I - 17 SYSTEM DESIGN / OPERATIONS STUDY

REPORT 1

EXISTING FACILITY EVALUATION AND CONCEPT DEVELOPMENT

FREEWAY CORRIDOR MANAGEMENT SYSTEM
CONTRACT No. 87-02
PROJECT No. IR-17-(179) PE
IR-10-3 (255) PE

ARIZONA DEPARTMENT OF TRANSPORTATION

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APRIL 1989

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EXECUTIVE SUMMARY

PURPOSE

The purpose of this design study is to expand upon previous planning studies of the I-17 corridor, and to develop design level long-range improvement and implementation plans for the 23 miles of freeway between the Maricopa Interchange and the Outer Loop, as shown in Exhibit 1. The study has been amended to include the development of an interim plan that will add a fourth freeway lane in each direction between Indian School Road and Thunderbird Road and adjust ramp and frontage road geometry to be compatible with the Freeway Management System.

PROJECT NEED

I-17 is the central link in the Phoenix Metropolitan area transportation network, serving interstate, regional and local traffic needs. The facility, designed in the late fifties and constructed in the early sixties, is a structurally aging roadway that will require increasing maintenance efforts to extend its service life. In addition, many features of I-17 do not meet current operational criteria and design standards. Further, unforeseen changes in land use and associated traffic increases have far exceeded earlier forecasts. As a result, most sections of I-17 are operating at or above capacity (level of service E-F) during the peak hours and accident rates are significantly higher than the statewide average for urban freeways.

During the next 20 years it is projected that the traffic demand within the corridor will increase dramatically. In some sections, the forecasted demand is nearly double the existing freeway volume. If this facility is to accommodate these volumes efficiently and safely, extensive system-wide improvements will be needed.

PROJECT OBJECTIVES

The major objectives of this study are summarized below:

- To detail and analyze, at a design level, concept improvement plans previously developed for the I-17/I-10 corridor;
- To develop and analyze, at a design level, viable double deck or elevated roadway alternatives, or other improvement schemes;
- To prepare functional design plans of an interim improvement plan to be constructed between Indian School Road and Thunderbird Road that are compatible with long range alternatives;
- To develop specific geometrics that are compatible with, and enhance the Freeway Management System.
- To establish a phased implementation scheme to address prioritization of improvements in a systematic form; and
- To generally define future right-of-way requirements in the corridor so that it can be protected or reserved.

PROJECT APPROACH

The study has been divided into two phases, as shown in Figures 1 and 2. The first phase includes evaluating the existing conditions and developing a future design framework. The second phase includes developing and evaluating alternative concepts and preparing functional design plans.

The first phase of the project began by assessing existing conditions within the I-17 corridor including roadway geometrics: major utilities; traffic and traffic circulation; and environmentally sensitive issues. In order to complete this assessment, an extensive data base was collected. Initially, the I-17/I-10 Corridor Study Report and 14 working papers prepared by JHK and Associates were thoroughly reviewed. Applicable information, data, and other findings were incorporated into the data base. Additional and essential data, not available in the data base were then collected and analyzed. These data included a complete present day traffic count base; detailed present-day geometric information; and updated accident experience information.

In conjunction with the assessment of existing conditions, future traffic requirements were established. Year 2010 traffic volumes were determined based on the MAGTPO 2010-34 traffic assignment model. Selected link model runs provided origin and destination information within the study area. Additional information collected includes programmed and planned highway improvements and future development plans within the corridor.

Data collected in Phase I formed the basis for establishing a long-range design framework to address existing deficiencies on I-17, and for developing long-range improvement concepts. Phase I concluded by developing preliminary improvement concepts for both long-range and interim plans.

Phase II is divided into two major tasks. In the first task, a long-range plan will be developed. In the second, interim improvement plans will be developed. Both long-range and interim plans will be prepared simultaneously.

The long-range concepts will be detailed and evaluated in relation to how well they resolve present deficiencies and satisfy future requirements. The detailed alternatives will be investigated as to their ability to be phased in response to evolving and changing needs. After a preferred plan is selected, engineering evaluations will be performed to ensure the viability of the selected plan.

Several widening concepts will be investigated for the interim plan. These widening schemes will form the nucleus for developing alternative interim improvement plans. Up to three (3) alternatives will be prepared.

PHASE I FINDINGS

The background and results of the work completed in Phase I are depicted graphically, and detailed within the body of this report. The summarized findings of Phase I are described below.

Existing Freeway Evaluation

The evaluation of the existing conditions of the I-17 corridor relied on current guidelines, criteria and policies enumerated in the 1984 AASHTO policy; Arizona Department of Transportation design manuals and policies; and other generally accepted guidelines on highway design and operations practice.

These sources provided the basis for establishing rating criteria to evaluate the I-17 freeway. The evaluation and rating criteria for each freeway feature are described in detail in the body of the report. Freeway features were analyzed and assigned a "good", "fair", or "poor" rating according to the established rating criteria. Evaluation results were then summarized and are presented graphically in Exhibits 11 through 22.

Systemwide, 1988 AM and PM peak hour and 24 hour traffic volumes were developed to analyze and rate existing freeway operations. Mainline freeway capacity analyses, weaving analyses and ramp terminal operation analyses were performed. Analysis results are depicted graphically in Exhibits 5 through 10.

In general, current traffic demands equal or exceed the capacity of the existing facility. Level of Service E-F conditions are prevalent in both directions during the peak periods throughout most of the length of the facility. The exception is in the extreme north section of the project where the freeway operates below capacity. The portion of the freeway between the Maricopa and Papago Interchanges experiences nearly equal directional distribution and high peak period flows. Completion of the Papago Inner Loop is expected to offer some relief to this segment of the corridor.

Geometrically, the freeway reflects both urban and rural design characteristics. The southern sections (urban design) exhibit inadequate ramp terminal design, according to current design standards. In most cases, there are insufficient taper lengths to safely complete merge and diverge maneuvers. In addition, poor cross-sectional features occur primarily in the depressed sections as the mainline undulates to pass under the cross streets. In the north section the freeway profile is uniformly above grade while the cross streets pass under I-17. In this section there are several full and partial cloverleaf interchanges that are operationally incompatible with the evolution to a suburban/urban environment.

The combination of older design standards and the high traffic demand are reflected in the poor freeway operational characteristics, low level of service and high accident rates.

Future Design Framework

Before developing improvement concepts, a long range planning framework was established. The primary purpose of this framework is to establish future traffic design and other requirements that assist in focusing on the viable alternatives.

Year 2010 peak hour and 24 hour volumes were developed based on the MAGTPO 2010-34 traffic projection model and are depicted in Exhibits

24 through 29. These volumes were then used to develop basic lane requirements for the corridor and are shown in Exhibit 23. Selected link model runs provided origin and destination information used in determining trip lengths, and the viability of implementing express lanes on the facility. Results of the selected link analysis are presented in Exhibits 30 through 33.

Existing right-of-way widths, land use, and local access adjacent to I-17 were reviewed to evaluate physical constraints within the corridor. Discussions with ADOT, City of Phoenix, Maricopa County as well as public transportation and public and private utility staff also assisted in gaining insight into existing and future developments along I-17. Programmed transportation improvement plans such as the Outer Loop and Paradise Freeways are another important component of the design framework.

