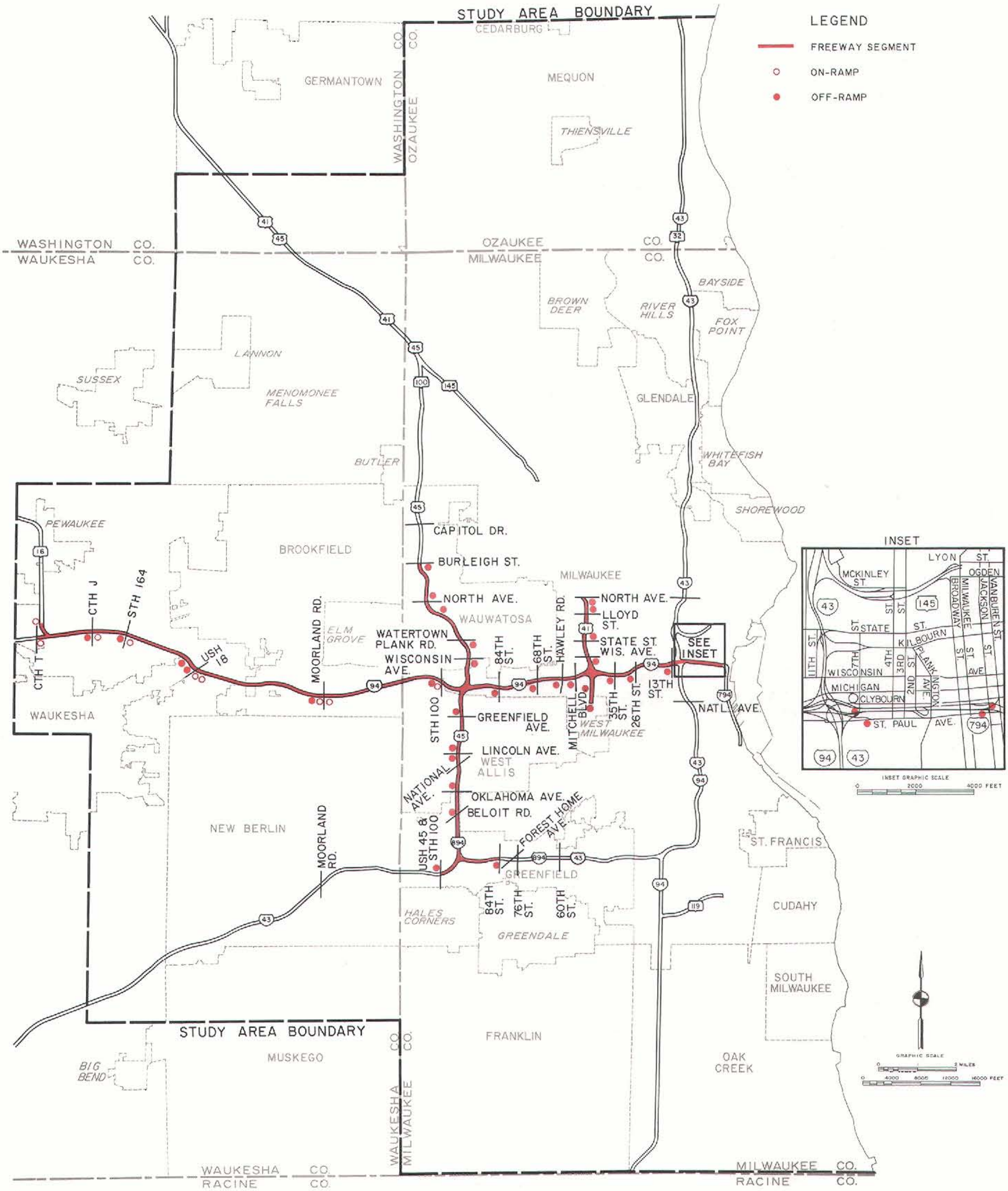
IH 94 (NORTH-SOUTH)-MORNING



Source: SEWRPC.

Map A-4

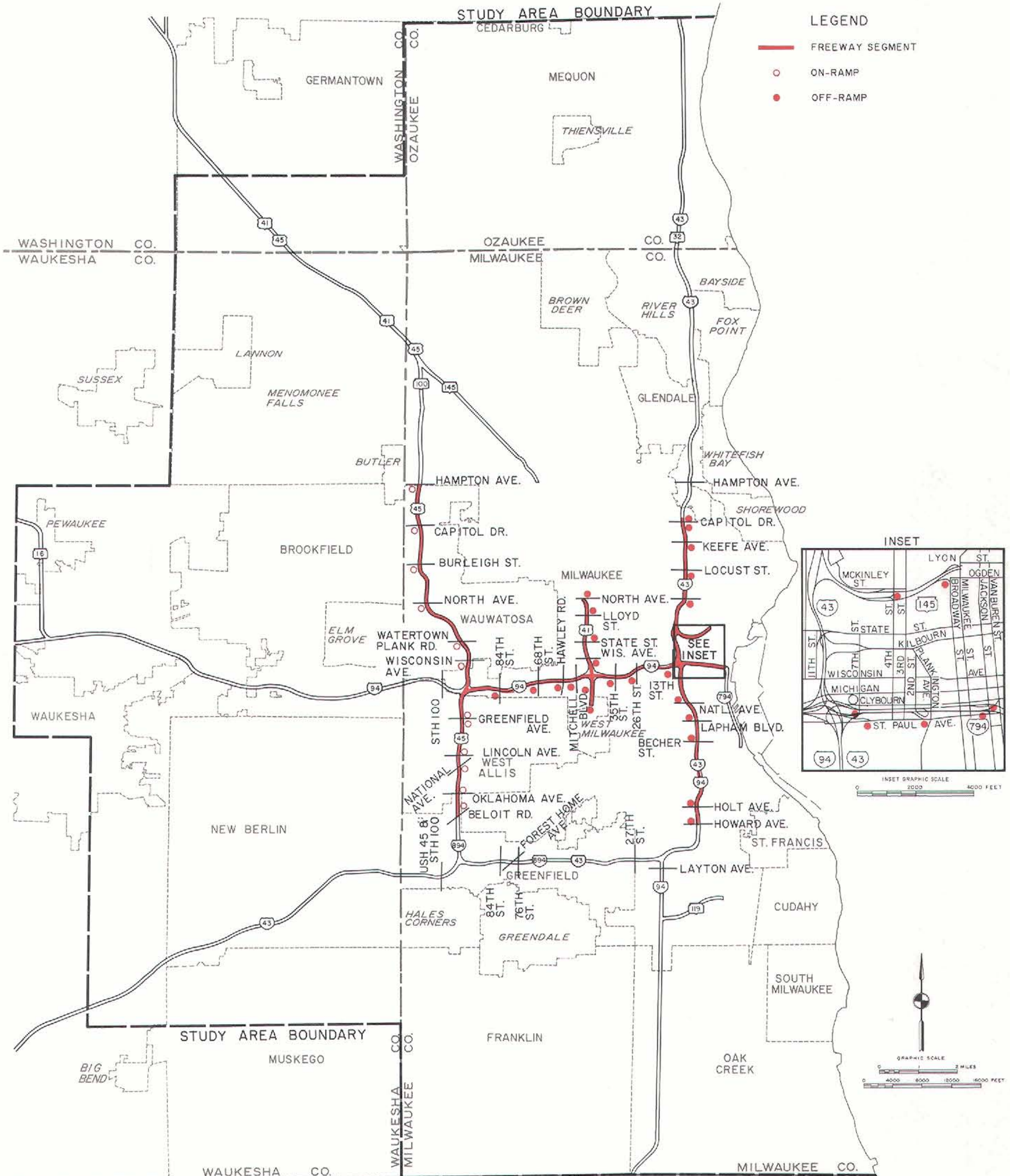
IH 94 (EAST-WEST)-MORNING



Source: SEWRPC.

Map A-5

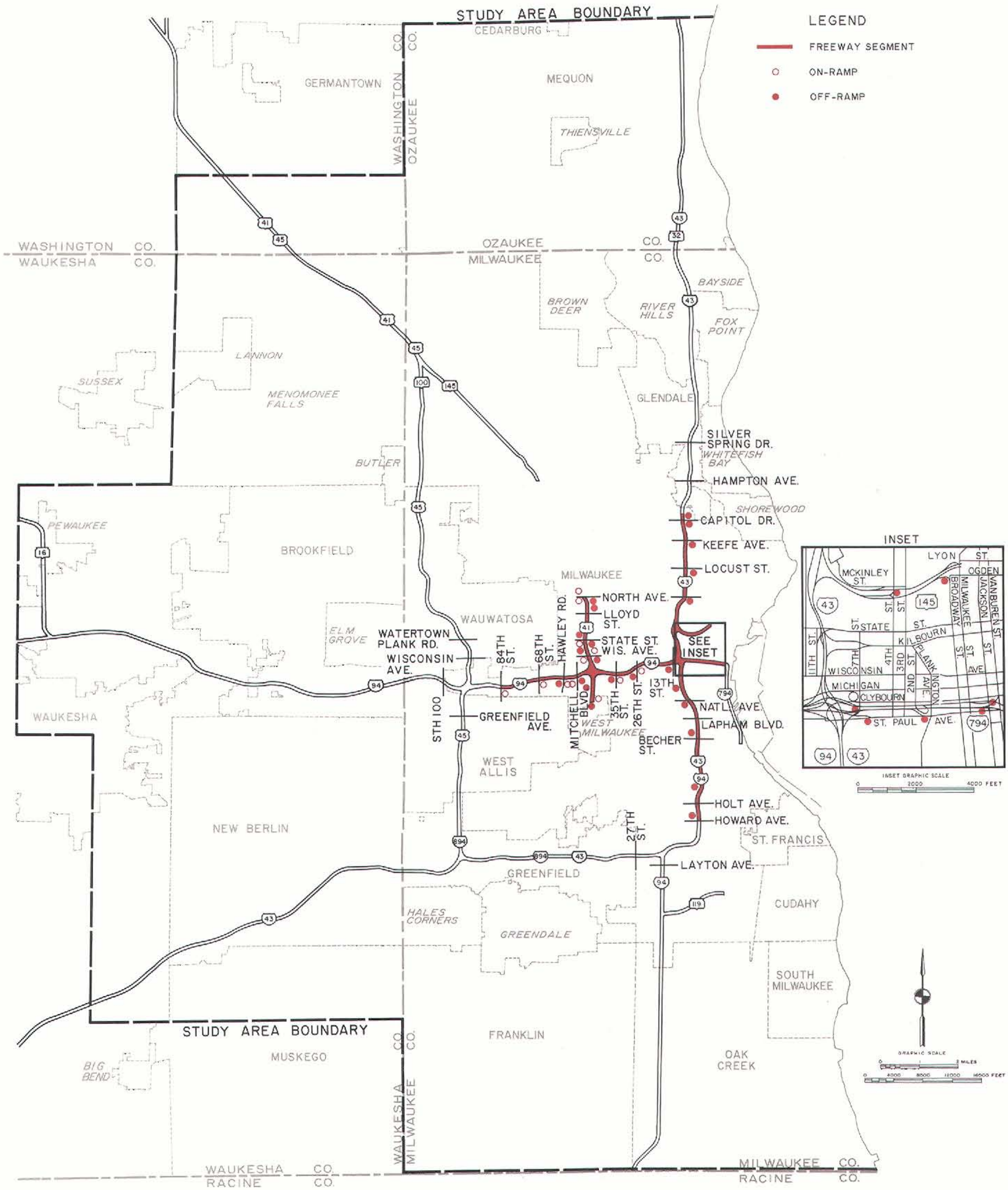
IH 94 (EAST-WEST)-MORNING



Source: SEWRPC.

Map A-6

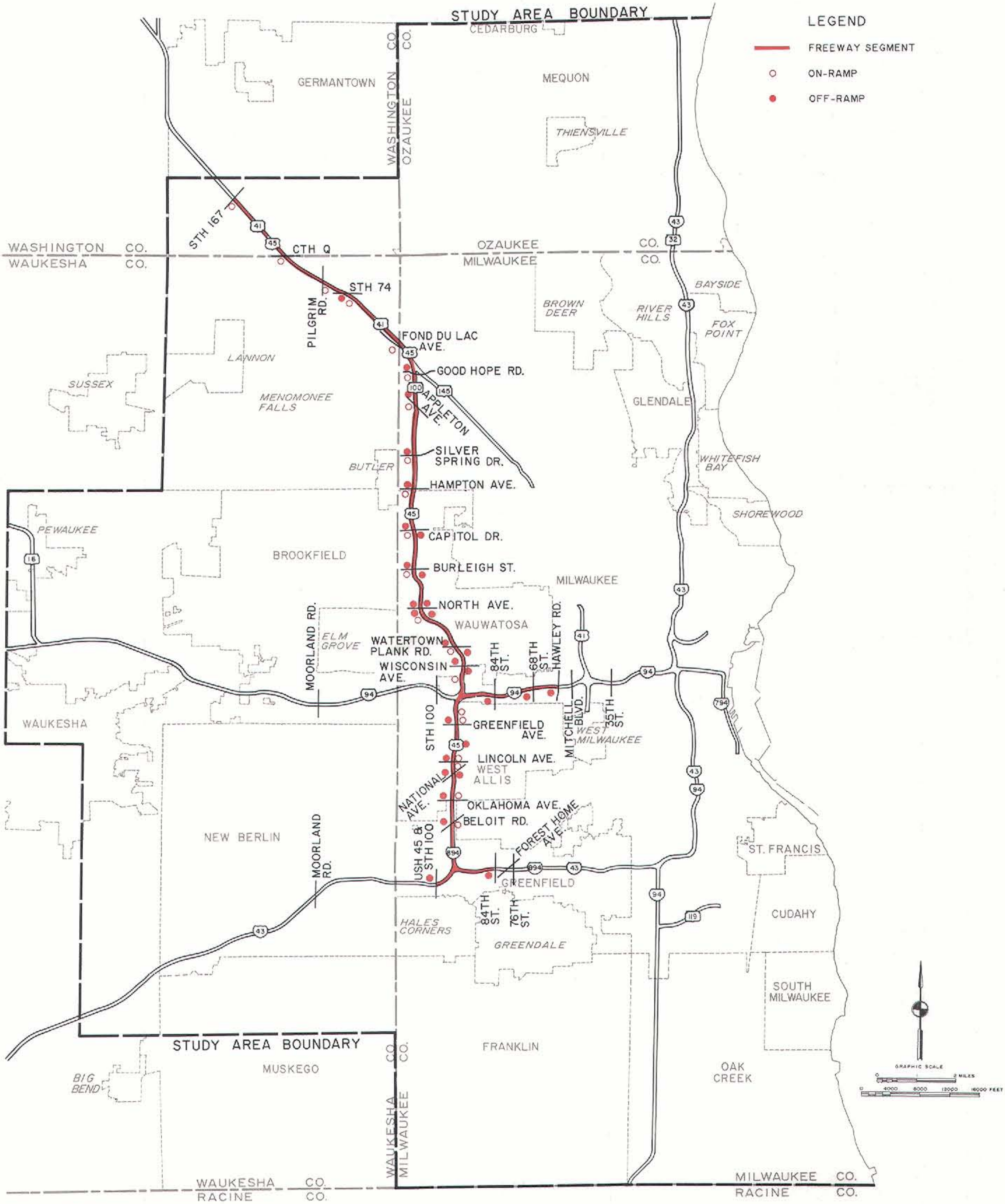
IH 94 (EAST-WEST)-MORNING



Source: SEWRPC.

Map A-7

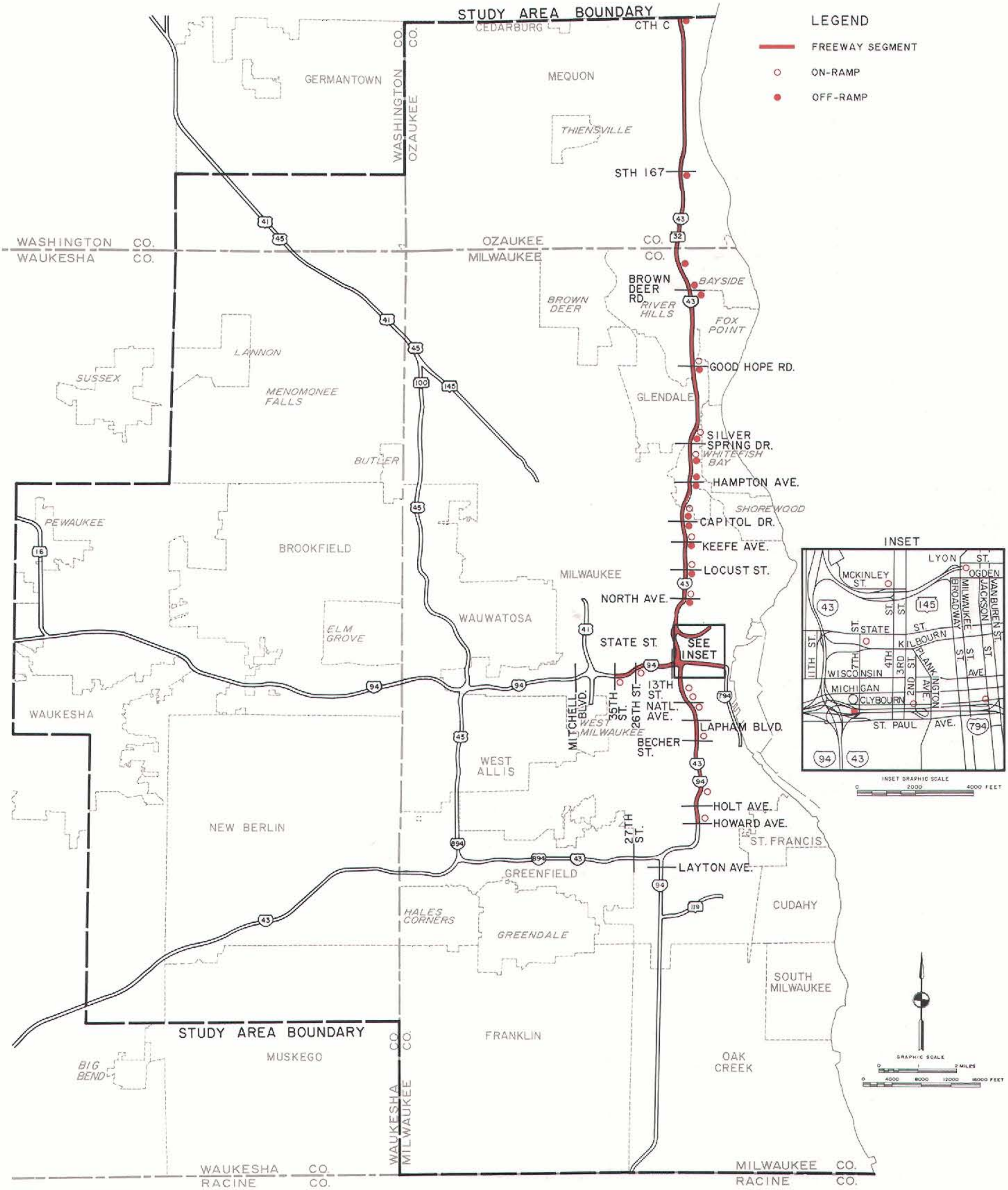
USH 41/45-MORNING



Source: SEWRPC.