Improvement Concepts

Based on future traffic requirements and physical constraints within the corridor, eight improvement concepts were developed. The concepts, labeled A to H, and diagrammed in Exhibits 36 through 43 range from a collector-distributor (C-D) freeway system to an improved conventional freeway, flanked by high-type frontage roads. Other concepts developed include elevated and/or double-decked freeway mainlines and others utilizing elevated express roadways.

As part of the concept development, alternative transfer and slip ramp spacing schemes were qualitatively analyzed. The spacing configurations, from one to three miles, relate to conventional frontage road and to combination C-D/frontage road concepts. These schemes, shown in Exhibits 44 and 45, will be evaluated in detail under Phase II and will be utilized to develop alternative long-range plans.

In addition to long-range improvement concepts, interim improvement concepts were also developed to provide immediate capacity enhancements to I-17 between Thomas Road and Thunderbird Road. These improvements would minimize or require no right-of-way acquisition, utilize existing cross street structures, and minimize implementation costs.

Ideally, these short-range improvements would be a component of the long-range plan and could be implemented in a way to minimize "throw-away" construction. Widening concepts depicted in Figure 46 include adding an auxiliary lane between one-mile interchanges, adding a basic freeway lane, or adding an auxiliary lane with interchange ramps spaced every two miles. These concepts will be input to the development of the alternatives during Phase II.

CONCLUSIONS AND RECOMMENDATIONS

The results of the Phase I tasks were presented at a review meeting with representatives of ADOT held on February 22, 1989. The input from this review session provided recommendations and guidance regarding the improvement concepts that will be detailed as long-range and interim alternative plans in Phase II.

Long Range Plans

The following long-range improvement concepts have been selected for further development and evaluation.

- Concept E - Elevated express roadway located between the freeway and the frontage road.
- Concept F - Improved Freeway facility with combination C-D/frontage roadways.
- Concept G - Improved freeway facility with continuous, high-type frontage roads.
- Concept H - Double-deck freeway facility (one-way operation on each level) with continuous, high-type frontage roads.

Interim Improvement Plans

The following interim improvement concepts were selected for further development and evaluation:

- A base case within the existing right-of-way that provides a fourth freeway lane in each direction, reduces shoulder widths and improves ramp geometry via minor adjustments.
- One or more alternative plans will be developed, requiring additional right-of-way. These alternatives will provide increased freeway capacity; improved ramp design compatible with the freeway management system; continuous two-lane frontage roads; and accommodation for HOV bypass ramps.

INTRODUCTION

PROJECT BACKGROUND

The I-17 corridor is the backbone of the Phoenix area transportation system. I-17 is also the central link in the proposed regional freeway network and is expected to continue to serve interstate, regional and local traffic demands. The regional transportation network and project study area are shown in Exhibit 1.

In recent years, large segments of the system have become incapable of serving traffic at the high quality of service expected on interstate highways. Other segments are quickly approaching breakdown operations. There are several factors affecting the performance of the I-17 corridor.

- Most of the facility is nearly 30 years old and is approaching the design service life expected for freeway facilities.

- Land use patterns and population have evolved quite differently from when the facility was planned and designed. Changing land use patterns have created an imbalance in the quality of transportation service provided to different areas along the freeway. In particular, significant growth in population and employment has occurred to the north. This places a heavy burden on I-17, which is the primary transportation corridor serving that area.

- In many locations, the arterial street system has not been improved as rapidly as the growth in the area. Consequently, the local system is operating near capacity, reducing the opportunity for alternative routes, as I-17 reaches capacity.

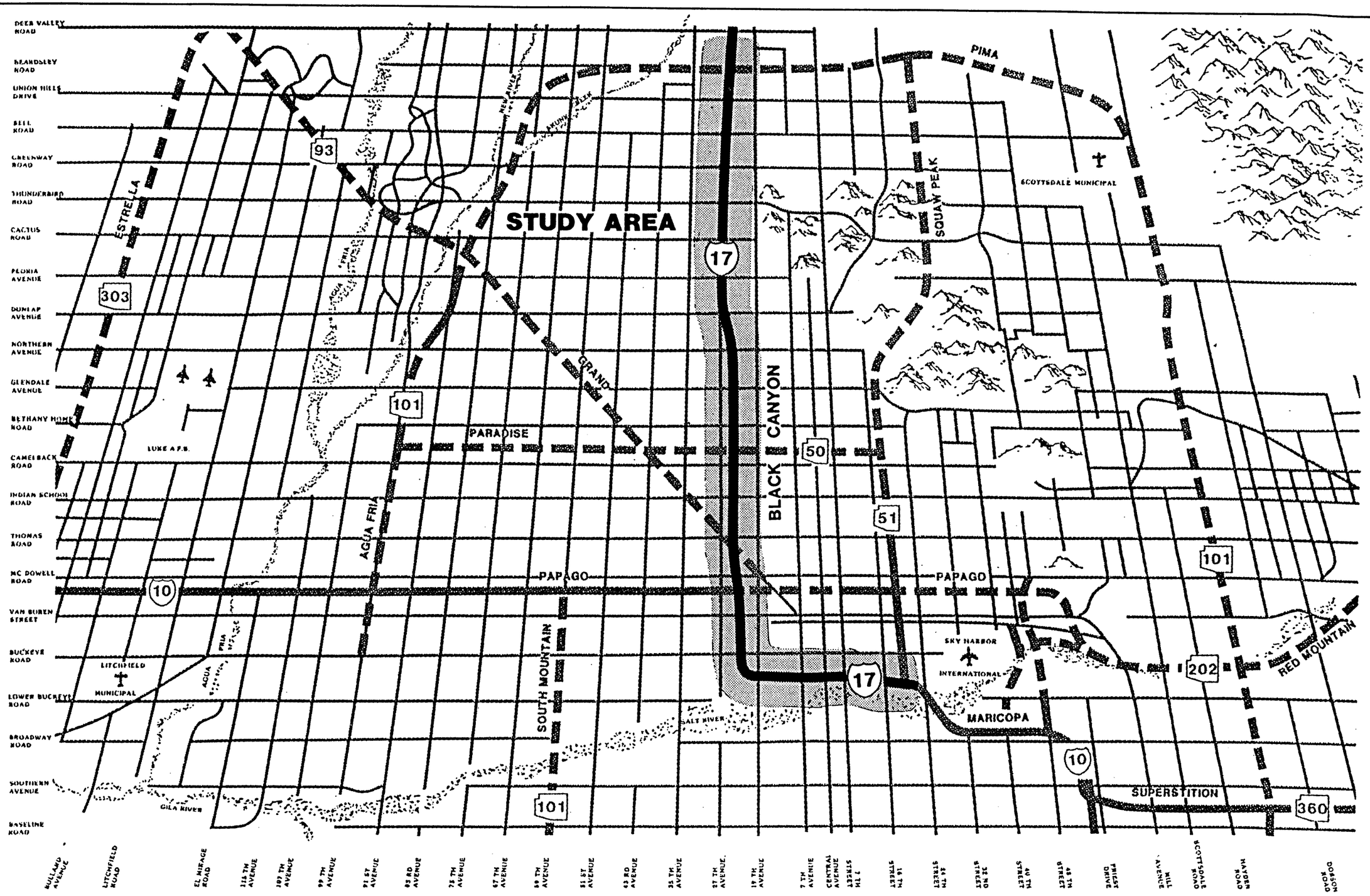
- Overall, traffic growth has reached or exceeded the capacity of many parts of the system which produces poor operations during both the morning and evening peaks.

For the first reason alone, major capital expenditures will be necessary in the future to upgrade, or replace pavement and structures. In fact, the current five year program calls for pavement rehabilitation in the depressed section of I-17 between Buckeye Road and Van Buren Street.

Improvement projects for reconstructing overcrossings have been completed at McDowell Road and Thomas Road as part of the Papago Interchange Project. Presently, work is underway to rebuild the structure at Union Hills Drive and design plans are being prepared for reconstructing the overcrossing at Indian School Road.

While the planned and completed improvement projects have primarily focused on physical rehabilitation and are of benefit to the freeway in local areas, other design issues such as safety, capacity, and operations have not necessarily been addressed on a systemwide basis. When reviewing completed and planned improvement projects certain questions can be raised:

- Aside from physical deterioration, what are the current operational and safety problems on the freeway system?



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ARIZONA DEPARTMENT OF TRANSPORTATION

INTERSTATE 17 CORRIDOR STUDY

VICINITY MAP

SCALE : NTS

FEBRUARY 1989

EXHIBIT

1

- How can I-17 be rehabilitated or reconstructed to address both current deficiencies and long range needs?

- What are the most cost effective interim improvement concepts that will provide additional capacity to the corridor as a whole and yet remain compatible with long range plans including implementation of the Freeway Management System?

- How can interim and long-range programs be implemented in stages while maintaining the integrity of the long range concept and provide reasonable operations during each stage?

- What are the costs (construction, right-of-way, environmental, socioeconomic) of rehabilitating the I-17 freeway corridor?

To answer the previous questions, the project team conducted a comprehensive study of the I-17 corridor. The study encompasses approximately 23 miles of freeway including 18 service interchanges, four partial service interchanges, and two system interchanges.

STUDY OBJECTIVES

The objectives of this study are:

1) To systematically assess the location, extent and nature of the full range of geometric and operational conditions of the freeway system;

2) To develop refined traffic forecasts for the year 2010 based on regional traffic forecasting models;

3) To develop a long-range plan for the existing freeway system that will address existing problems and accommodate year 2010 traffic needs;

4) To develop near-term improvement schemes to offer immediate relief to the existing facility while remaining compatible with long range plans; and

5) To recommend a staged approach that will implement the long range freeway improvement plans, including the Freeway Management System, in a systematic fashion.

PROJECT APPROACH

The study has been divided into two major phases. Flow charts diagramming the study elements of each phase are shown in Figures 1 and 2. The first phase includes a detailed evaluation of the existing freeway and the development of a design framework for future improvement. As part of Phase II, alternative improvement plans will be detailed and evaluated. The study will conclude with a recommendation for long-range and interim improvement plans. Phase I efforts are documented in this report and are briefly summarized below.

The first phase of this project included collecting and analyzing available data to evaluate the geometric and operational features of the existing facility. This information served as the basis for

FIGURE I

PHASE I

EXISTING FACILITY EVALUATION AND CONCEPT DEVELOPMENT

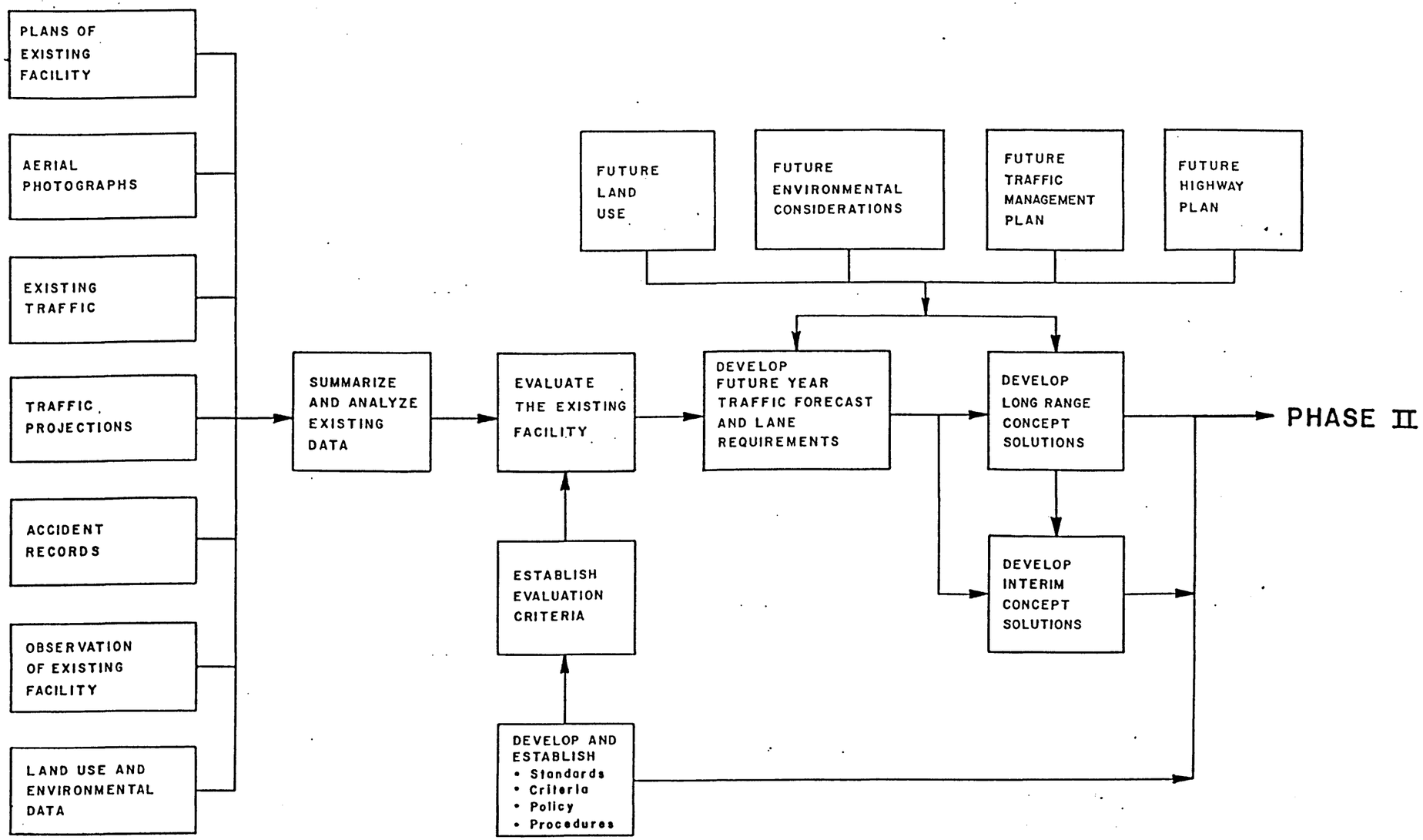
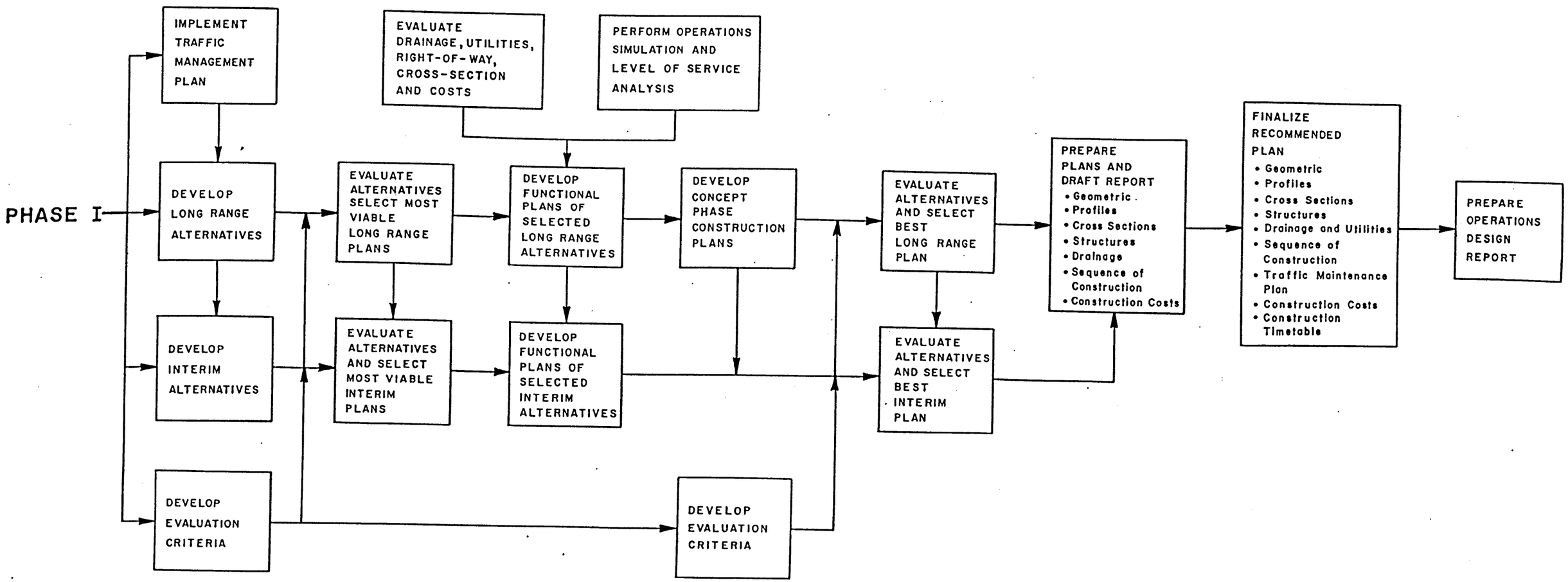