Map A-8

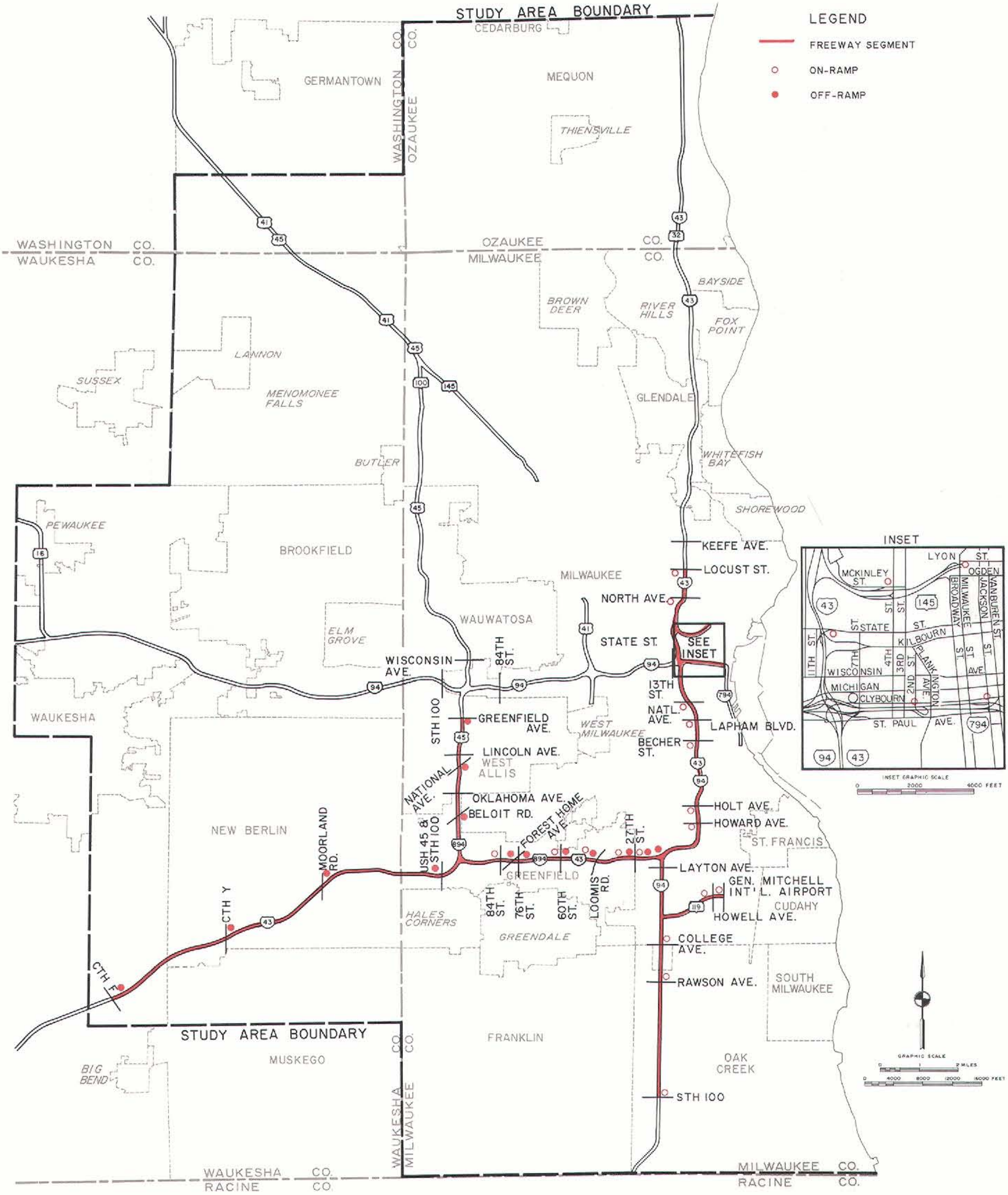
IH 43-EVENING



Source: SEWRPC.

Map A-9

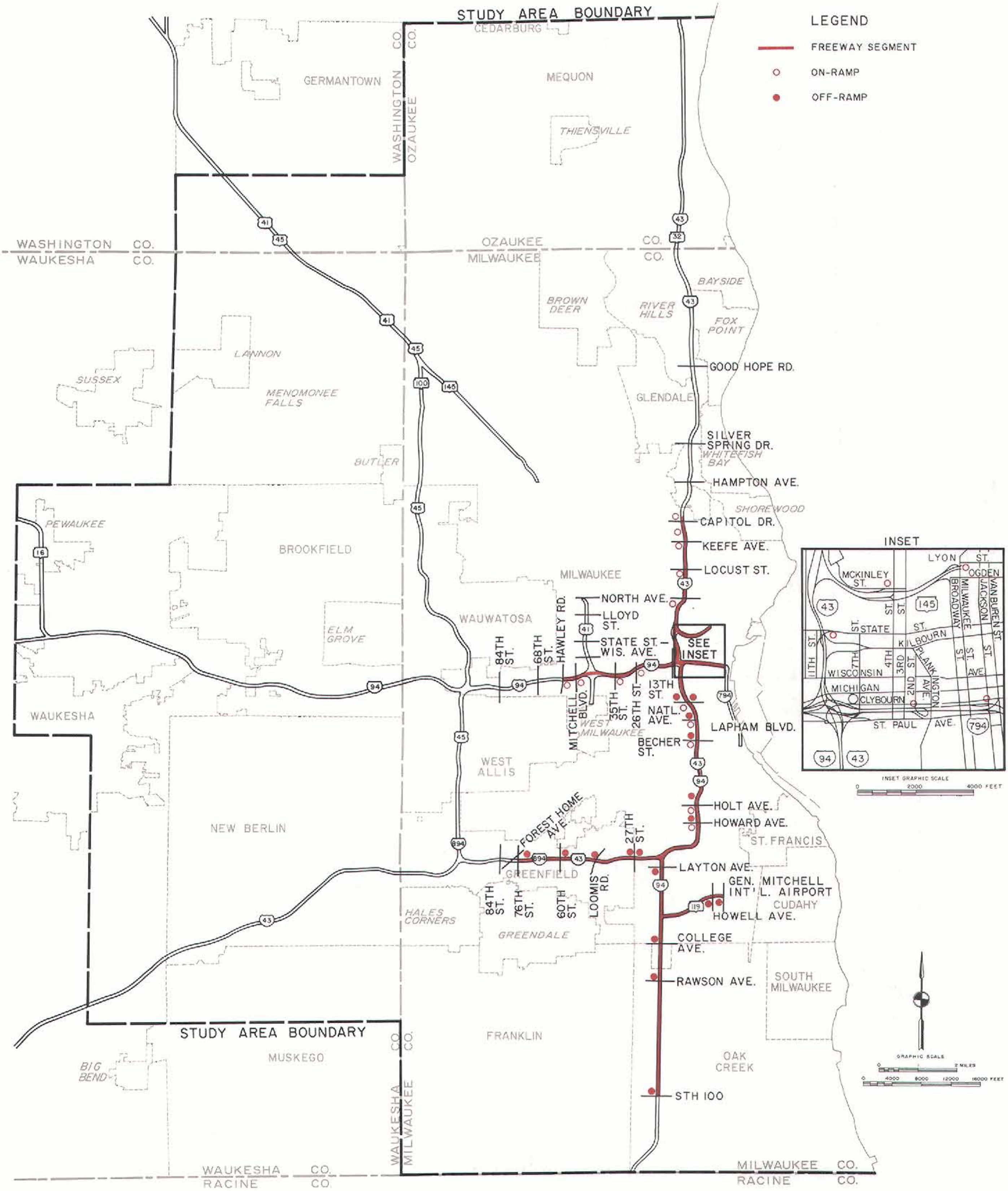
IH 894 AND IH 43-EVENING



Source: SEWRPC.

Map A-10

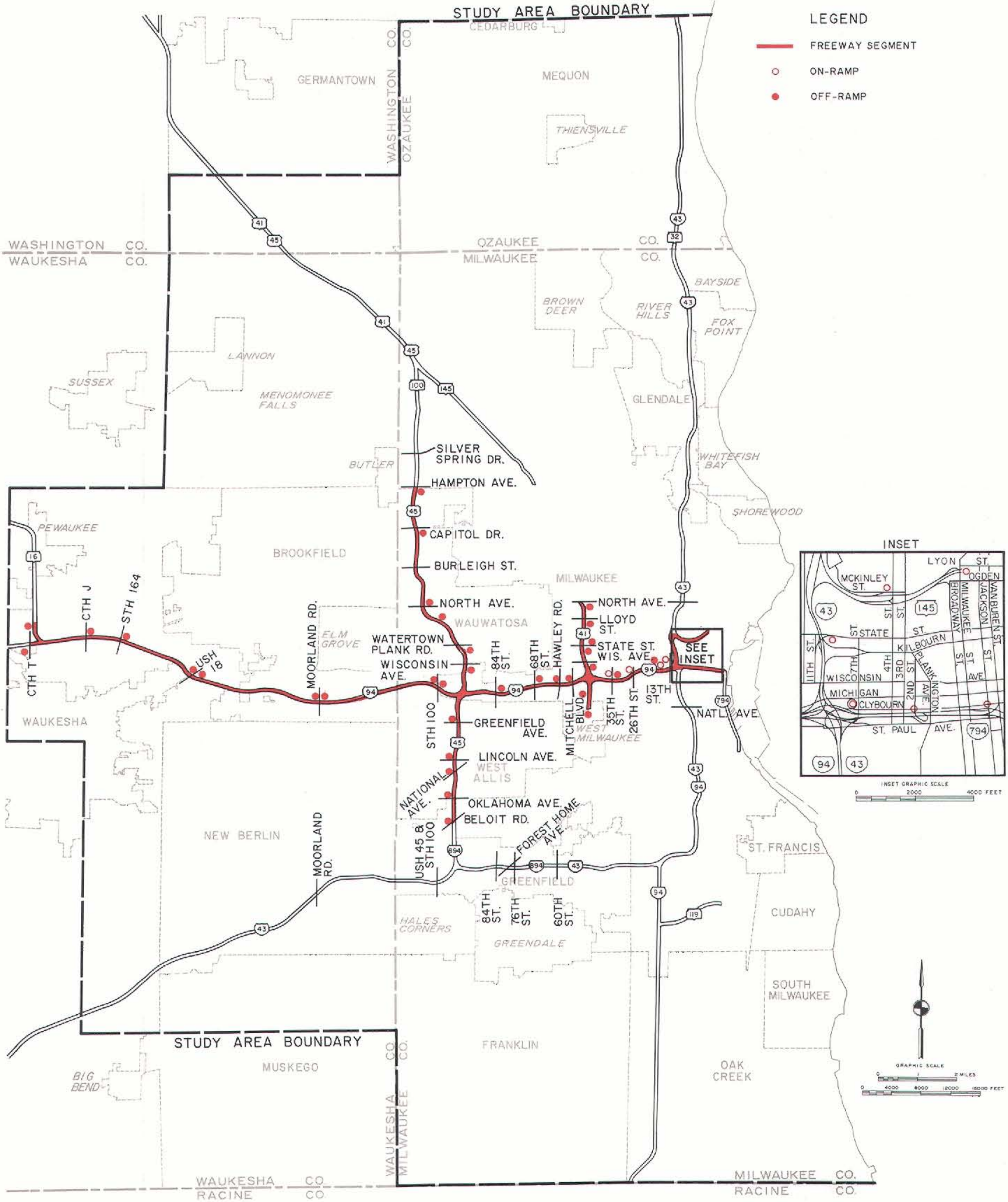
IH 94 (NORTH-SOUTH)-EVENING



Source: SEWRPC.

Map A-11

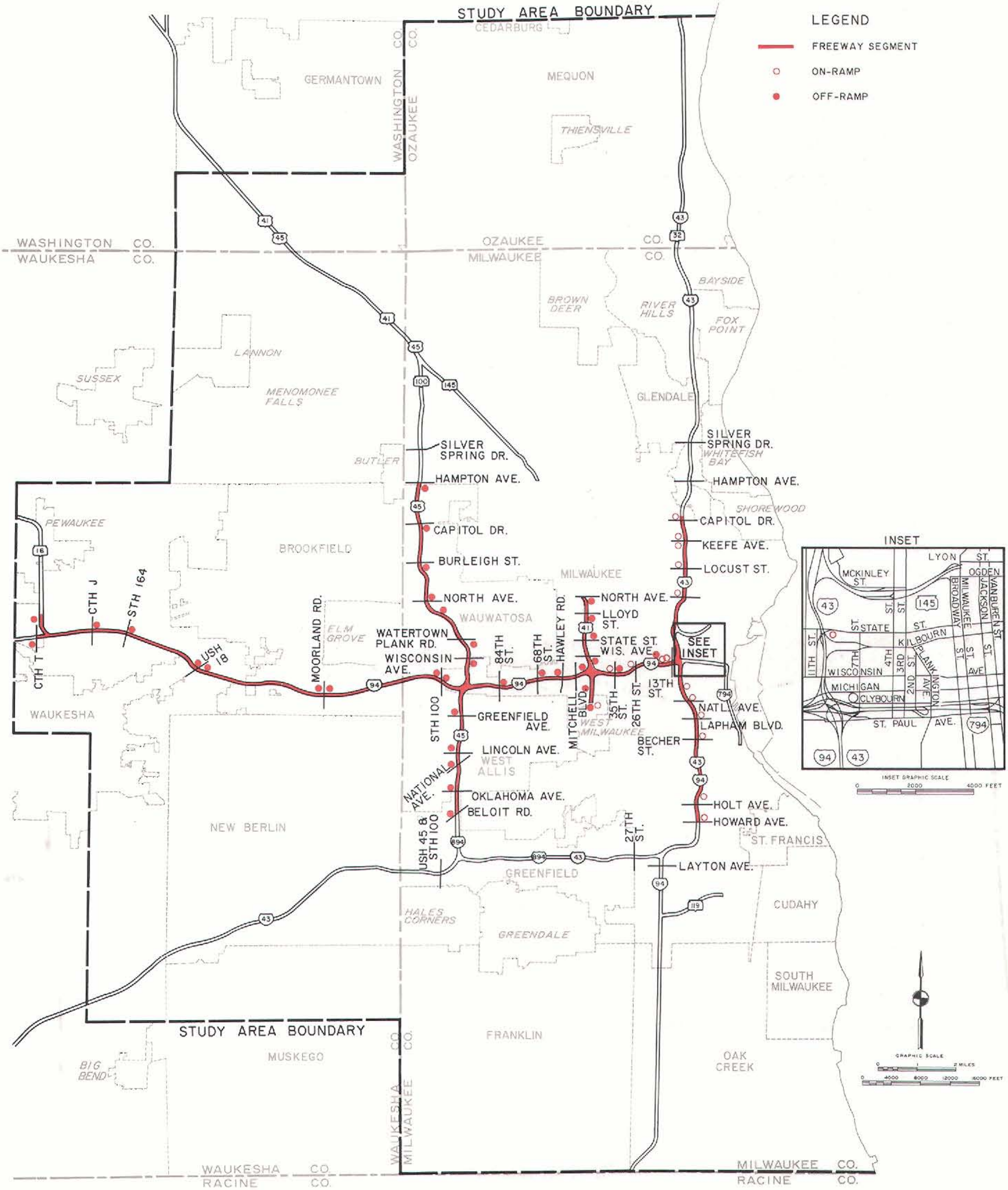
IH 94 (EAST-WEST)-EVENING



Source: SEWRPC.

Map A-12

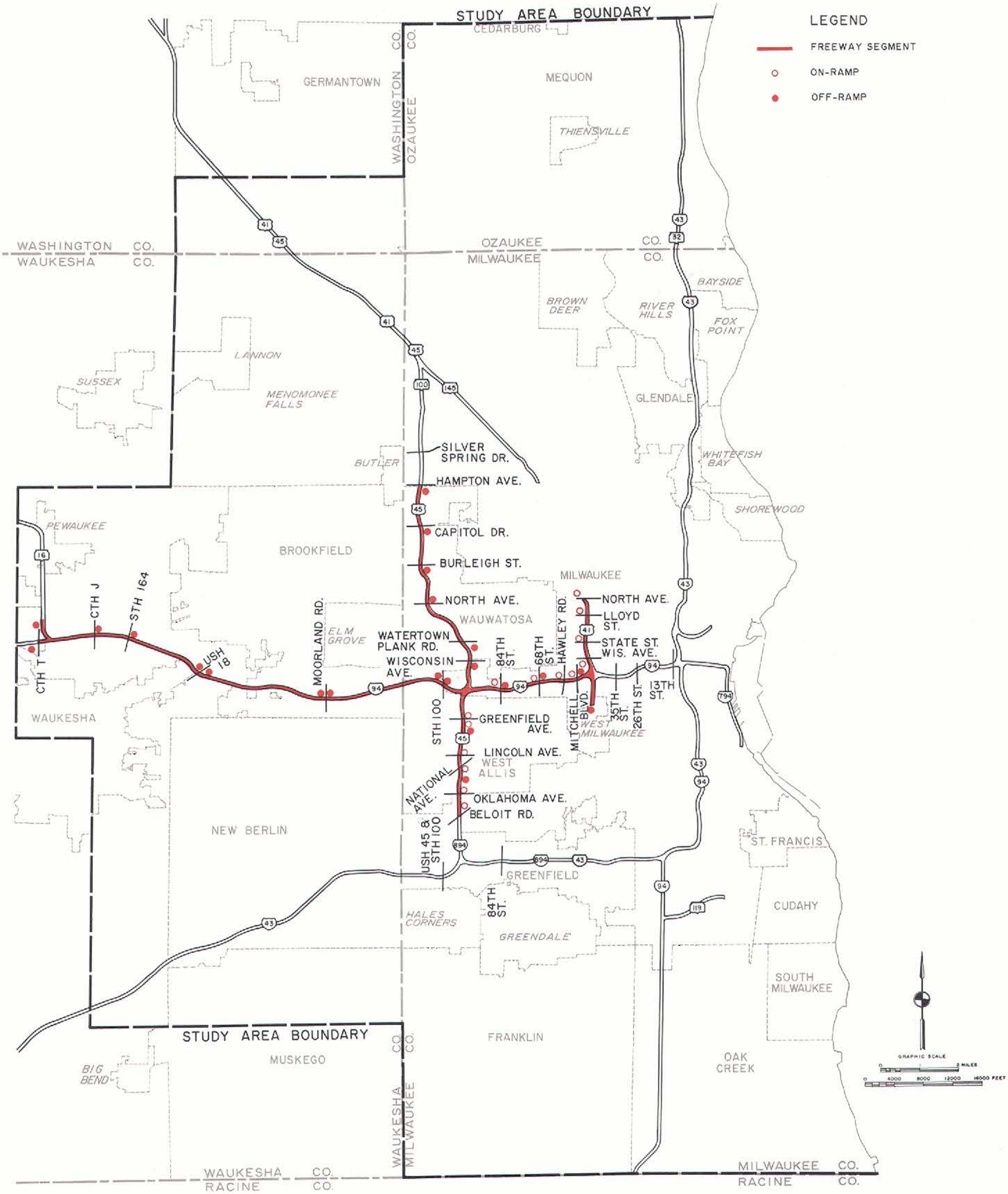
IH 94 (EAST-WEST)-EVENING



Source: SEWRPC.