FIGURE 2

PHASE II

LONG RANGE AND INTERIM IMPROVEMENT PLAN DEVELOPMENT



the development of the design framework for interim and long-range improvements to the corridor. Initially, the I-17/I-10 Corridor Study Report and 14 working papers prepared by JHK and Associates were reviewed. As appropriate, information and findings contained in JHK report documents were used to establish a data base to assist with the existing facility evaluation.

Additional and essential information, not available in these reports was collected and analyzed. This information included: a present-day count base; current accident data; as-built record drawings; video tapes of the corridor for office review; current land use and development information; planned and proposed highway and public transportation improvements; and major utility locations. Meetings with the City of Phoenix, Maricopa County, and Arizona Department of Transportation staff also yielded valuable information related to operational experience, right-of-way constraints and access requirements. A detailed listing of data sources are presented in Appendix A.

In addition to the extensive data collection process, evaluation and rating criteria were established. Current Arizona Department of Transportation and AASHTO design criteria and standards formed the basis for the rating criteria. Once rating criteria was established for the geometric and operational features and performance measures, the entire facility was reviewed and rated.

Future traffic demands, AM and PM peak hour and 24-hour volumes were developed for the year 2010. Selected link analyses were also reviewed to determine the origins, destinations, and trip lengths of vehicles using the facility. Future traffic requirements and existing facility evaluation results served as input in developing interim and long-range improvement concepts.

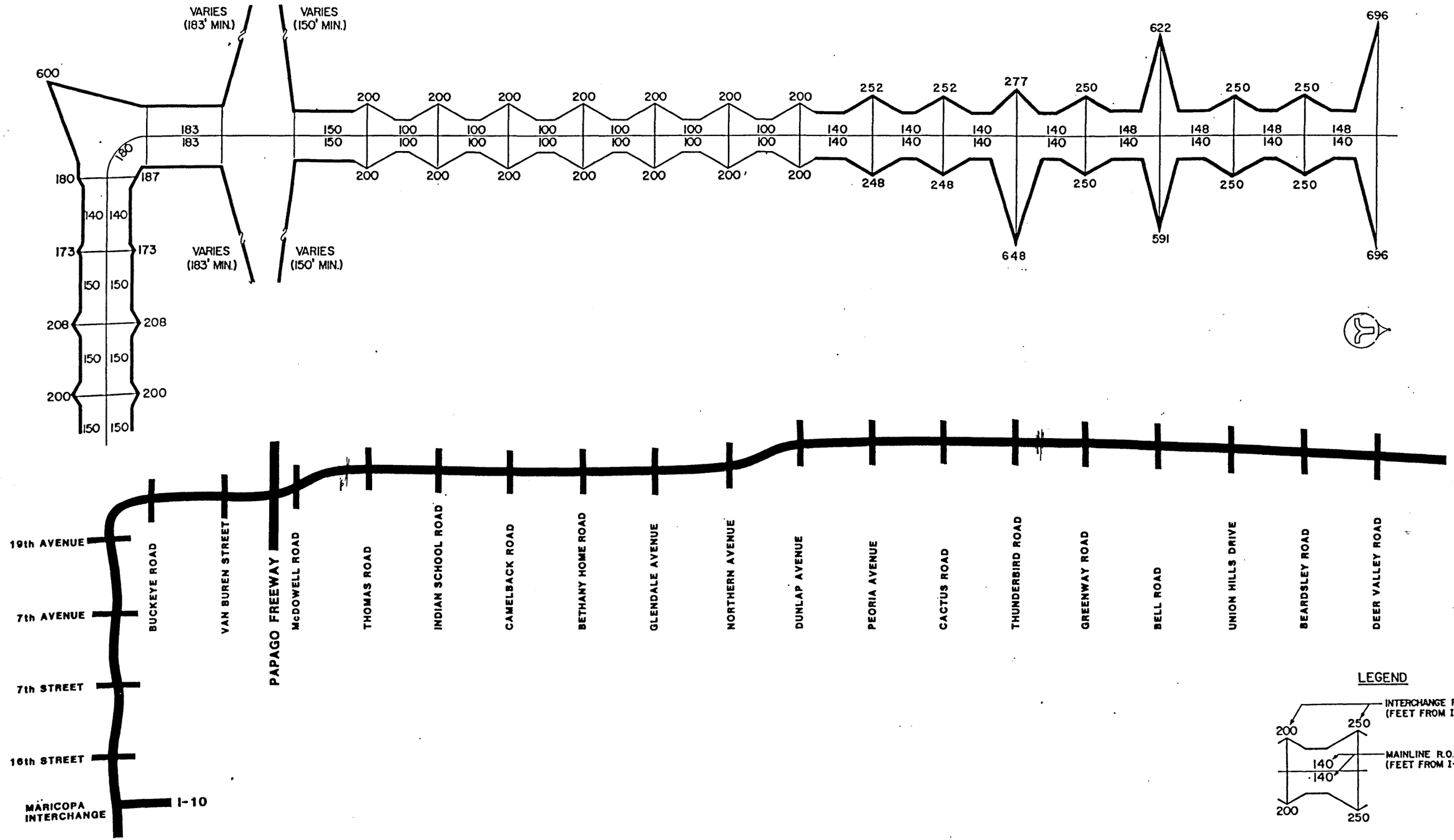
The results of the existing facility evaluation; year 2010 traffic assignments, selected link analyses, and interim and long-range improvement concepts are detailed in later sections of this Phase I report. The work in Phase II will detail, refine and evaluate the viable concept alternatives, and finally make recommendations for the long-range and interim improvement plans.

I-17 CORRIDOR OVERVIEW

The I-17 corridor includes a diversity of freeway design elements and land use characteristics. Constructed during the early 1960's, the original freeway design reflects both urban and rural design characteristics. Since the time of the original construction, tremendous growth has occurred in the Phoenix metropolitan area. Freeway sections once designed as rural are now serving rapidly expanding commercial and industrial development.

Initially, I-17 was designed to provide a link between Interstate 10 and Interstate 40, providing access to central Arizona. Over the years, the I-17 corridor has developed into an important component of the Phoenix transportation network serving commuter traffic from the northern and western residential areas destined for the central area of the city. As mixed land use development occurred to the north, I-17 also began to serve commuter traffic attracted to the outlying areas of the city. The combination of interstate, regional, and local traffic demands have placed a tremendous burden on the I-17 corridor.

The southern and central sections of I-17, constructed between 1961 and 1965 reflect urban freeway design of the era when closely spaced interchanges, restricted geometry, and narrow right-of-way widths were common. The north section, constructed in 1965, exhibits both suburban and rural design characteristics. Right-of-way widths were increased, ramp geometry improved and



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ARIZONA DEPARTMENT OF TRANSPORTATION

INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY RIGHTS-OF-WAY

SCALE : NTS

FEBRUARY 1989

EXHIBIT 2

interchange configurations expanded. Exhibit 2 delineates the present right-of-way widths which are consistent with the urban versus rural or suburban design of the facility.
Exhibit 3 highlights the original construction dates for each segment of I-17. Additional construction improvements and implementation dates are also noted. Most of I-17, within the study area was constructed during the early 1960's, which means the design of the facility began in the late 1950's--over 30 years ago.

The age of the system is important not only with respect to its physical condition but also in terms of its design. As will be discussed in later sections of this report, highway design standards and practices have changed over the past 25 to 30 years, therefore, many features of the existing freeway system, while initially built to appropriate standards, no longer meet current design criteria.

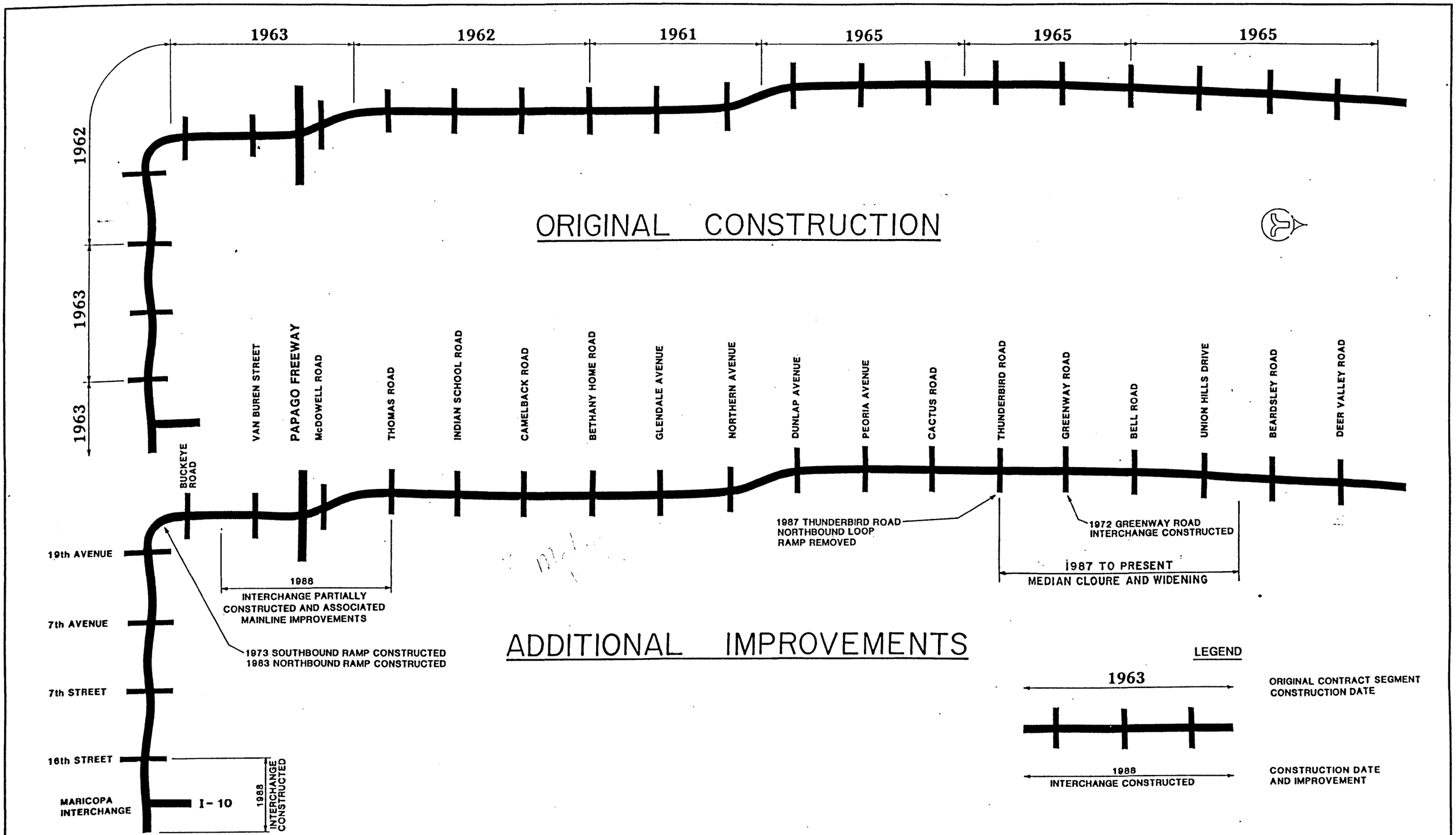
Connecting Freeways

Presently, I-10 is the only freeway that interchanges with I-17 in the study area. I-10, a transcontinental route, forms the north and east boundaries of the Papago Inner Loop in downtown Phoenix, while I-17 forms the south and west boundaries. Two directional interchanges between I-17 and I-10 complete the Papago Inner Loop. The directional interchange located on the east side, commonly referred to as the Maricopa Interchange is the origin of I-17. This three-level interchange has recently been reconstructed and was opened to traffic in the summer of 1988.