Map A-13

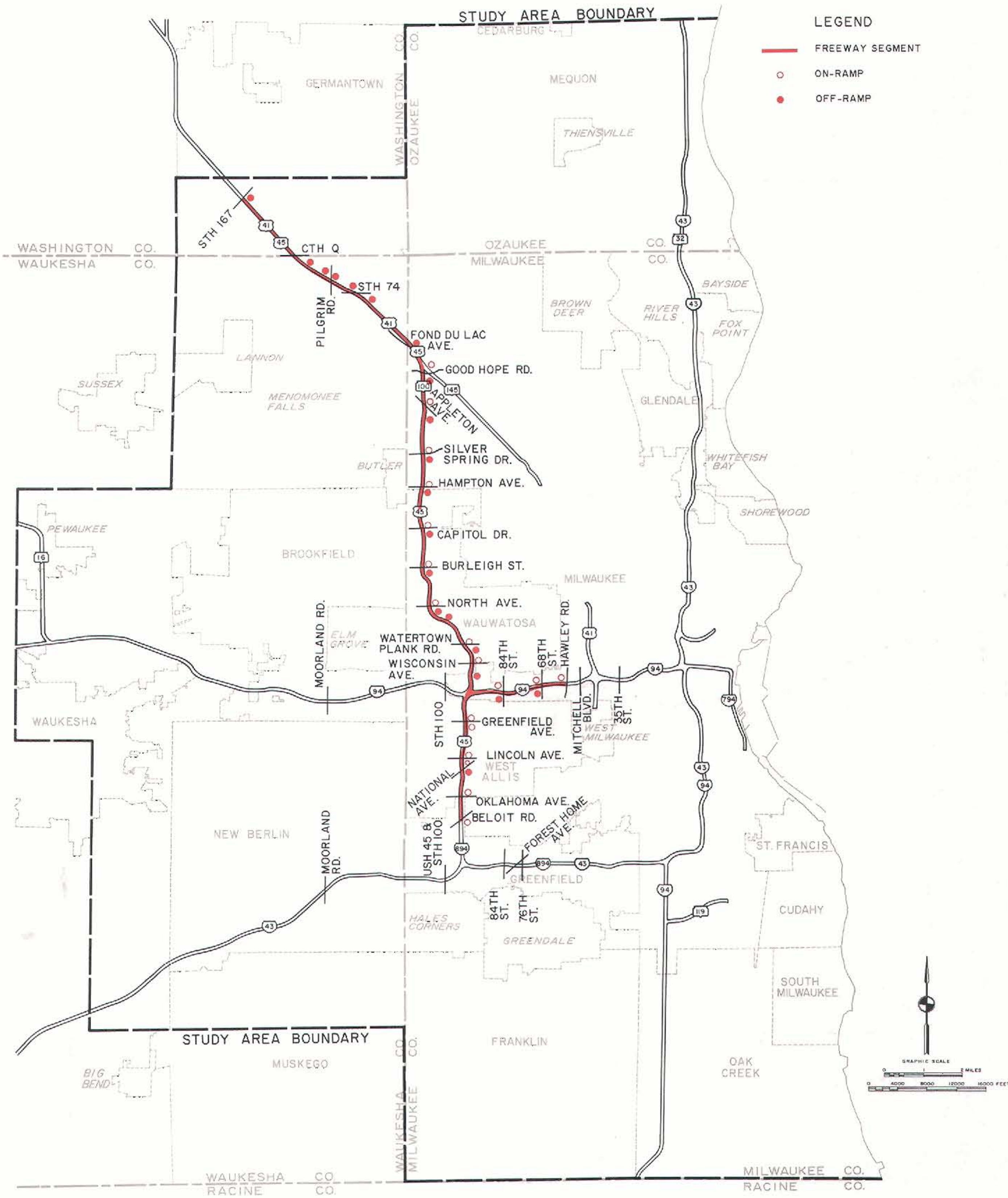
IH 94 (EAST-WEST)-EVENING



Source: SEWRPC.

Map A-14

USH 41/45-EVENING



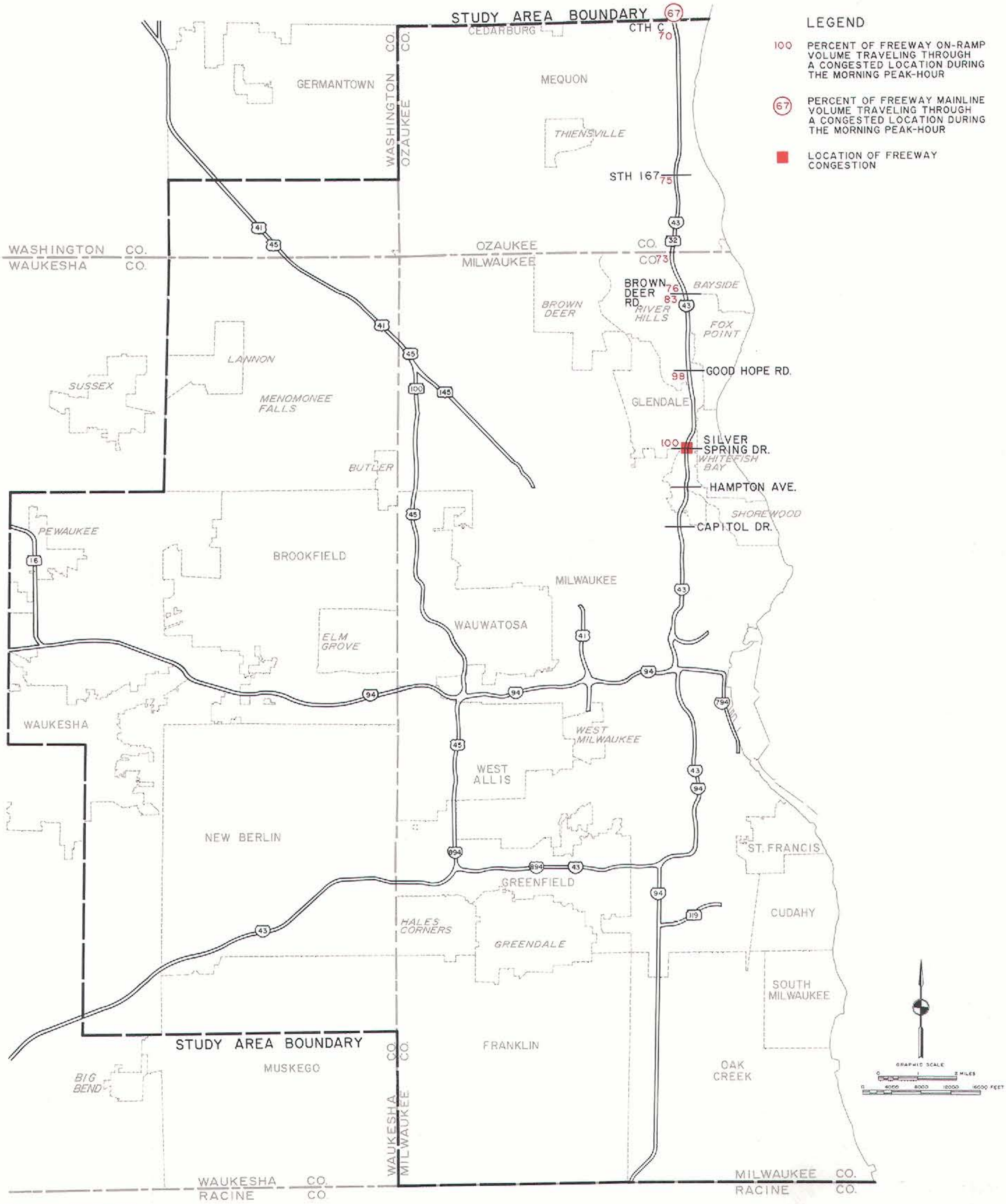
Source: SEWRPC.

Appendix B

MILWAUKEE AREA FREEWAY TRAVEL PATTERNS

Map B-1

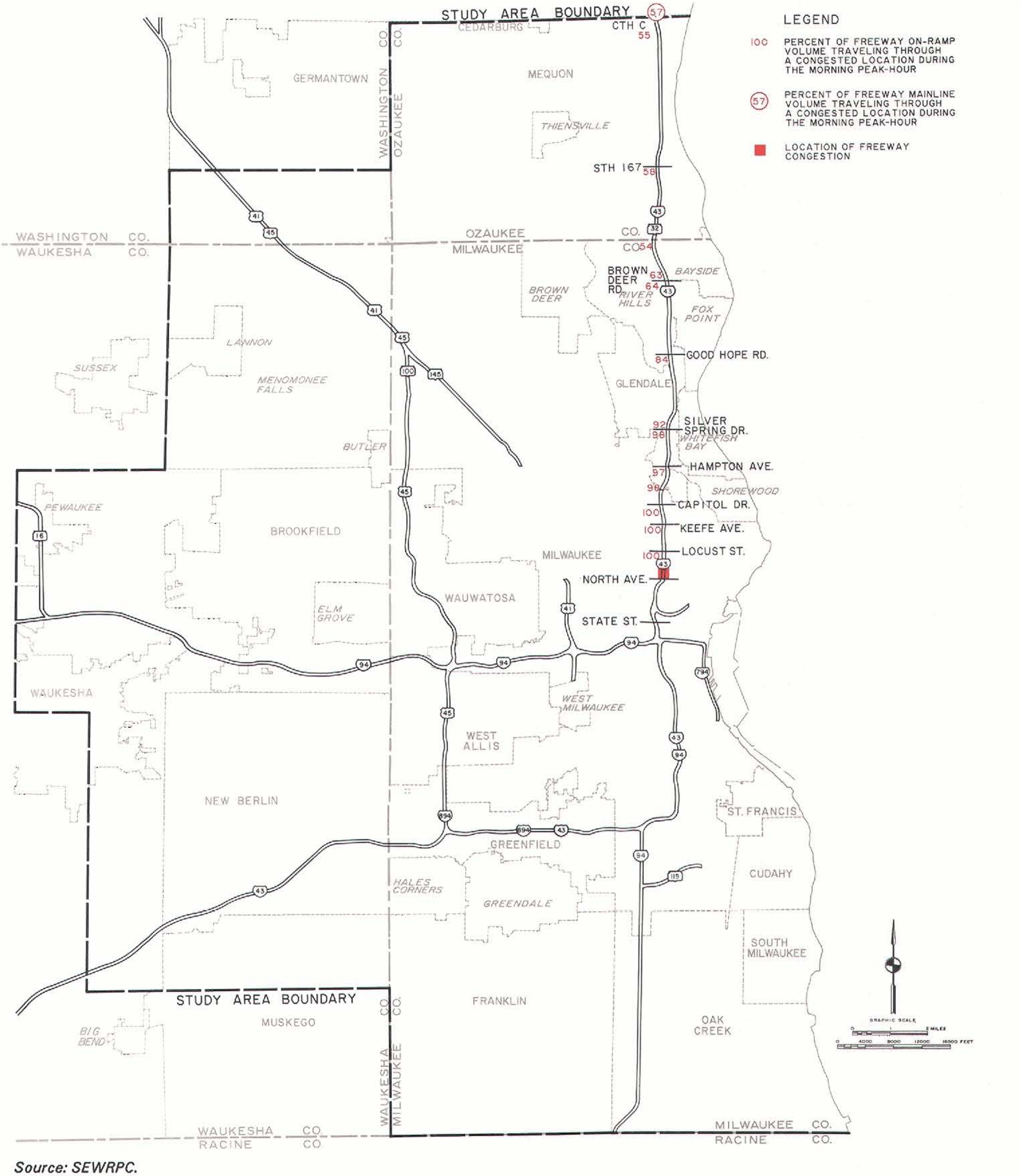
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING SOUTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. SILVER SPRING DRIVE: 1983



Source: SEWRPC.

Map B-2

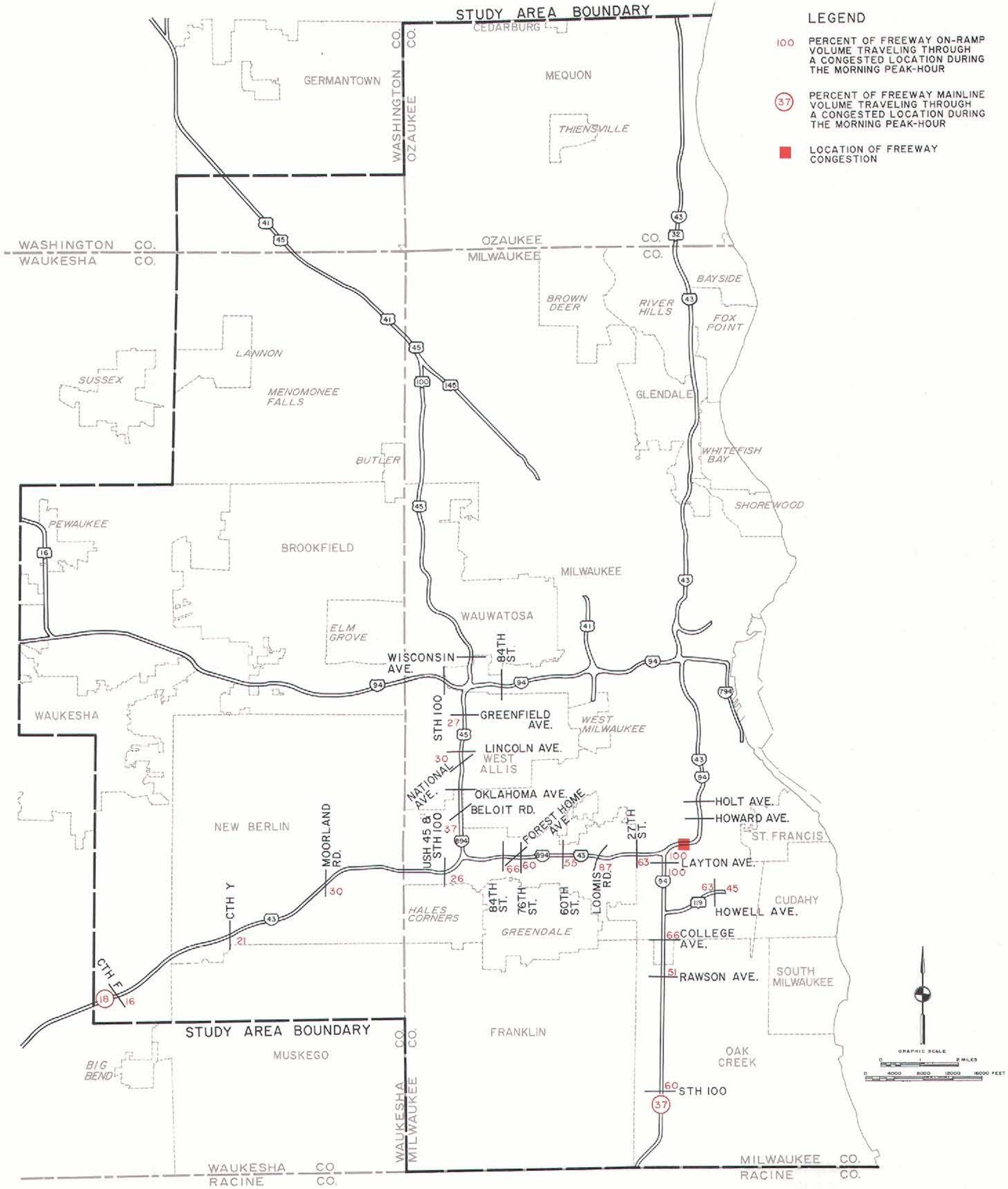
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING SOUTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. NORTH AVENUE: 1983



Source: SEWRPC.

Map B-3

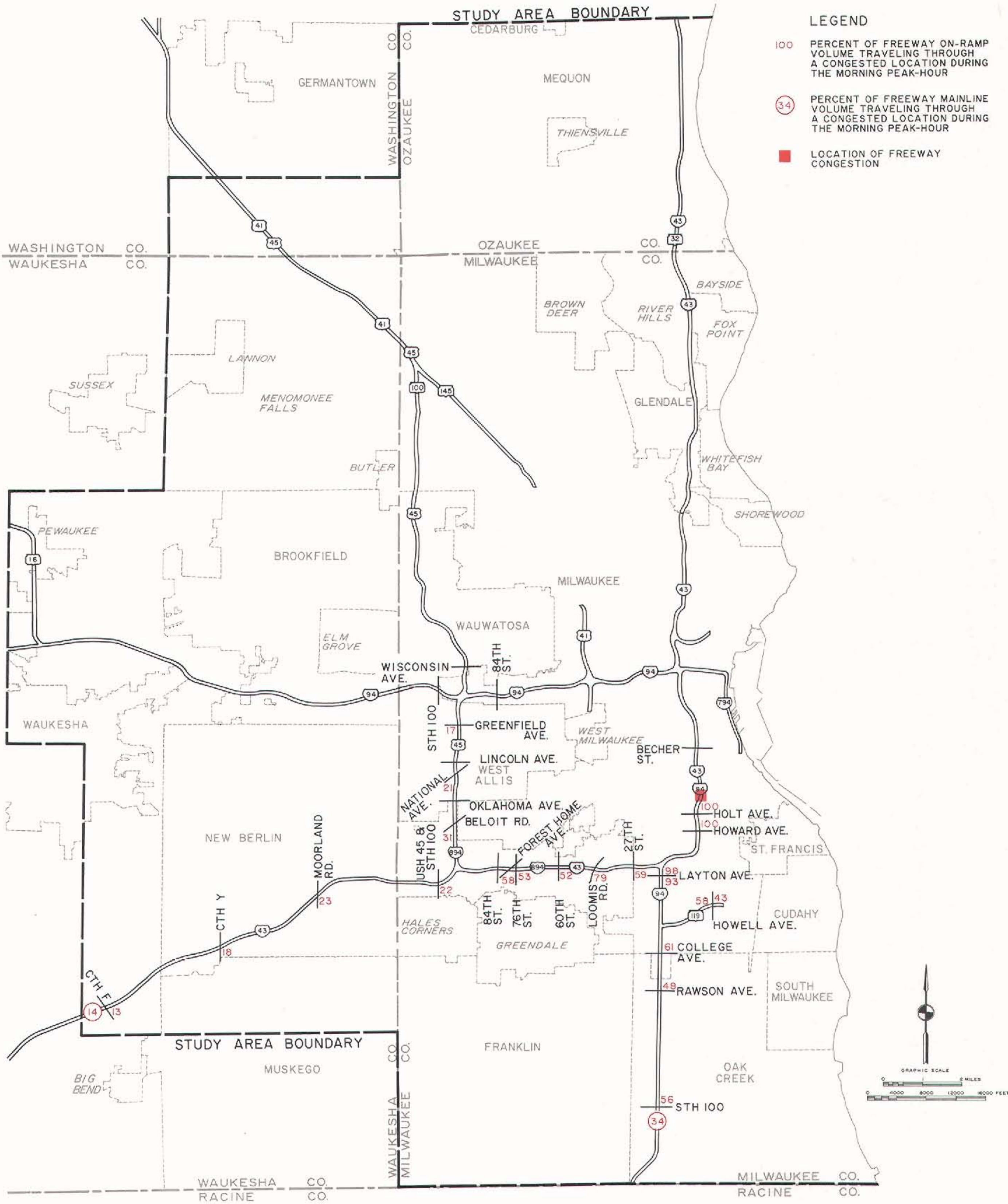
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING NORTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 13TH STREET: 1983



Source: SEWRPC.