The second system interchange located on the west side, generally identified as The Papago Interchange, is currently under construction. The directional ramps to and from the west of this "four-level stack" interchange were opened to traffic in 1988. The remaining ramps will open to traffic upon completion of the segments of the Papago Inner Loop which pass through central Phoenix. The south segment of I-17 currently serves as a link to I-10. Demand through this segment is expected to initially decrease once the final segments of I-10 are completed and are opened to traffic.

In the future, another fully directional system interchange is programmed in the north section of the project, near Beardsley Road. This interchange, scheduled for completion in the late 1990's, will connect the Outer Loop freeway with I-17. Improvement projects on I-17 near Union Hills Drive, currently under construction, are part of the initial stages of the Outer Loop project.

The Paradise Freeway, currently under study, may provide a fourth system interchange with I-17. Construction of this east-west facility, located between Camelback Road and Bethany Home Road will have a significant bearing on the future operations of I-17. Depending upon the type of interchange implemented between the Paradise Freeway and I-17 (full, partial, or none), there will be a significant variation in the pattern and magnitude of traffic on I-17.



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY CONSTRUCTION DATES

SCALE : NTS

FEBRUARY 1989

EXHIBIT 3

CORRIDOR EVALUATION PROCEDURE

BACKGROUND

The criteria used for evaluating the existing facilities was based on the 1984 AASHTO Policy, the Arizona Department of Transportation design manuals and policies, and other generally accepted guidelines on highway design and operation practices. These publications reflect state-of-the-art knowledge of the relationship between design features and operational characteristics of freeway systems. The following chapters discuss the design, capacity, safety and operational deficiencies of the existing facility. However, this should not be taken as an inference that the original design was substandard, since design standards have been refined over the years as experience and research have brought new knowledge of the actual operation of freeway systems. In addition, unforeseen changes in land use and associated traffic increases have far exceeded earlier forecasts.

FEATURES EVALUATED

The existing geometric and operational features of the facility were inventoried and analyzed. The deficiencies noted in the evaluation process help to identify high priority improvement areas in both short-and long-term solutions. Performance measures were also evaluated for each individual freeway segment. The elements considered in the analysis were:

Geometric Features

- Horizontal Alignment;
- Vertical Alignment;
- Stopping Sight Distance;
- Cross Section;
- Entrance and Exit Ramp Geometry, and;
- Decision Sight Distance.

Operational Features

- Lane and route continuity;
- Lane balance at Ramp Entrance and Exits;
- Ramp Sequencing, and;
- Guide Signing.

Performance Measures

- Accident Experience, and;
- Level of Service.

The Geometric (G) and Operational (O) features of each segment of the facility in comparison to its Performance Measures (PM) of safety (accidents) and quality of traffic flow (Level of Service) demonstrates the relationship between existing design features and the performance of the facility.

EVALUATION CRITERIA

For the existing features, a good rating implies a desirable standard, a fair rating equates with a minimum standard, while a poor rating indicates below standard design. The criteria used to evaluate the existing facility are summarized in Figures 3 through 5. A detailed documentation of basis and sources of these criteria is found in Appendix B.

Figure 3

GEOMETRIC FEATURES EVALUATION CRITERIA

FEATURE	RATING			1984 AASHTO POLICY PAGE REFERENCE
	GOOD	FAIR	POOR	
HORIZONTAL ALIGNMENT • Degree of Curve	Less Than 5°15'	5°15' To 8°15'	Greater Than 8°15'	191
VERTICAL ALIGNMENT • Grades	Level To 3%	3% To 4%	Greater Than 4%	633
STOPPING SIGHT DISTANCE • Distance • K ($^{L}/_{A}$)	Greater Than 525' Greater Than 190	450' To 525' 150 To 190	Less Than 450' Less Than 150	308
CROSS SECTION • Design Values	See Figure 5			629-719
DECISION SIGHT DISTANCE • Distance	Greater Than 1275'	1025' To 1275'	Less Than 1025'	147
RAMP TERMINAL DESIGN • Entrance Taper • Exit Diverge • Acceleration Length • Deceleration Length • Curvature At Nose	Greater Than 50:1 Less Than 4° Greater Than 910' Greater Than 430' Less Than 5°15'	40:1 To 50:1 4° To 5° 500' To 910' 315' To 430' 5°15' To 8°15'	Less Than 40:1 Greater Than 5° Less Than 500' Less Than 315' Greater Than 8°15'	1037 To 1045 1037 To 1045 1037 To 1045 1037 To 1045 191

Figure 4

OPERATIONAL FEATURES AND PERFORMANCE MEASURES EVALUATION CRITERIA

FEATURE	RATING			1984 AASHTO POLICY PAGE REFERENCE
	GOOD	FAIR	POOR	
LANE/ROUTE CONTINUITY	Maintains Continuity	N/A	Lacks Continuity	986 To 989
LANE BALANCE	Maintains Lane Balance	N/A	Lacks Lane Balance	FHWA, 1975
RAMP SPACING/SEQUENCING • En-En / Ex-Ex • Ex-En • En-Ex	 1500' 750' 3000'	 1000' To 1500' 500' To 750' 2000' To 3000'	 1000' 500' 2000'	1035
SIGNING Number of Message Units • One Panel • Two Panels • Three Panels Sequencing	 5 or Less 4 or Less 3 or Less Has Proper Advance Signing	 6 5 4 N/A	 Greater Than 6 Greater Than 5 Greater Than 4 Lacks Proper Advance Signing	Manual on Uniform Traffic Control Devices PP. 2E-1-2E-26
LEVEL OF SERVICE • Quality of Operation	A - C	D	E - F	274 - 275
ACCIDENTS • Per Million Vehicle Miles	1.07	1.07 To 2.11	2.11	ADOT Accident Rates

Figure 5

CROSS SECTION FEATURES EVALUATION CRITERIA

RATING	DESIGN VALUES
GOOD (Each of the features must meet criterion)	• Lane Width of 12 feet. • Right Shoulder Width at least 10 feet. • Left Shoulder Width at least 4 feet paved (4-lane sections) or at least 10 feet (for 6-lane and 8-lane sections). • Fore-slope designed to 6:1 for 0 to 5 ft. of fill; and 4:1 for greater than 5 ft. of fill. • Roadside barrier designed and placed according to current AASHTO standards. • Median barrier Provided for width and traffic volumes as described by current AASHTO standards.
FAIR (Each of the features must at least meet criterion)	• Lane Width of 12 feet. • Right Shoulder Widths at least 10 feet. • Left Shoulder Width of 1 to 4 feet (for all freeway sections). • Fore-Slope designed to 4:1 for 0 to 15 feet of fill; and 3:1 for greater than 15 feet of fill. • Roadside Barrier (Concrete or guardrail) with only minor deficiencies relative to current AASHTO standards.
POOR (Rating warranted if any of the features has noted deficiency)	• Lane Width less than 12 feet. • Right Shoulder Width less than 10 feet. • No left shoulder • Unprotected fore-slope 3:1 or steeper. • Roadside barrier designed or placed conflicting with current AASHTO

Reference: Chapter IV, pp. 353-412; Chapter VIII, pp 629-719, 1984 AASHTO A Policy on Geometric Design of Highways and Streets and Streets.

EXISTING FREEWAY PERFORMANCE

Measures of the operational effectiveness of the I-17 freeway is based on the system performance in terms of peak hour levels of service, and accident frequency. A significant part of the Phase I effort involved evaluating these performance measures.

EXISTING TRAFFIC VOLUMES

Traffic count data supplied by the Arizona Department of Transportation and collected by the project team were used to establish 1988 24-hour, and AM and PM peak hour traffic volumes for the entire project. The following procedure was used:

1. 1988 24-hour ramp and mainline traffic counts were furnished. Ramp counts were available throughout most of the corridor length, while mainline counts were available at intermittent locations only.

2. Manual count data for the ramp and cross street intersections for 1988 were also obtained and reviewed. These counts were available only at certain locations.

3. All of the above information was used to develop balanced 1988 AM and PM peak hour, and 24 hour volumes. Traffic count adjustments were made in order to accurately depict ramp and mainline volumes and to assure that balancing did not result in a significantly different volume than an actual count at any location.

To summarize, the project team used all available data to develop 1988 peak hour and 24-hour traffic volumes These volumes were balanced arithmetically and closely replicated mainline and ramp traffic movements at each interchange.

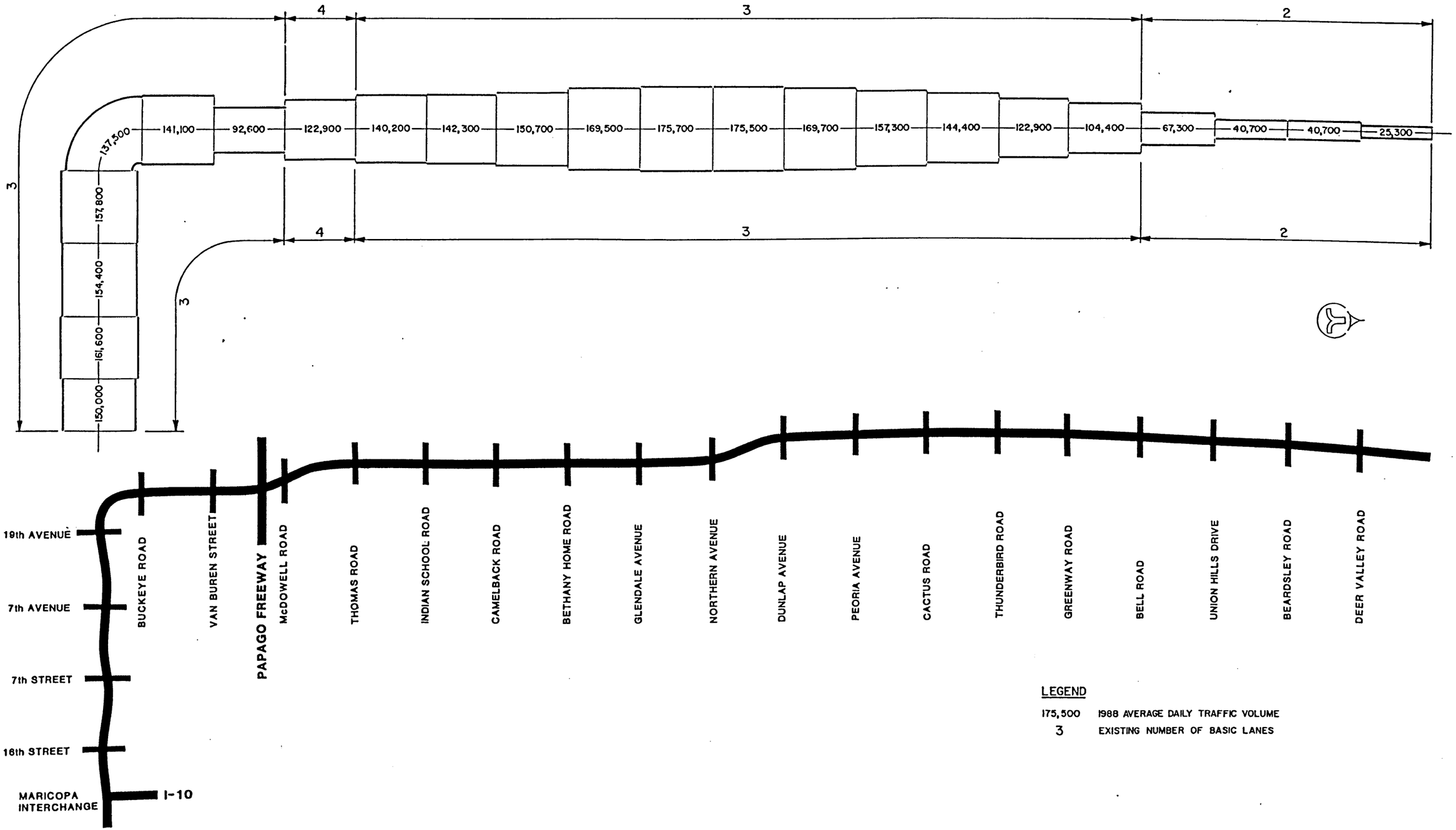
Exhibit 4 summarizes 1988 24-hour traffic characteristics for the entire system. The highest 24 hour volumes within the corridor occur between Peoria Avenue to Bethany Home Road reaching a maximum volume of 175,700 vehicles.

FREEWAY LEVEL OF SERVICE ANALYSIS

A complete analysis of traffic operations during the AM and PM peak hours were performed for the freeway proper and ramp terminals. Cross street operations were not included in the analysis. The traffic volumes and other pertinent traffic characteristics were evaluated using 1985 Highway Capacity Manual (HCM) techniques. Separate analyses were performed to determine the operation of mainline uninterrupted flow segments, exit and entrance ramp terminals, and weaving sections. The 1988 AM and PM peak hour and 24 hour traffic volumes and the results of the level of service analysis are denoted on Exhibits 5 through 10.

The HCM describes six levels of service for freeways. These levels range from free-flow operations (Level of Service A) to forced or breakdown flow (Level of Service F). For urban freeways, operations at Level of Service C is desirable, while Level of Service D is considered acceptable. Level of Service E is the capacity of the freeway.

Mainline Level of Service is largely a function of the volume of traffic across all lanes. Exit and entrance ramp Level of Service involves the volume of traffic in the lane from which the ramp exits or enters (generally, the right lane, or lane 1). Weaving Level of Service analysis considers the effects of closely spaced entrance and exit ramps that result in conflicting traffic streams along the mainline.