Map B-4

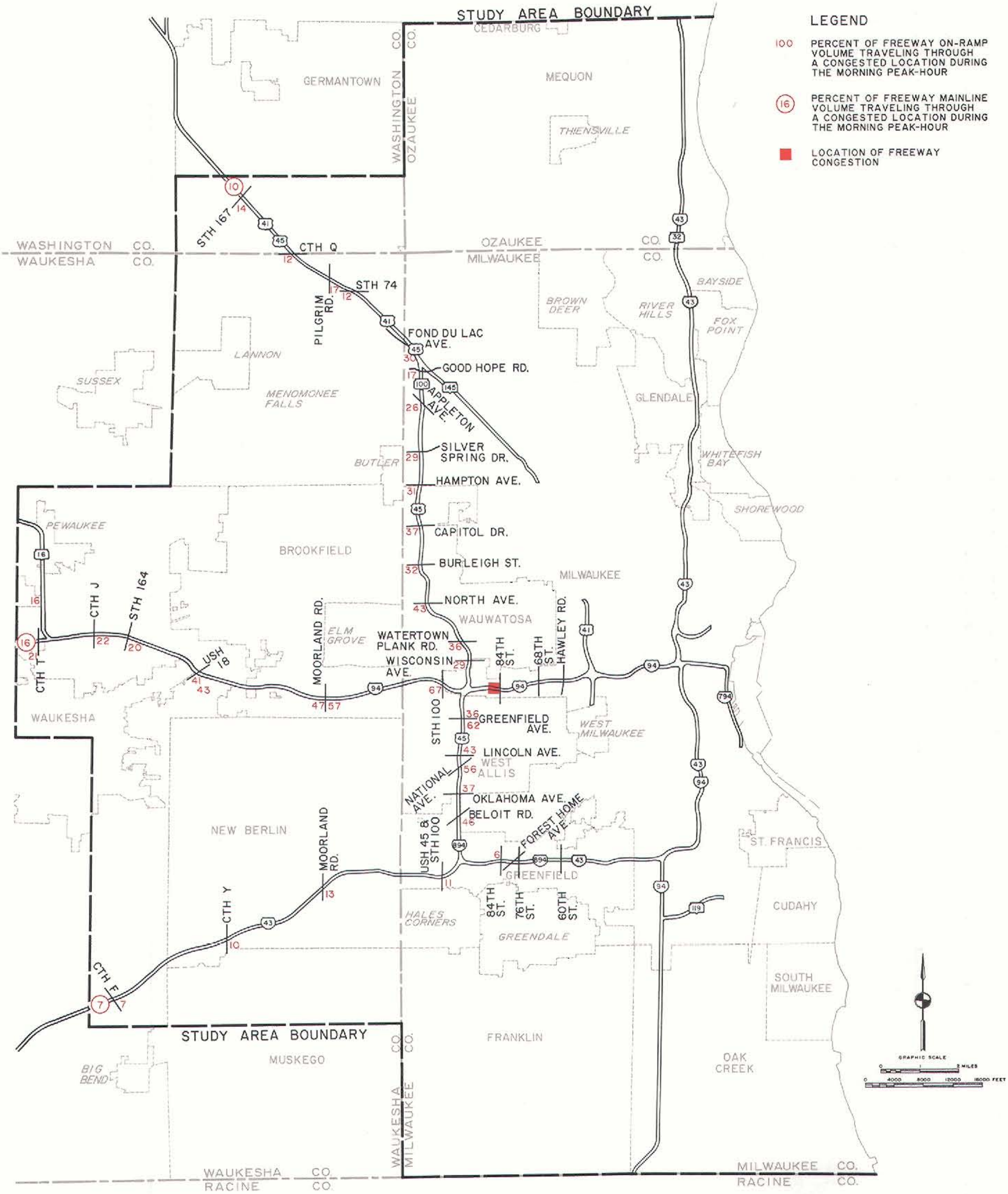
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING NORTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. OKLAHOMA AVENUE: 1983



Source: SEWRPC.

Map B-5

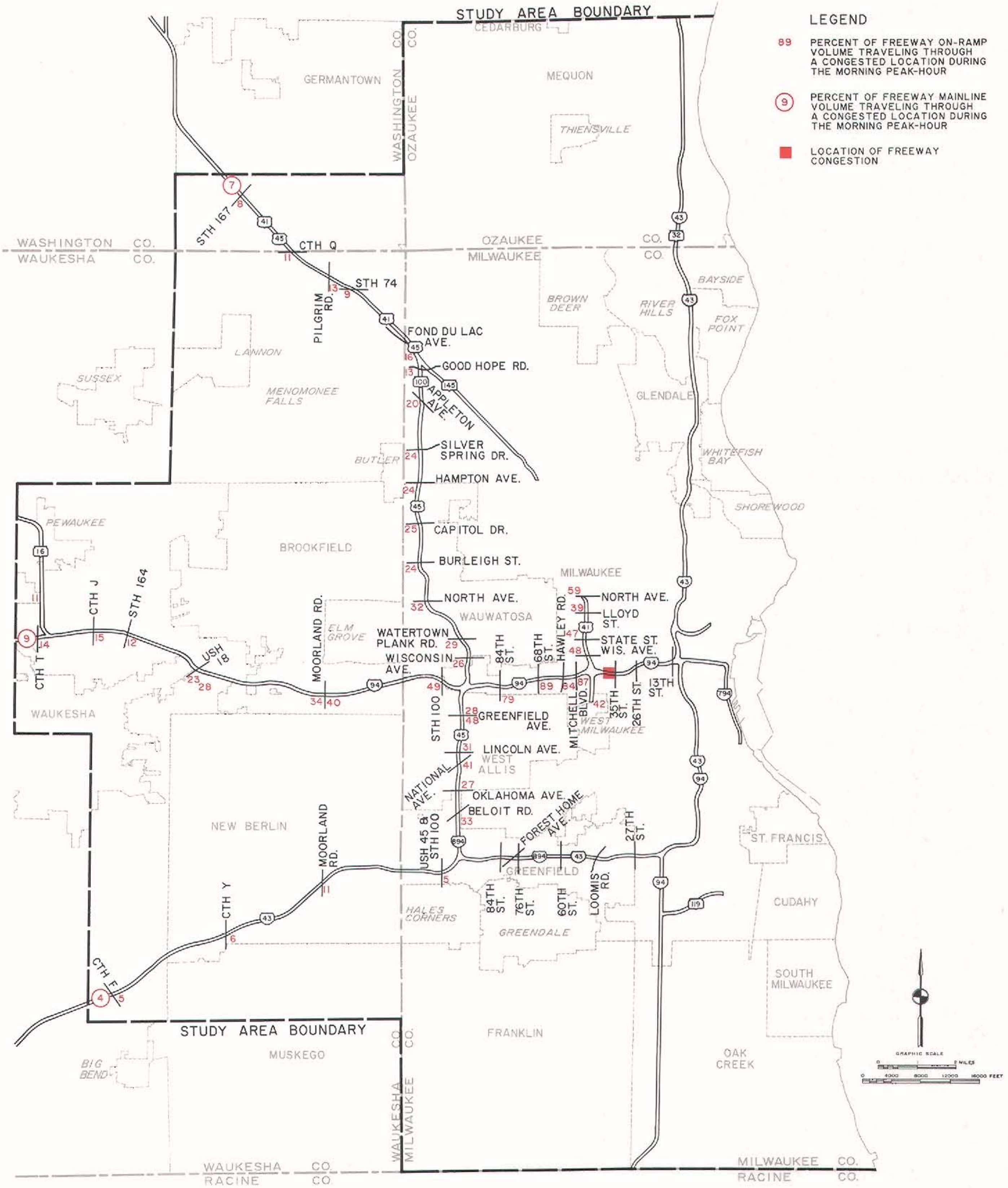
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING EASTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 92ND STREET: 1983



Source: SEWRPC.

Map B-6

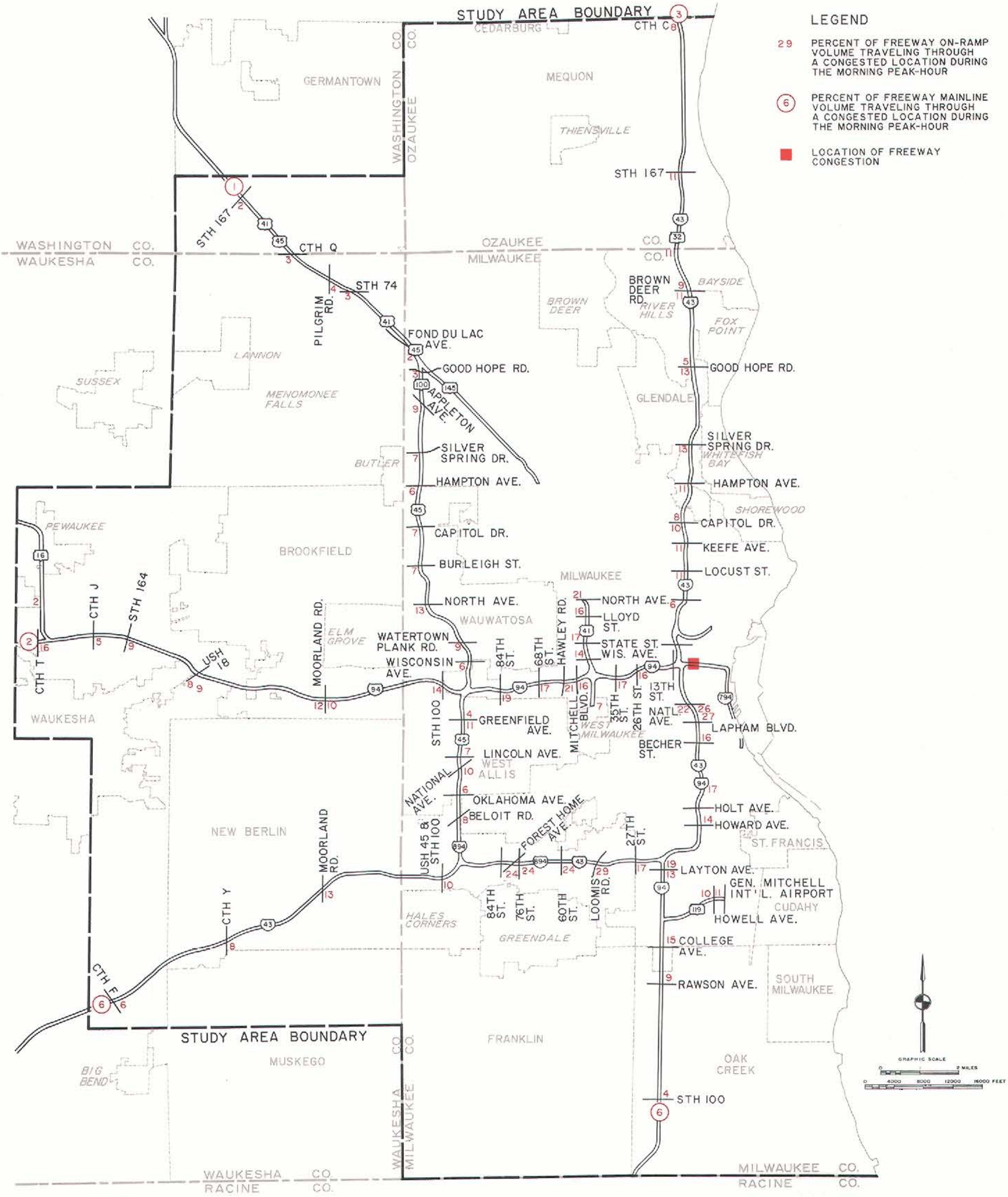
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING EASTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 35TH STREET: 1983



Source: SEWRPC.

Map B-7

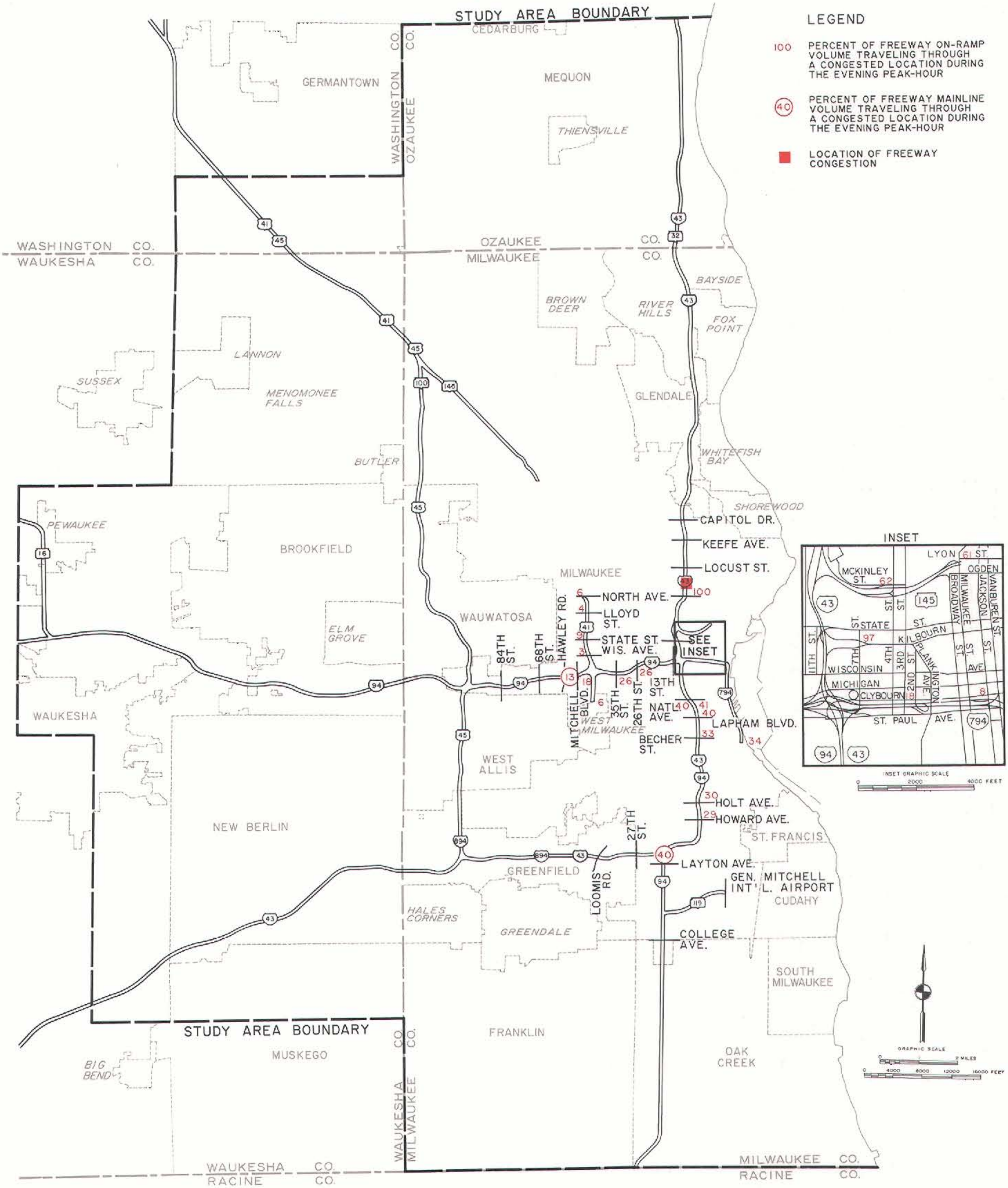
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING EASTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 6TH STREET: 1983



Source: SEWRPC.

Map B-8

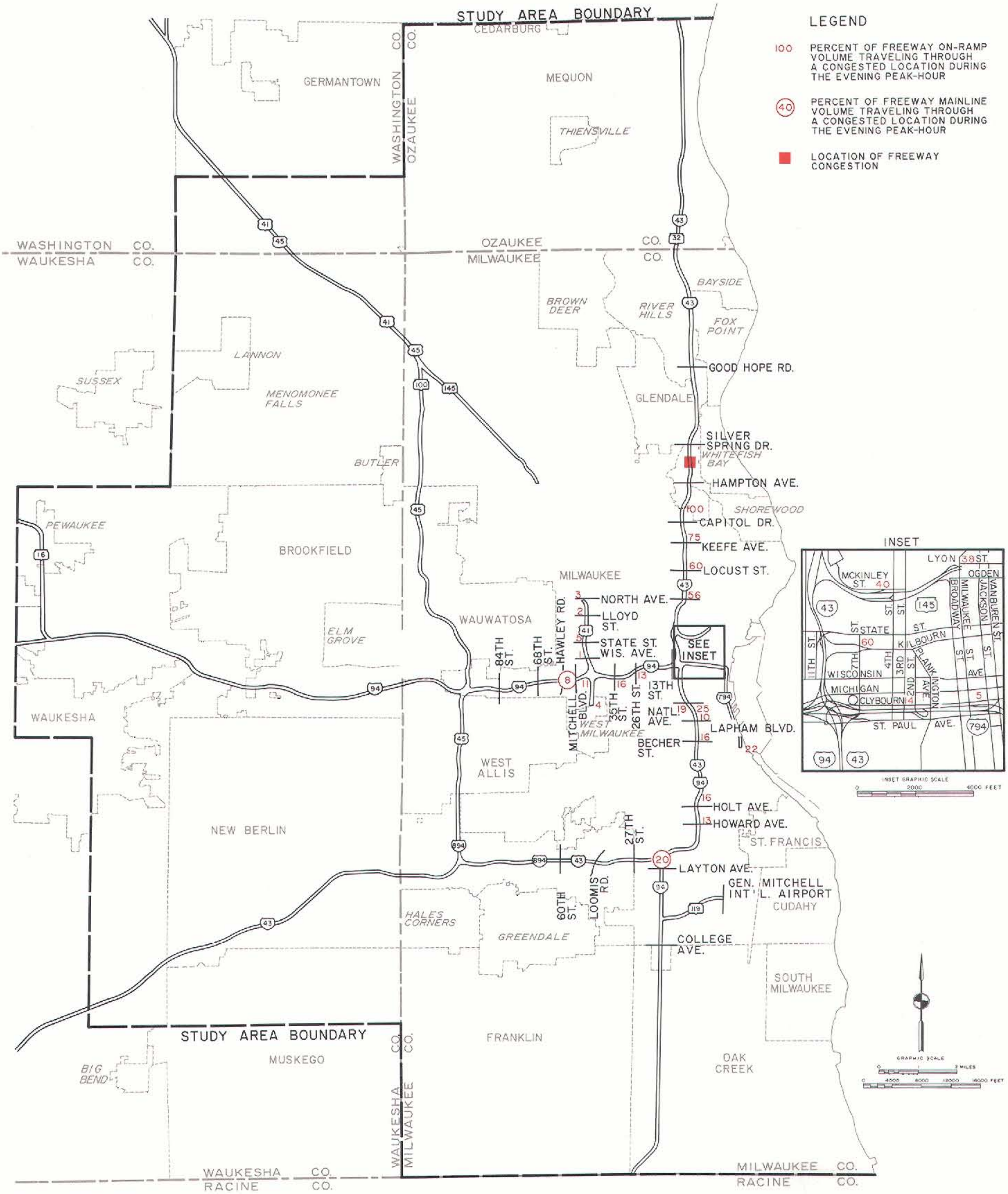
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING NORTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. NORTH AVENUE: 1983



Source: SEWRPC.

Map B-9

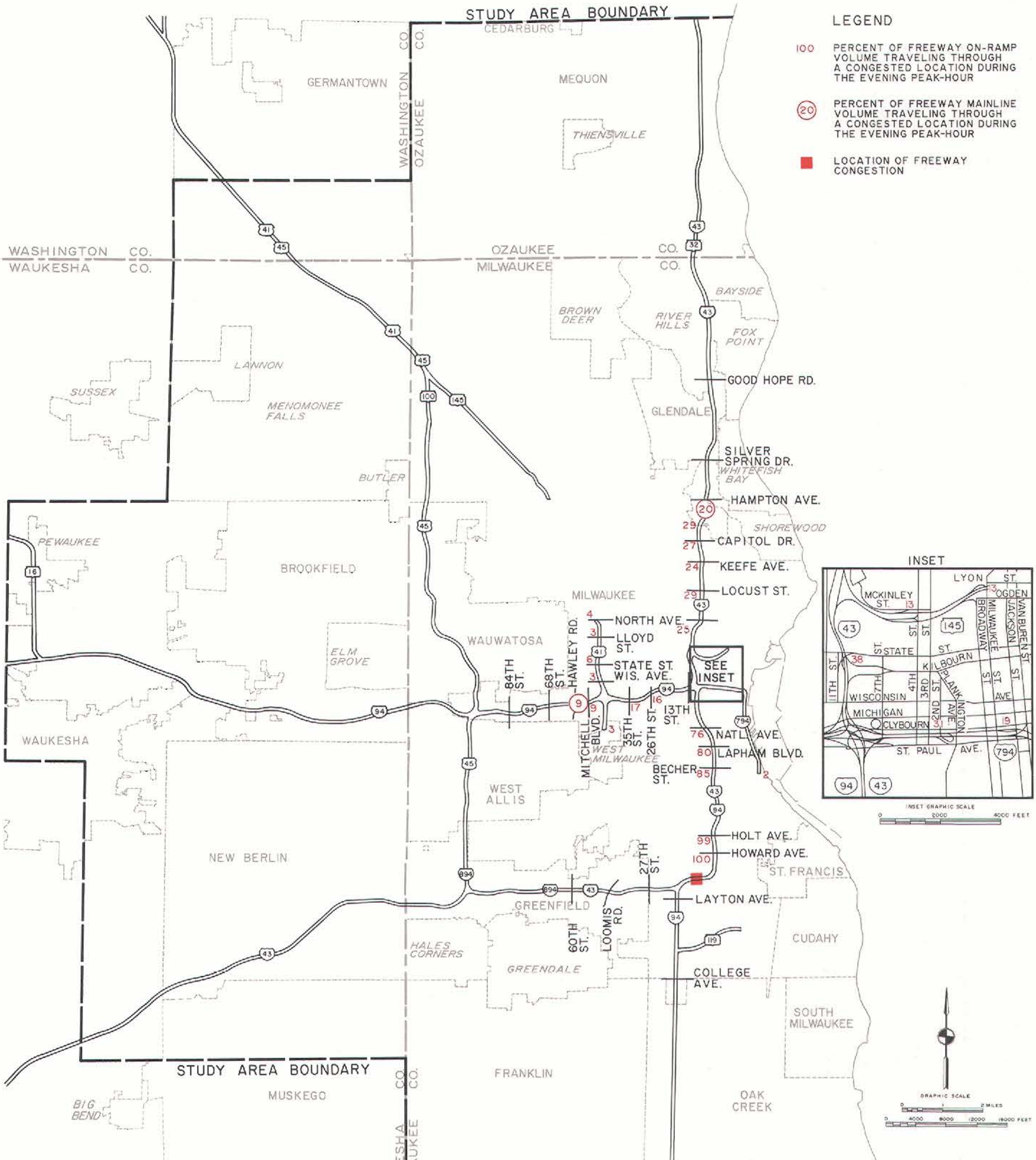
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING NORTHBOUND ON IH 43 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. SILVER SPRING DRIVE: 1983



Source: SEWRPC.

Map B-10

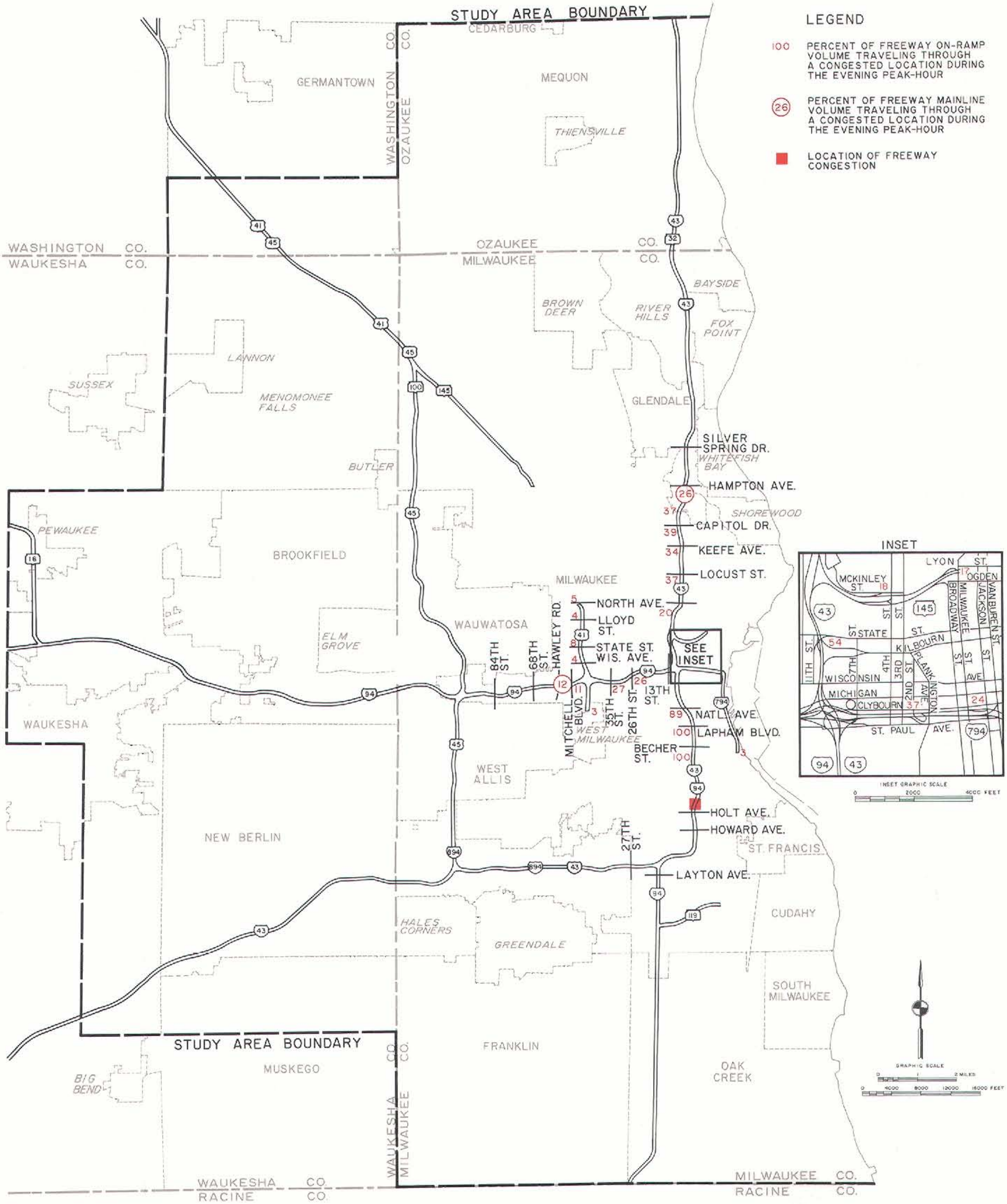
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING SOUTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 13TH STREET: 1983



Source: SEWRPC.

Map B-11

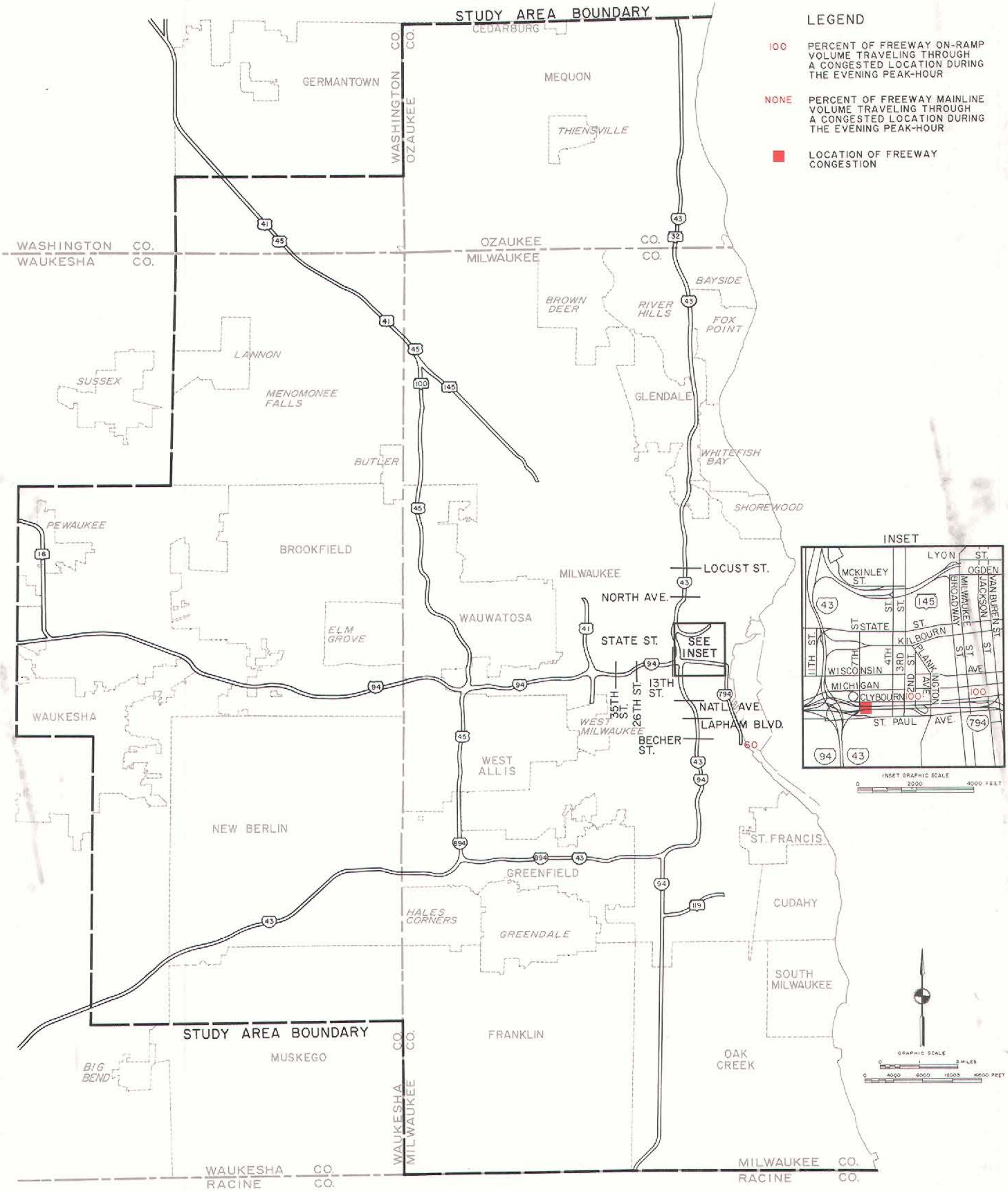
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING SOUTHBOUND ON IH 94 (NORTH-SOUTH FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT W. LINCOLN AVENUE: 1983



Source: SEWRPC.

Map B-12

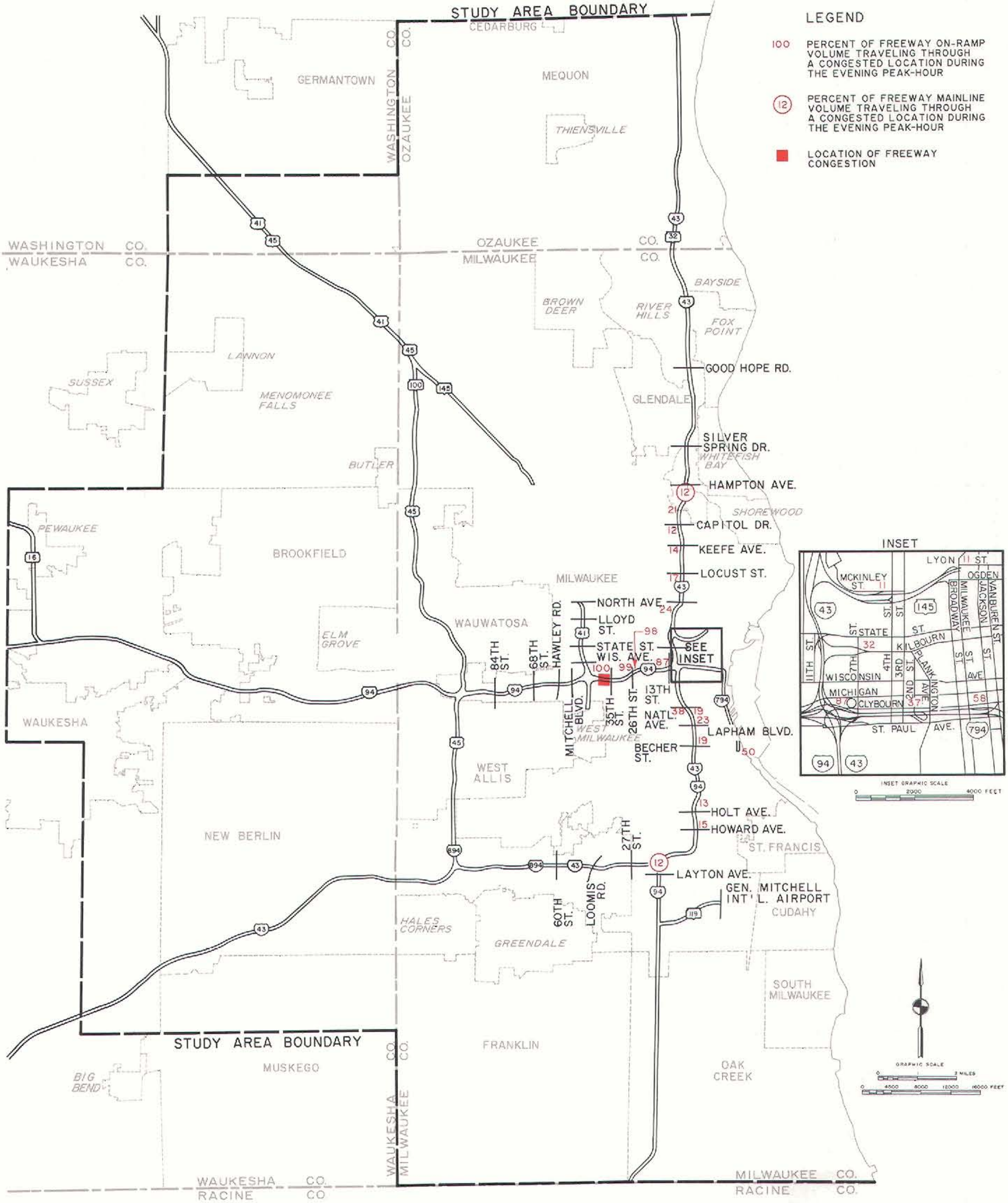
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING WESTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 6TH STREET: 1983



Source: SEWRPC.

Map B-13

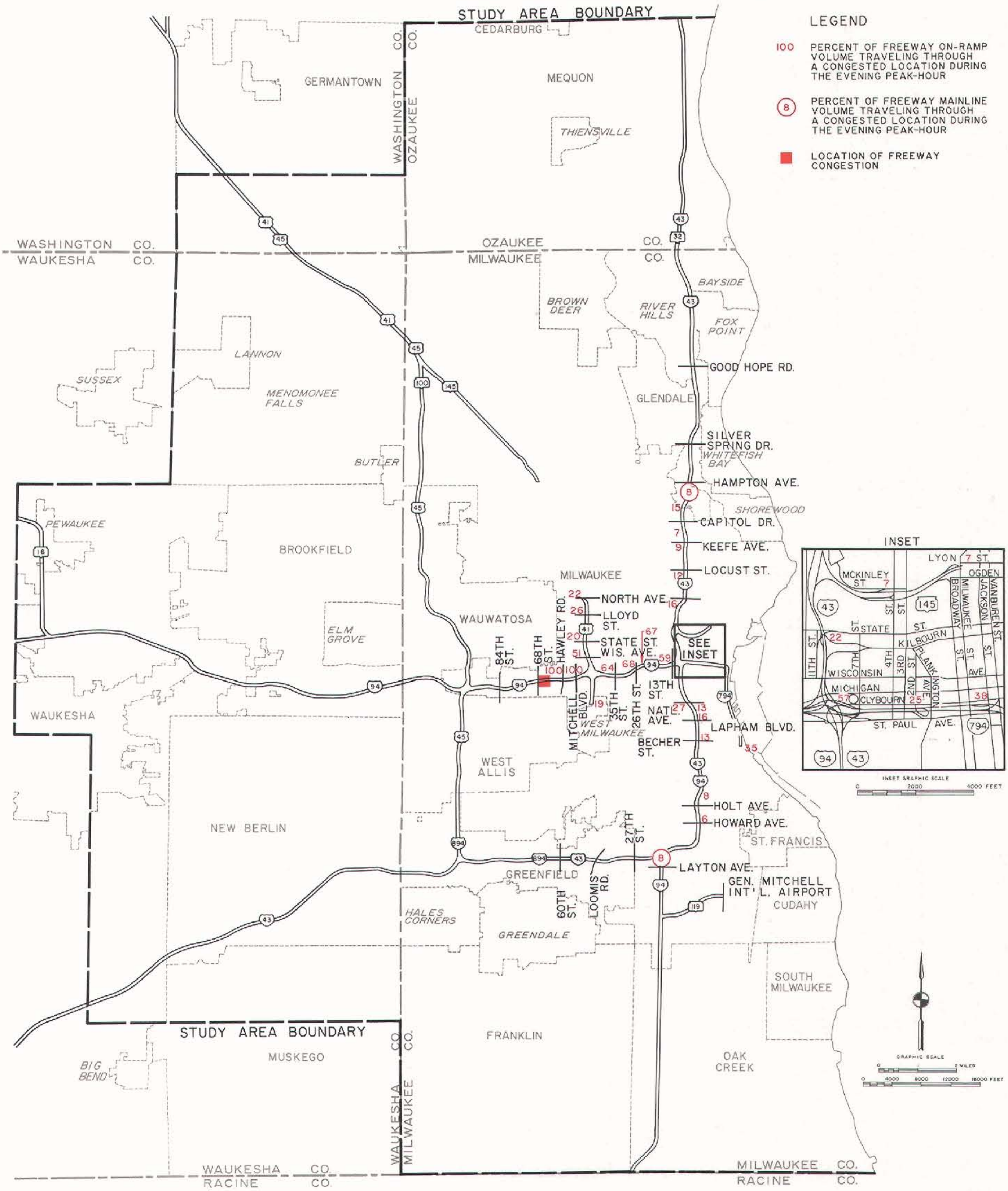
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING WESTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 35TH STREET: 1983



Source: SEWRPC.

Map B-14

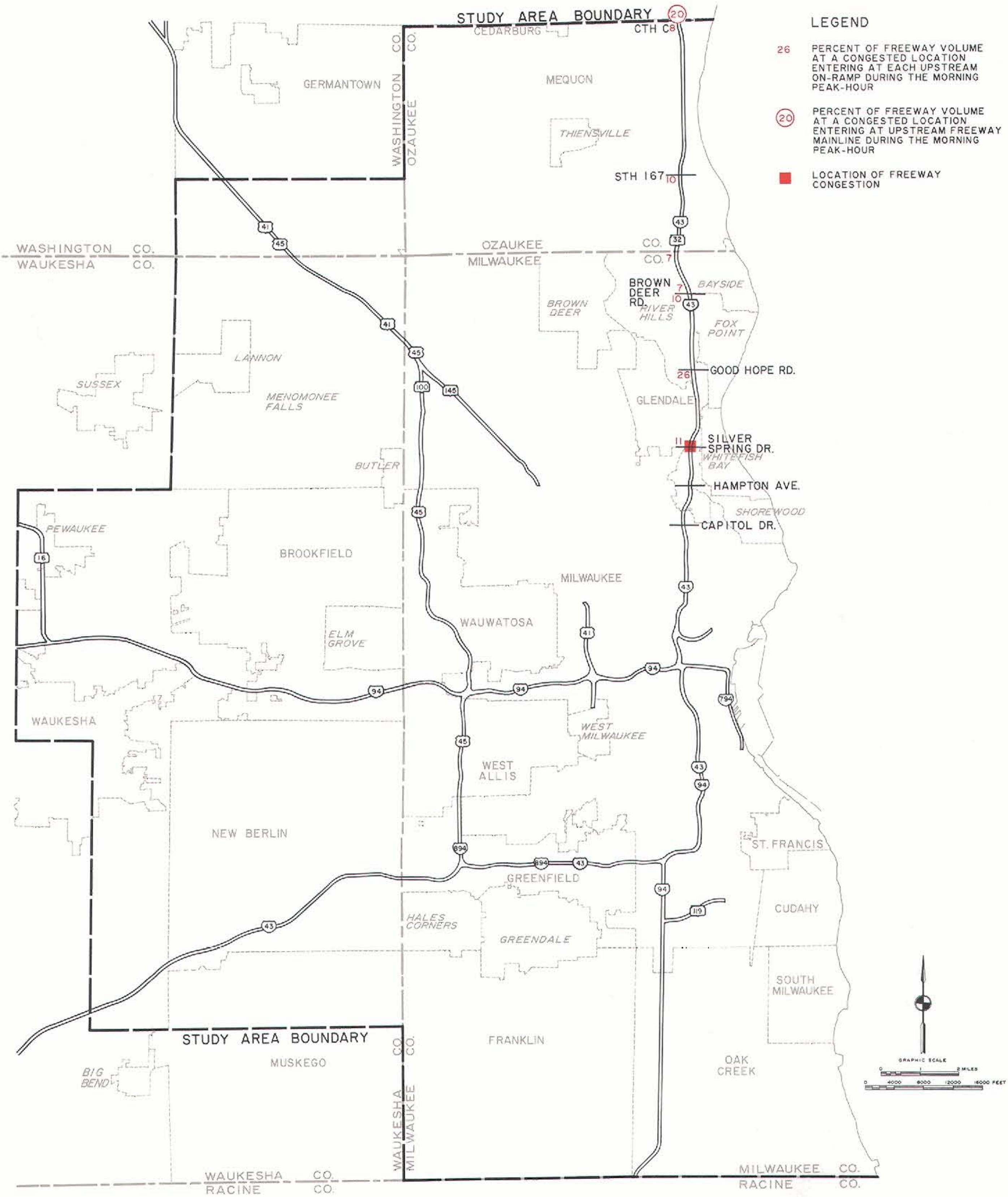
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME AT EACH FREEWAY ON-RAMP TRAVELING WESTBOUND ON IH 94 (EAST-WEST FREEWAY) THROUGH A CONGESTED FREEWAY SEGMENT AT N. 64TH STREET: 1983



Source: SEWRPC.

Map B-15

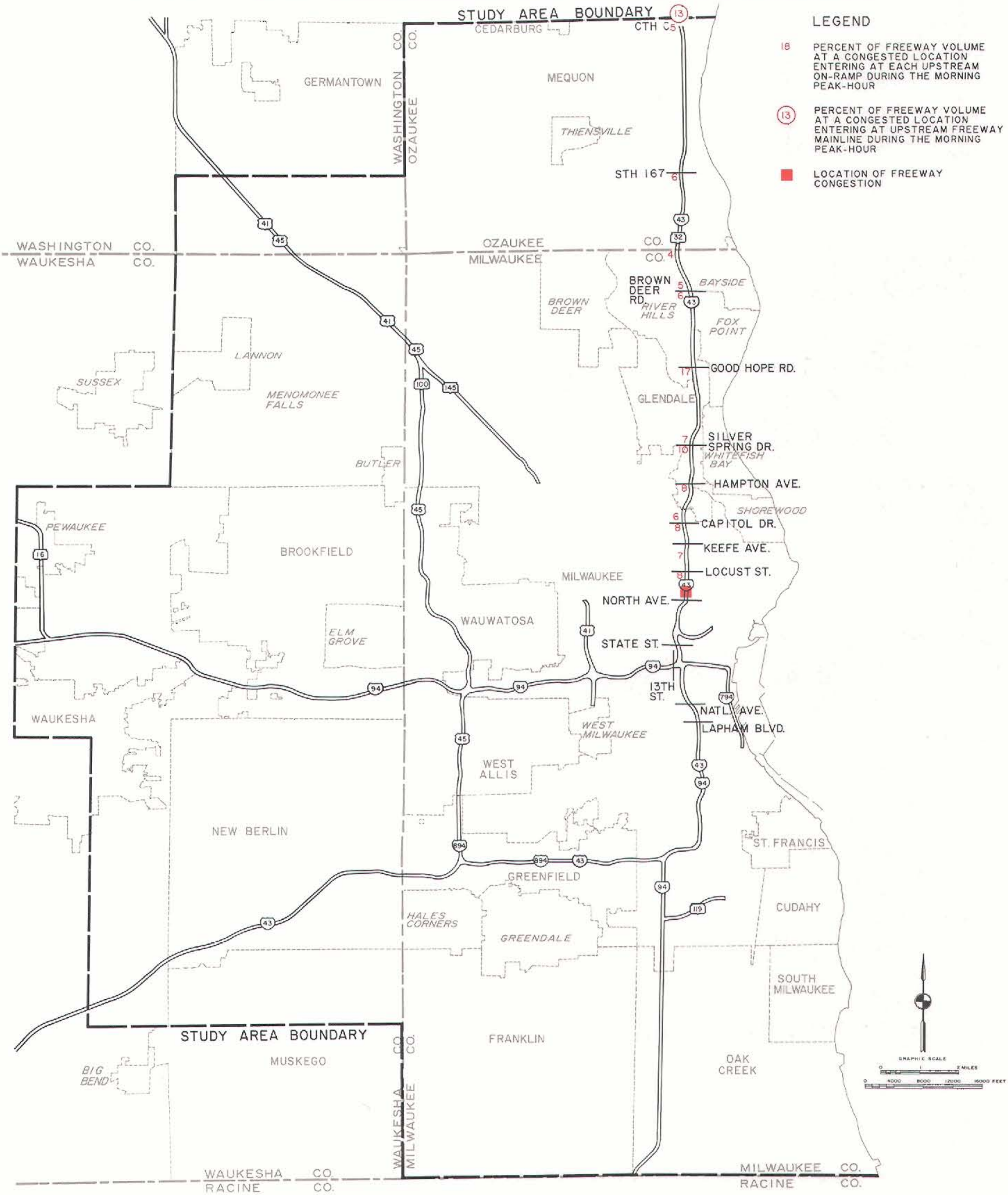
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON SOUTHBOUND IH 43 AT W. SILVER SPRING DRIVE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-16

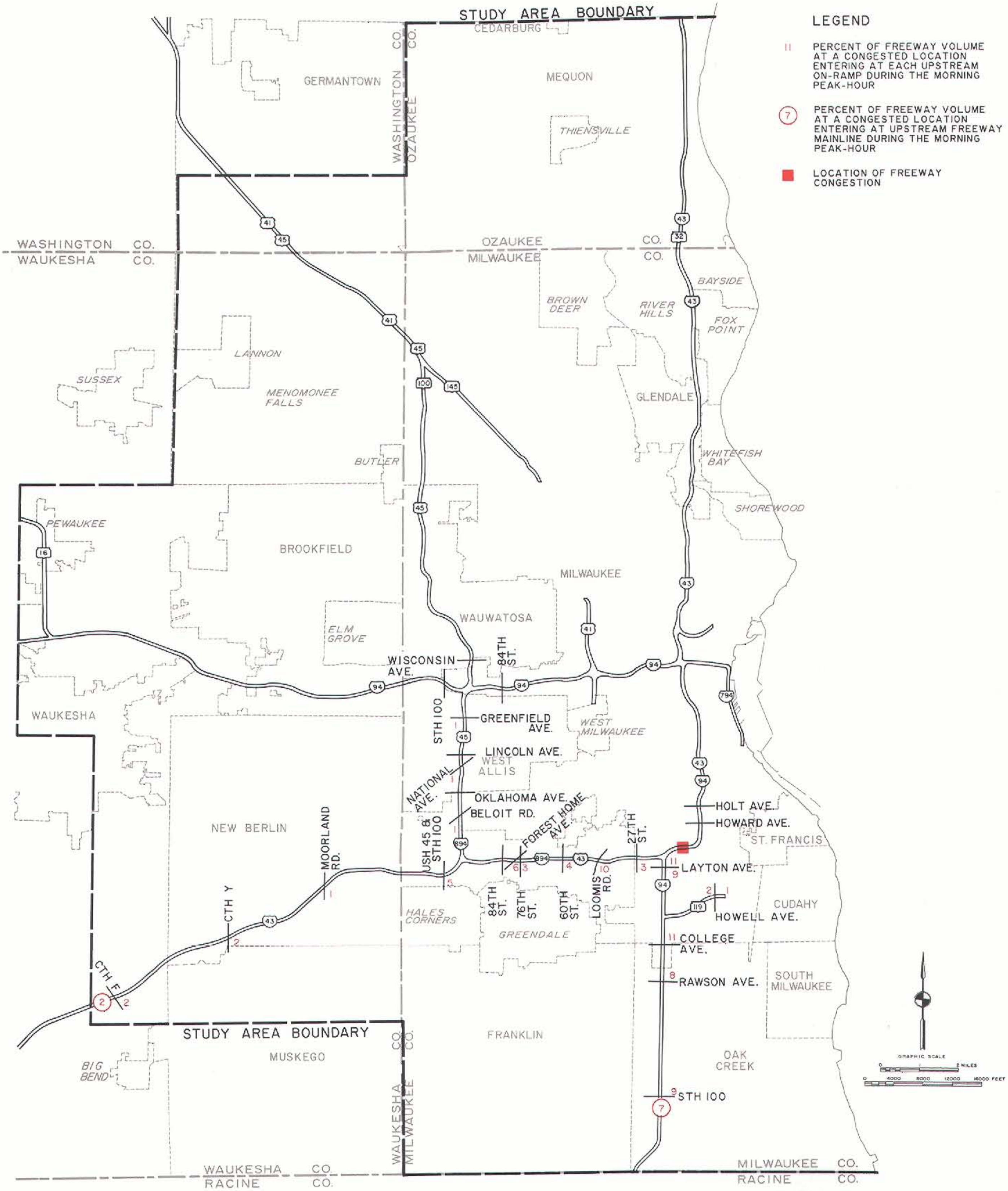
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON SOUTHBOUND IH 43 AT W. NORTH AVENUE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-17

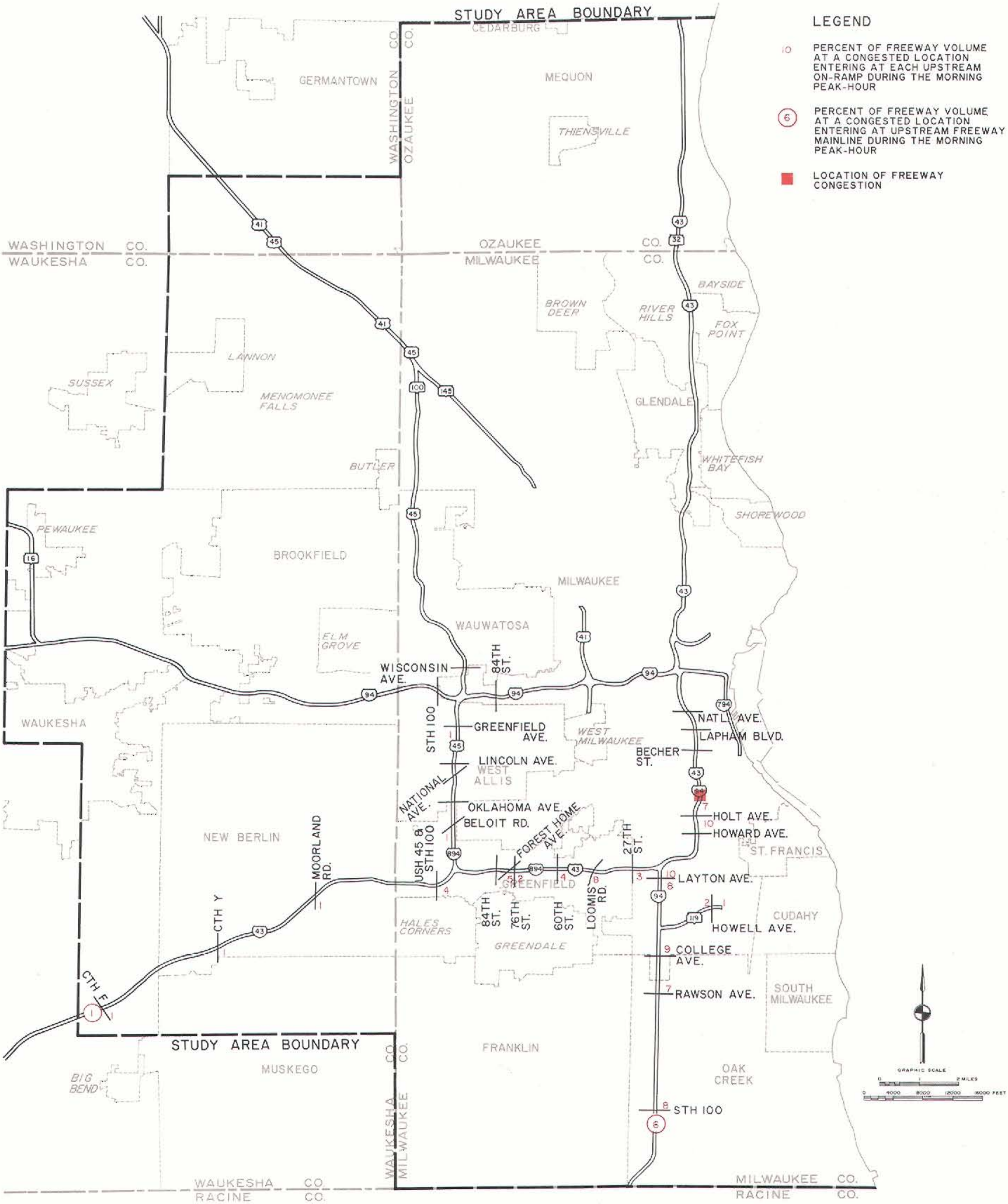
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON NORTHBOUND IH 94 AT N. 13TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-18

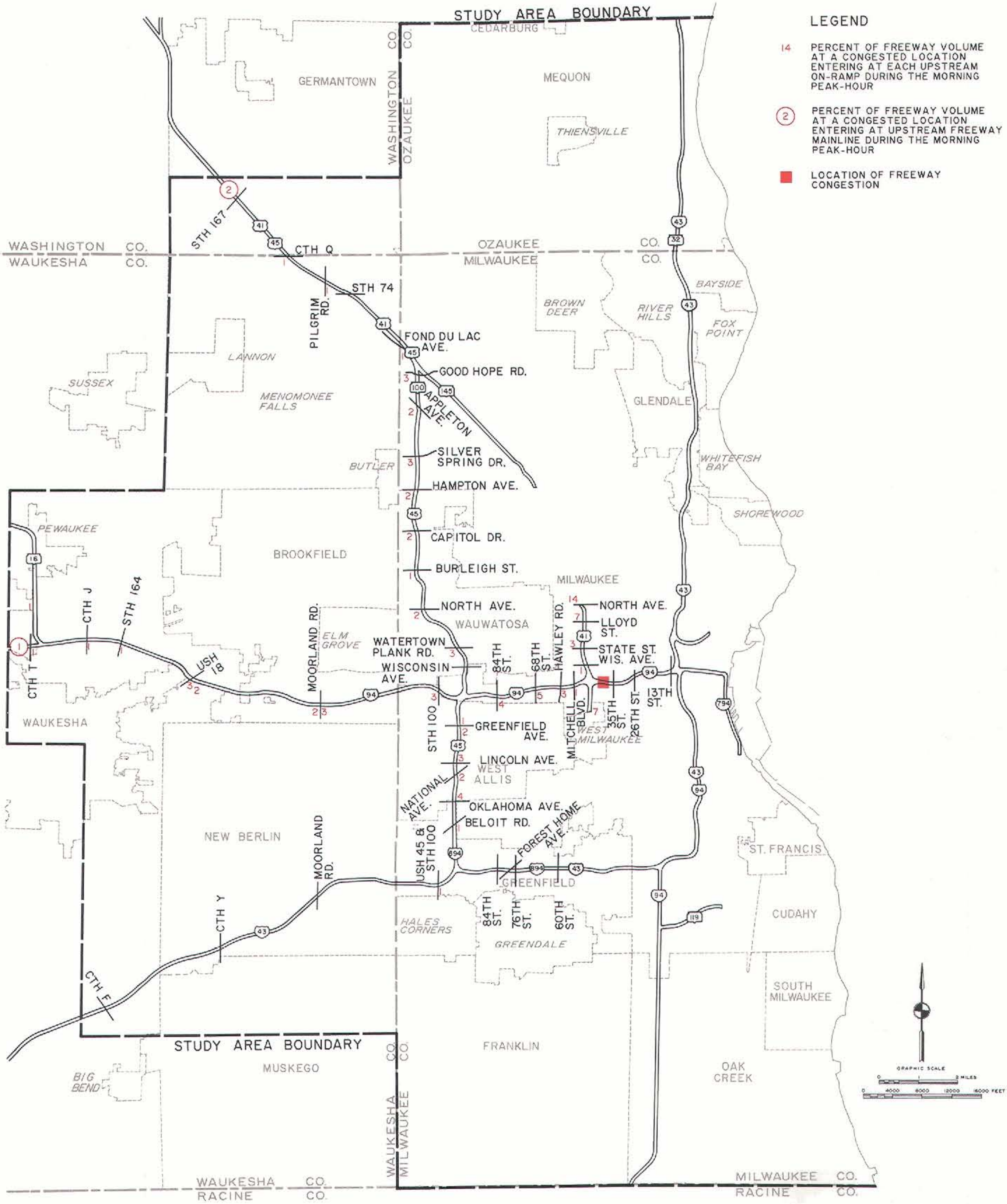
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON NORTHBOUND IH 94 AT W. OKLAHOMA AVENUE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-19

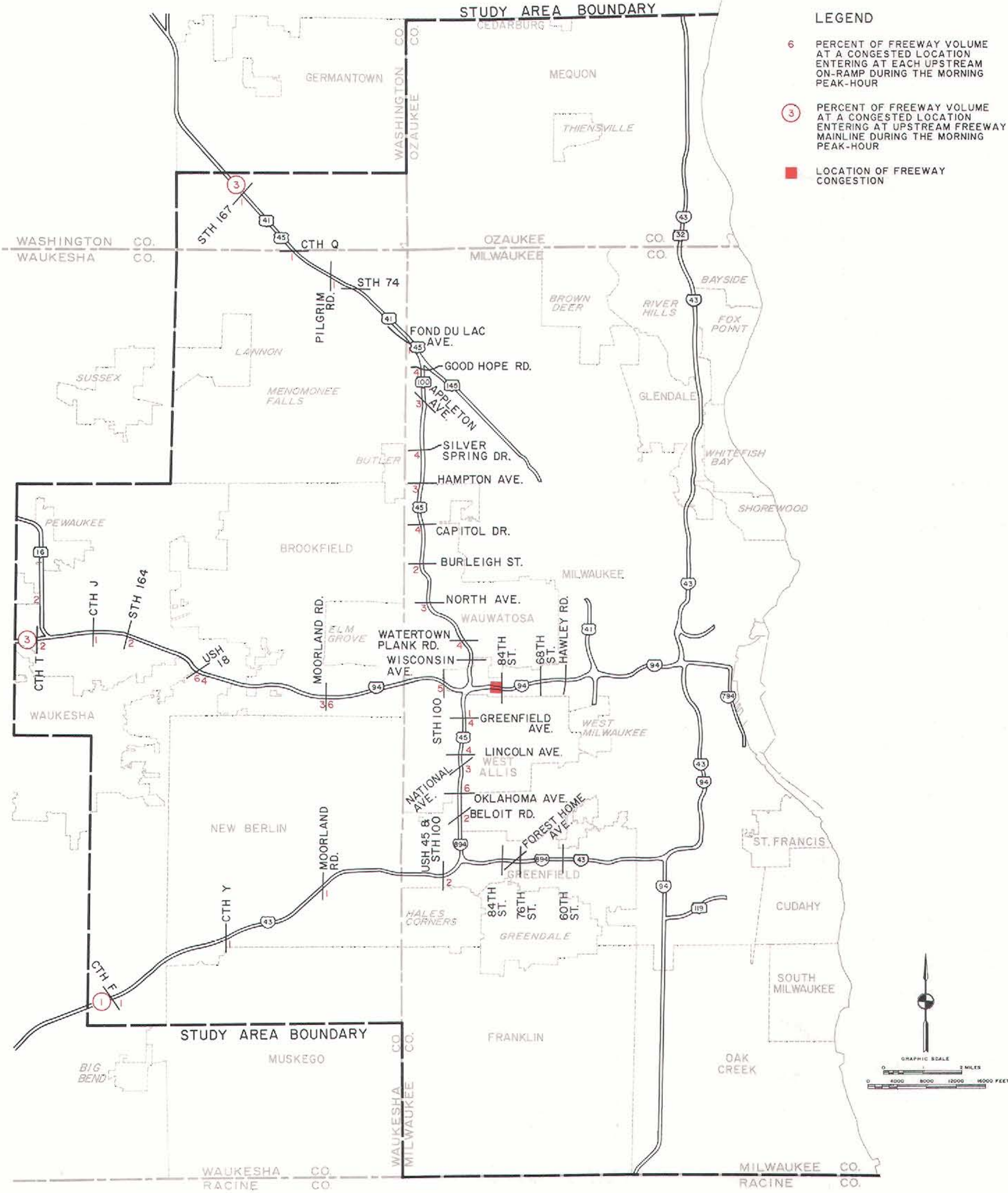
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON EASTBOUND IH 94 AT N. 35TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-20

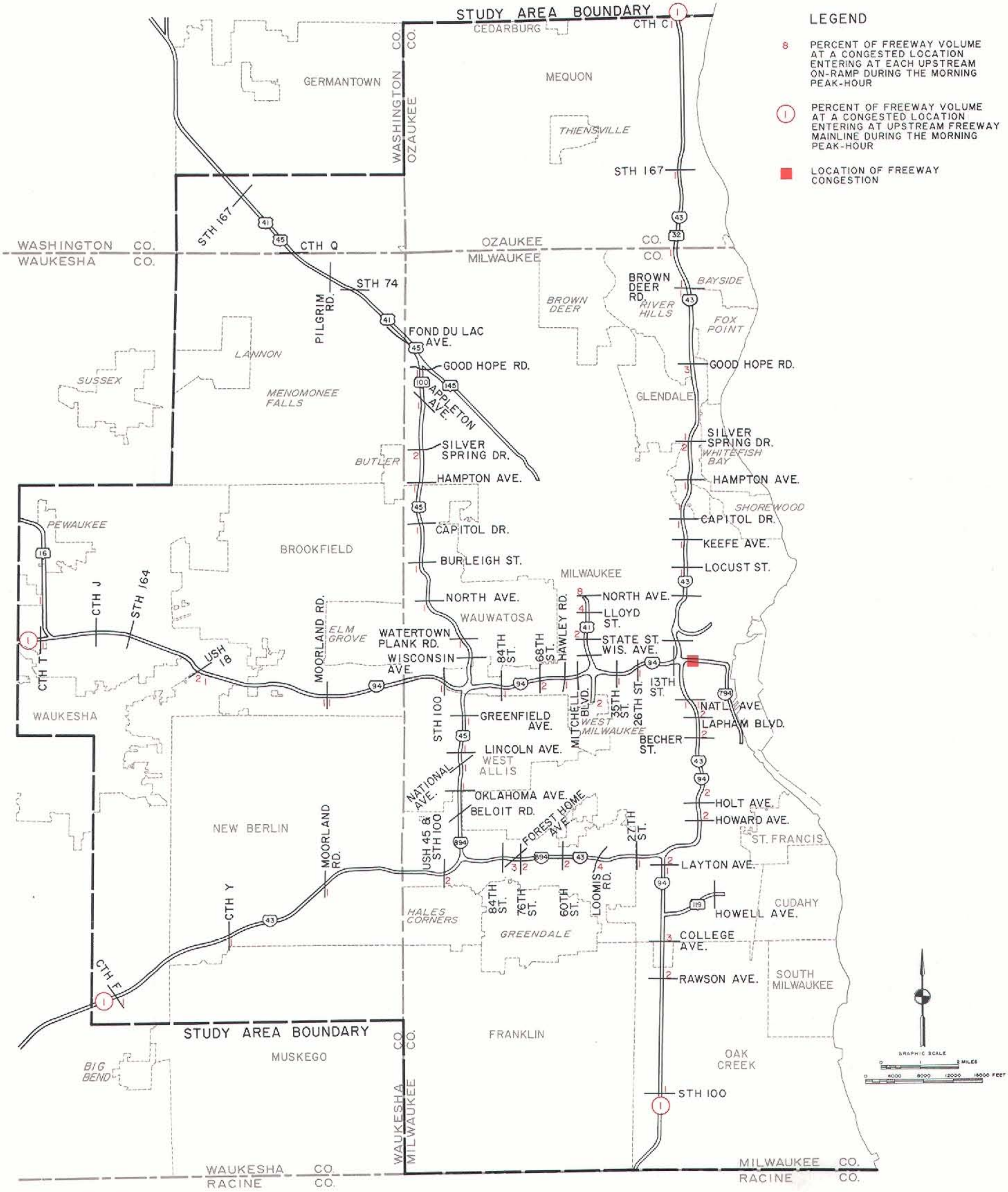
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON EASTBOUND IH 94 AT N. 92ND STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-21

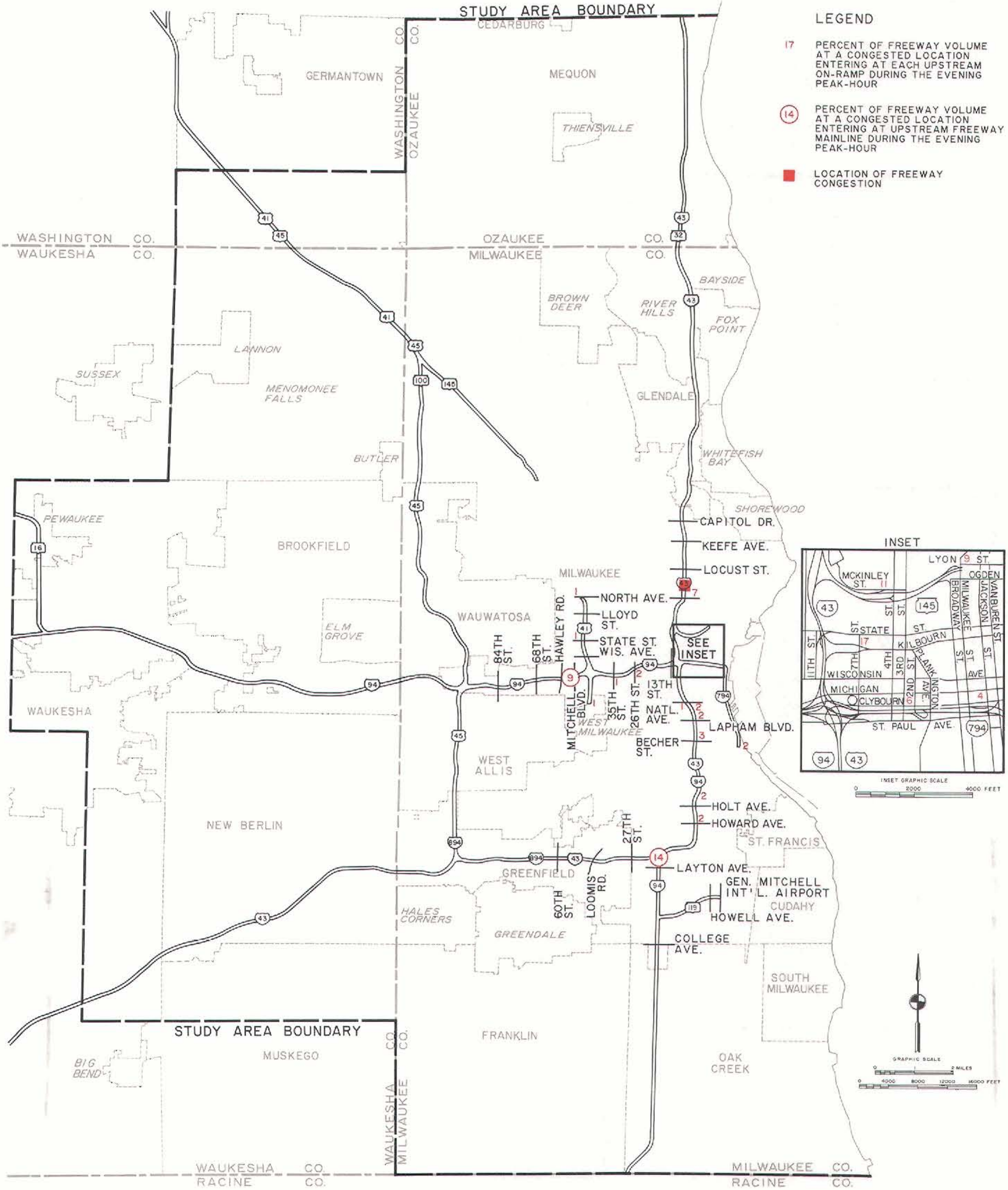
PERCENT OF TOTAL MORNING PEAK-HOUR TRAFFIC VOLUME ON EASTBOUND IH 94 AT N. 6TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-22

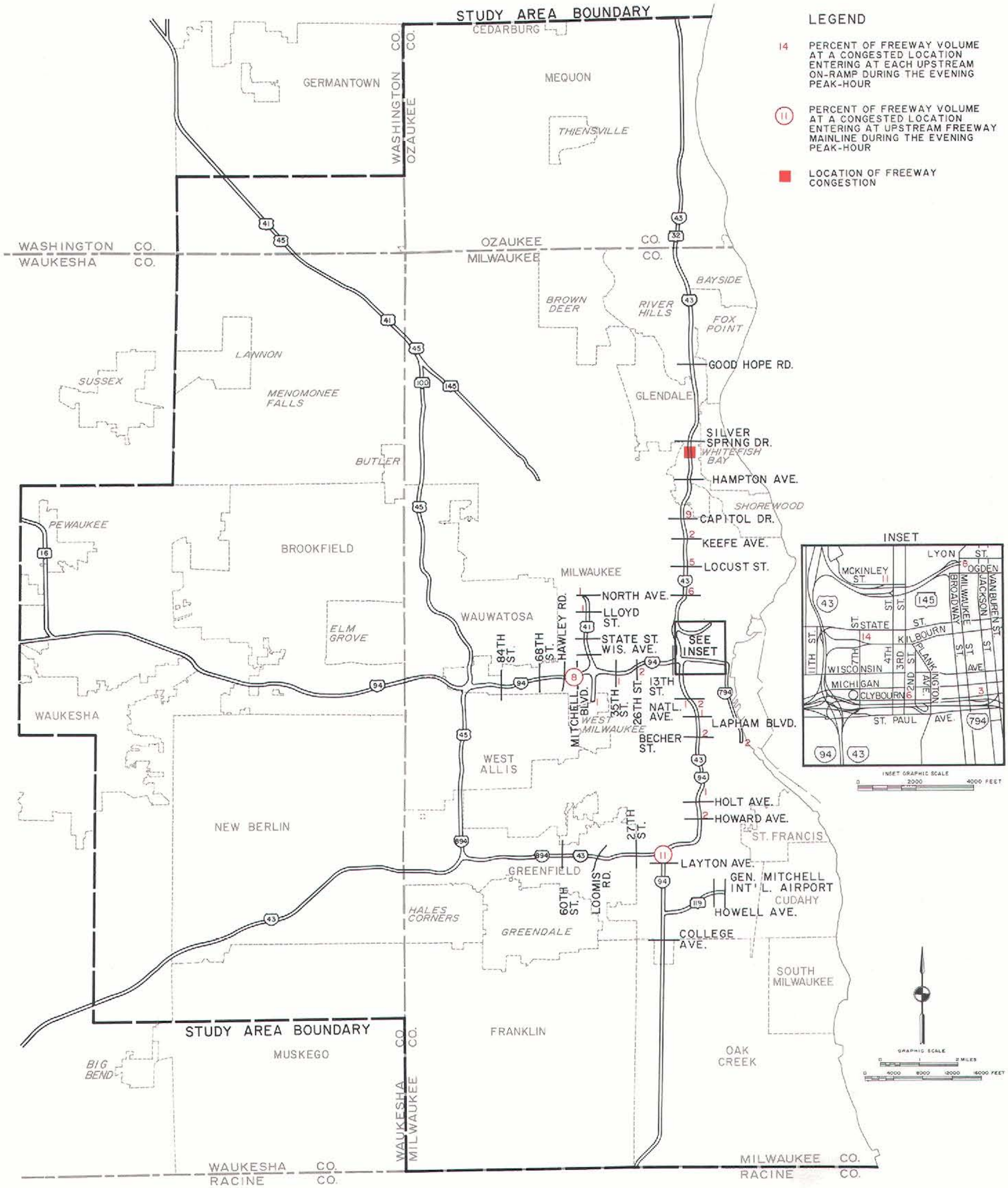
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON NORTHBOUND IH 43 AT W. NORTH AVENUE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-23

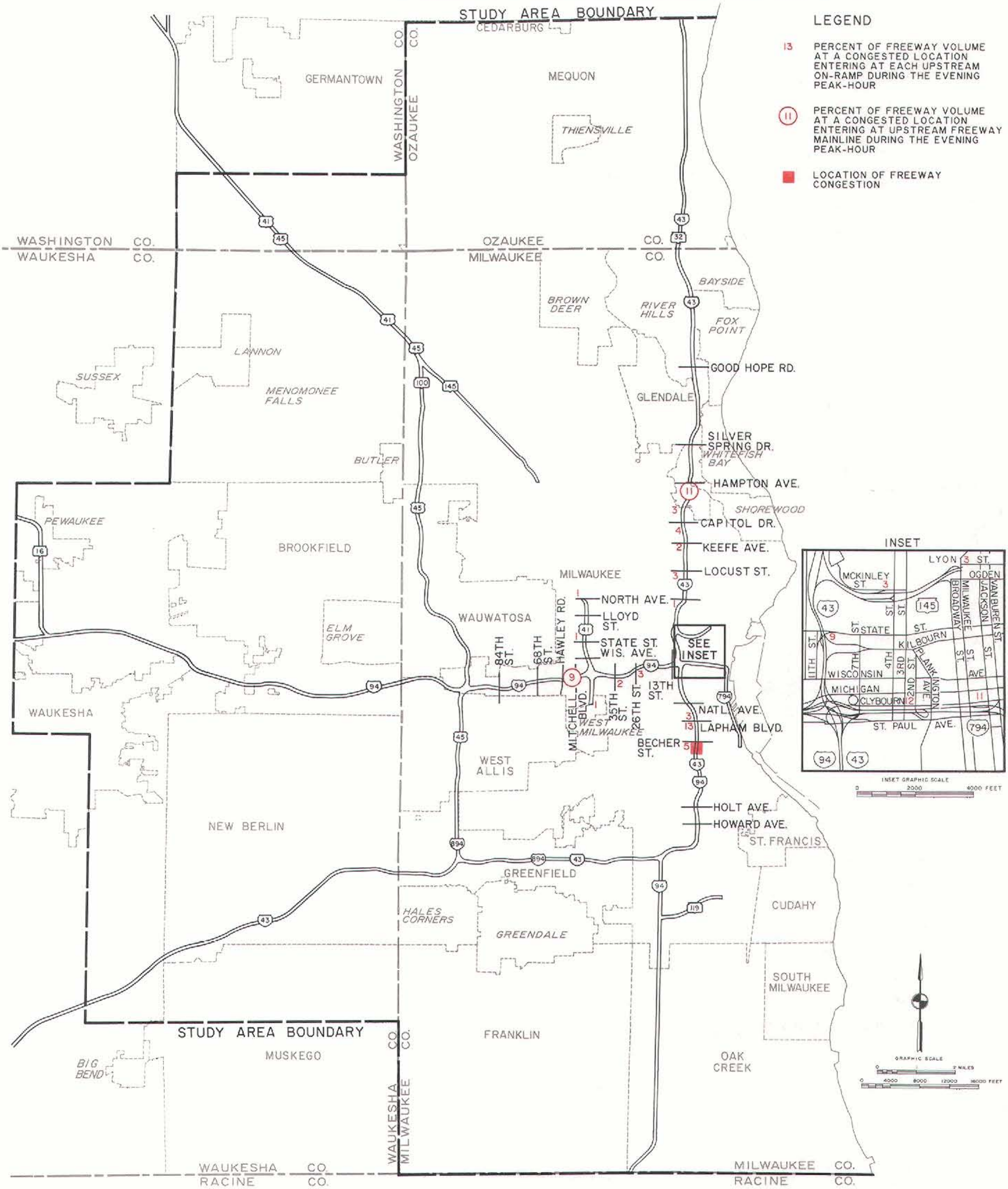
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON NORTHBOUND IH 43 AT W. SILVER SPRING DRIVE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-24

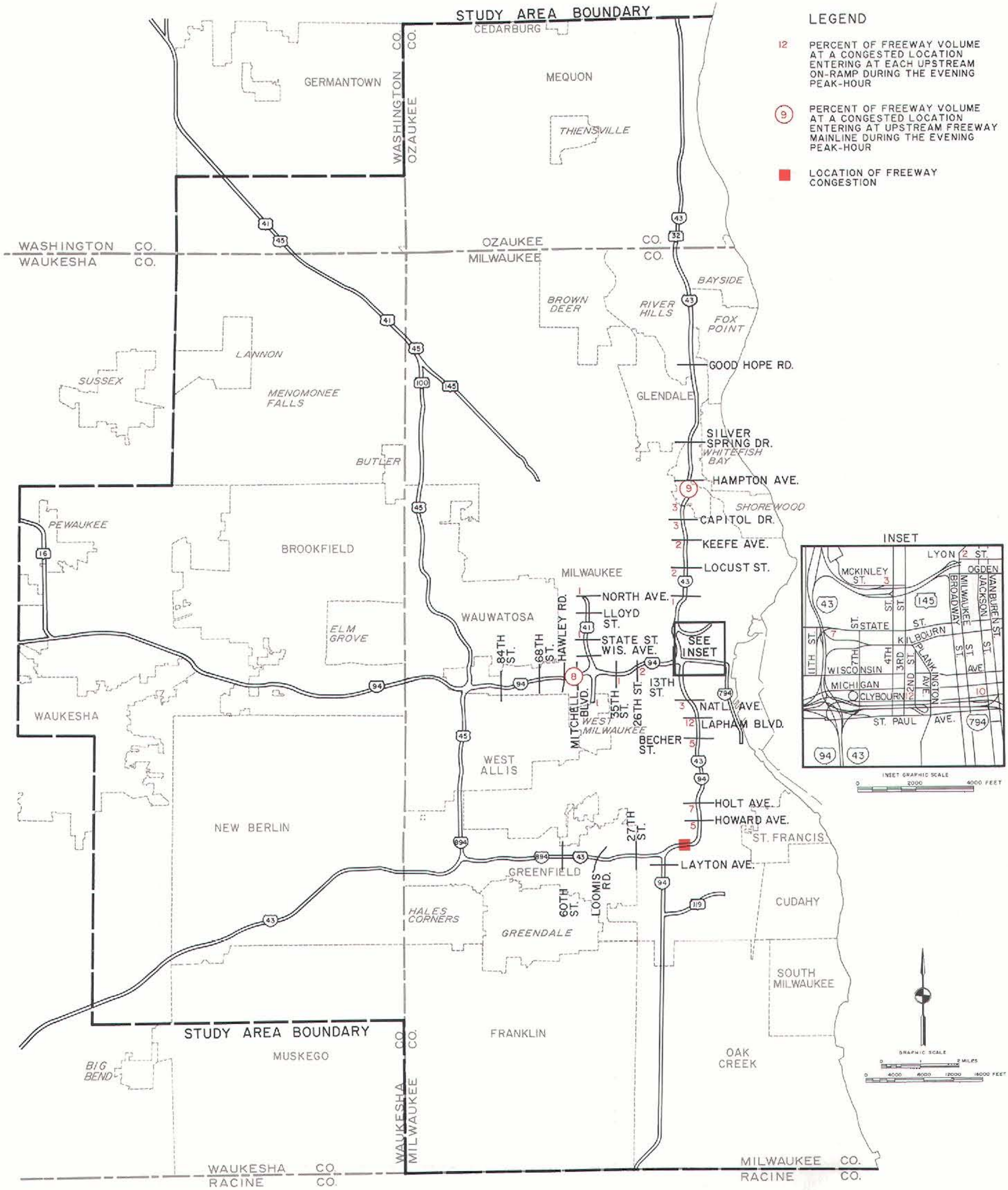
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON SOUTHBOUND IH 94 AT W. LINCOLN AVENUE ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-25

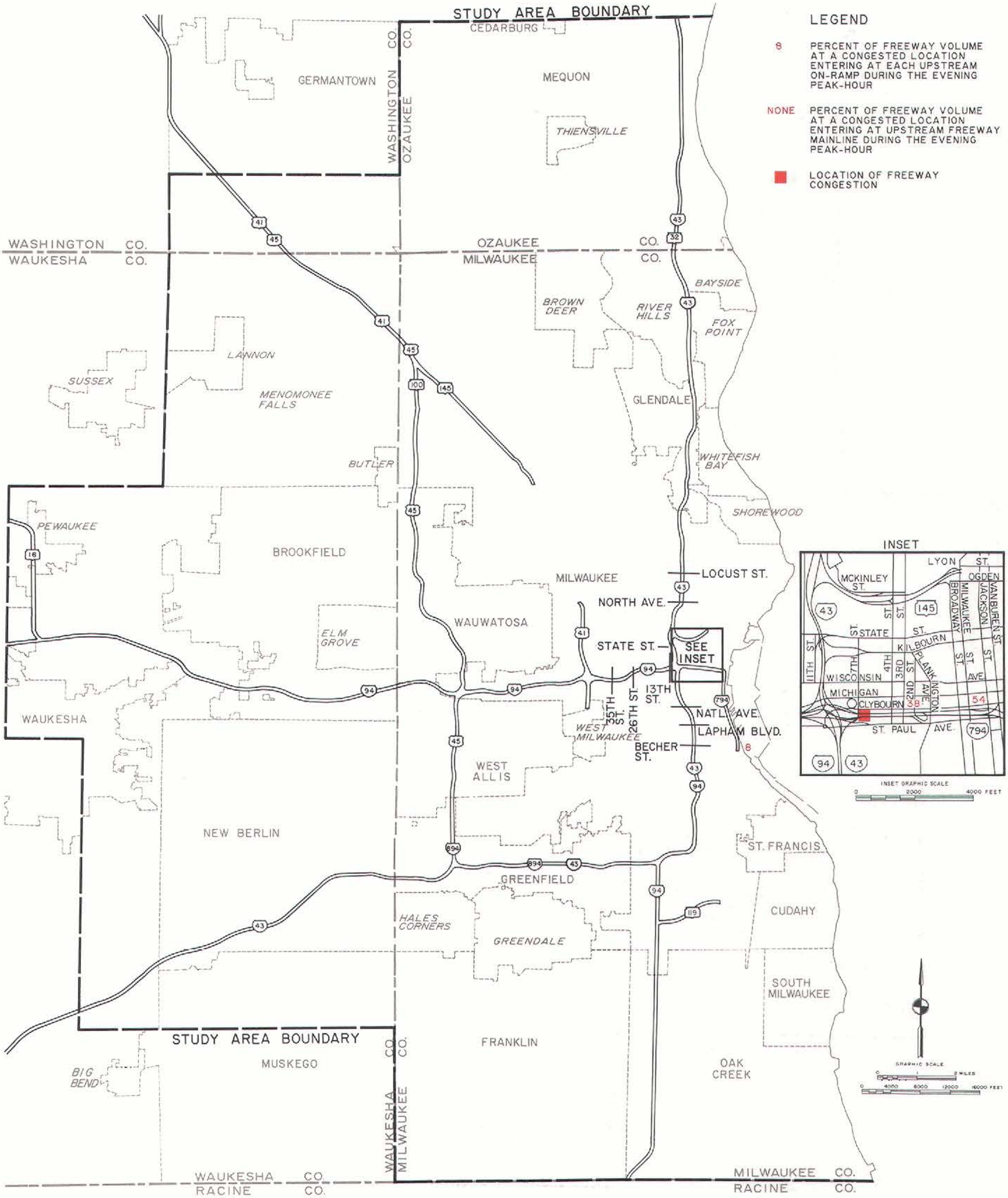
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON SOUTHBOUND IH 94 AT N. 13TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-26

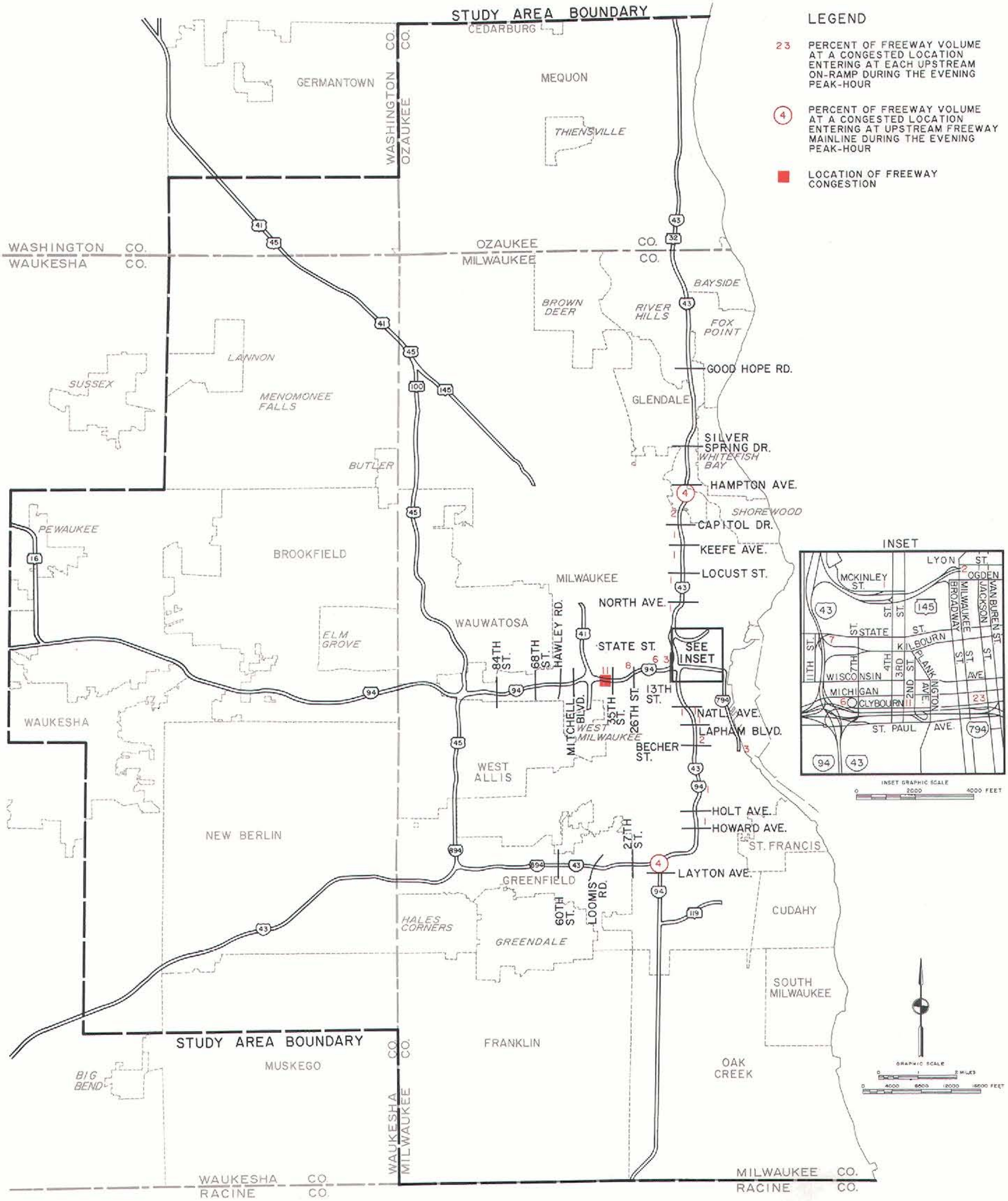
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON WESTBOUND IH 94 AT N. 6TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-27

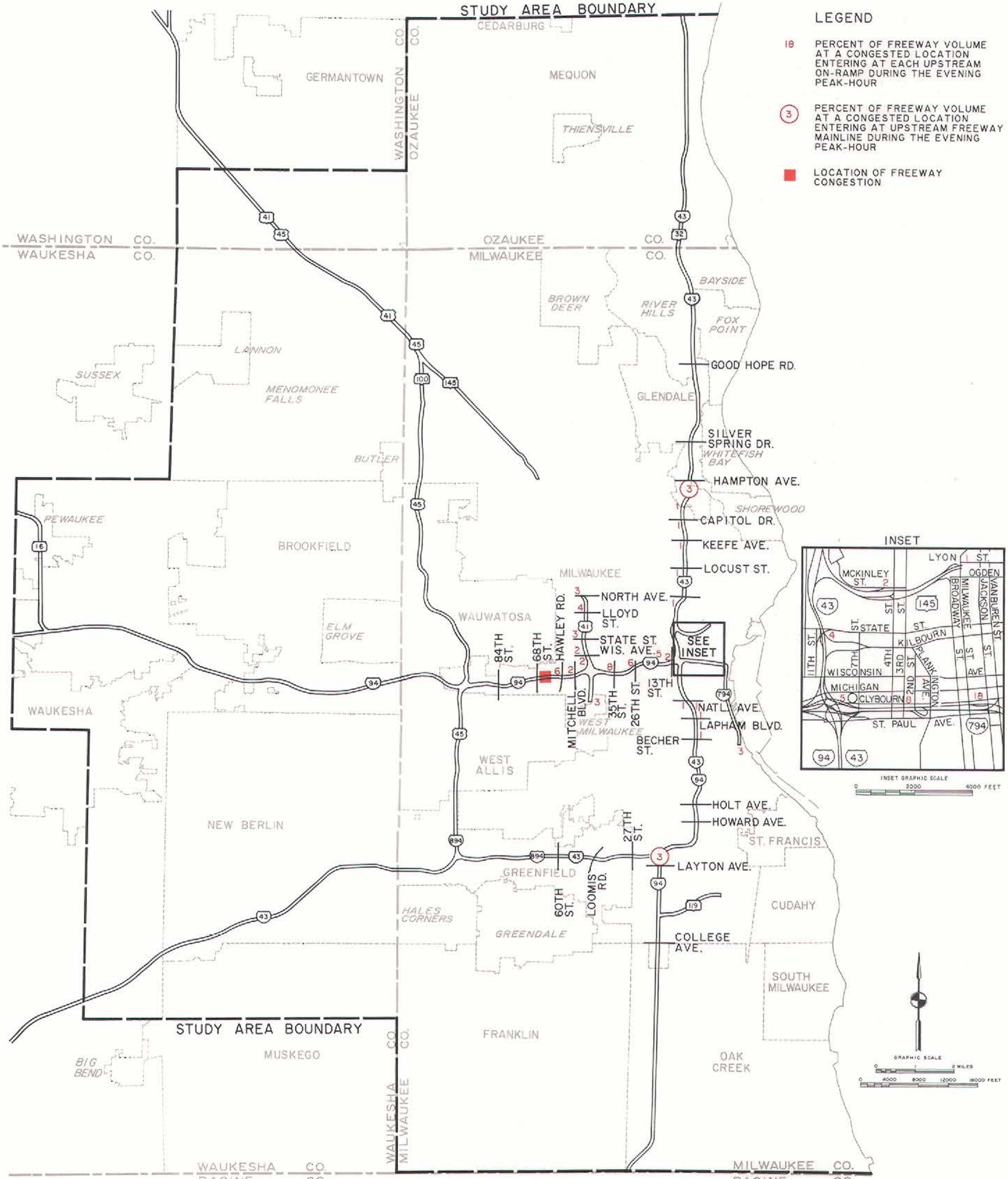
PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON WESTBOUND IH 94 AT N. 35TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.

Map B-28

PERCENT OF TOTAL EVENING PEAK-HOUR TRAFFIC VOLUME ON WESTBOUND IH 94 AT N. 64TH STREET ENTERING AT UPSTREAM FREEWAY ON-RAMPS: 1983



Source: SEWRPC.