JACK E. LEISCH & ASSOCIATES

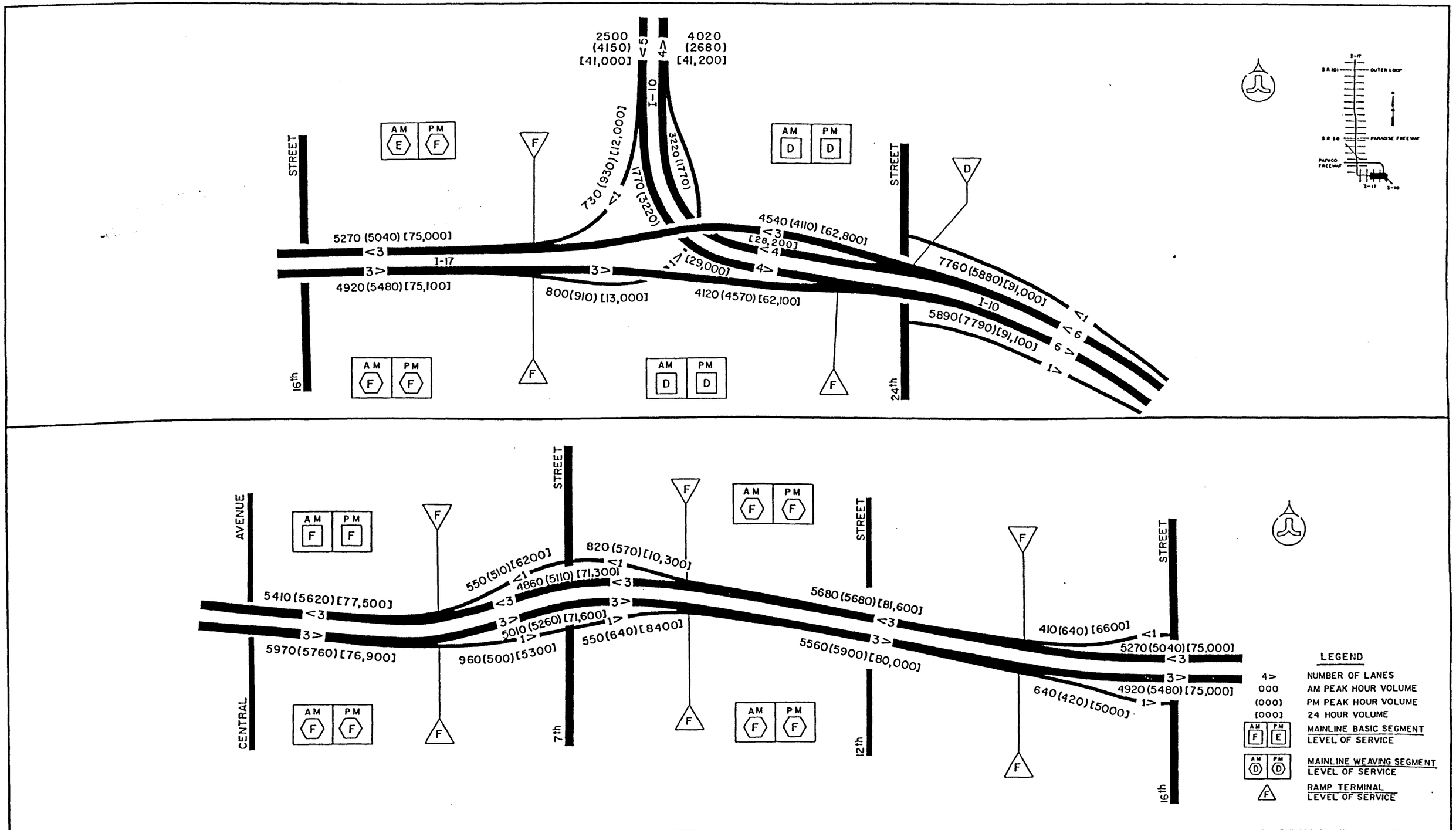
ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

1988 MAINLINE 24 HOUR TRAFFIC VOLUMES AND LANE CONFIGURATION

SCALE : NTS

FEBRUARY 1989

EXHIBIT 4



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

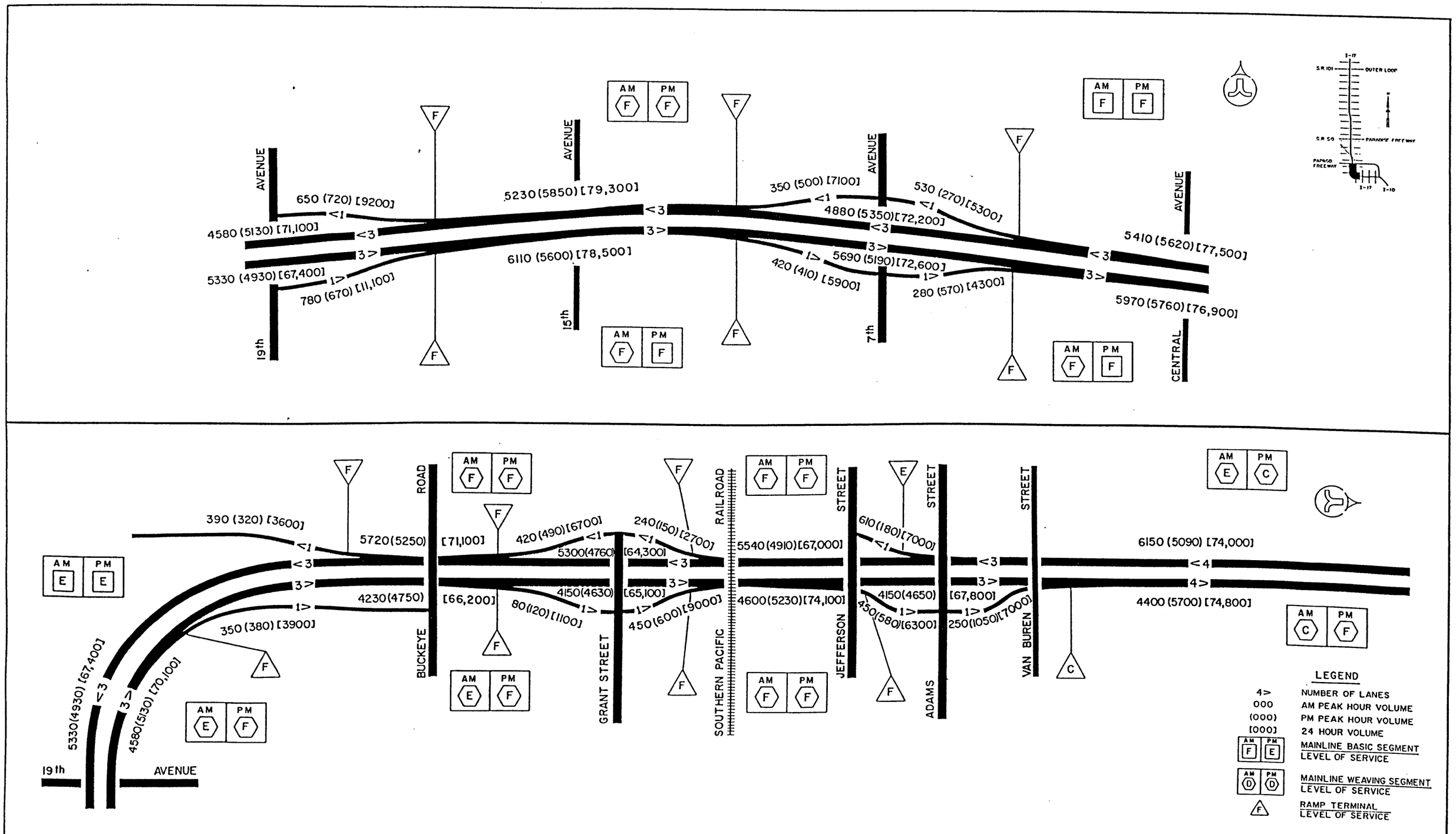
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF 1988 TRAFFIC VOLUMES
MARICOPA INTERCHANGE TO 7th STREET

SCALE : NTS

FEBRUARY 1989

EXHIBIT 5



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

INTERSTATE 17 CORRIDOR STUDY

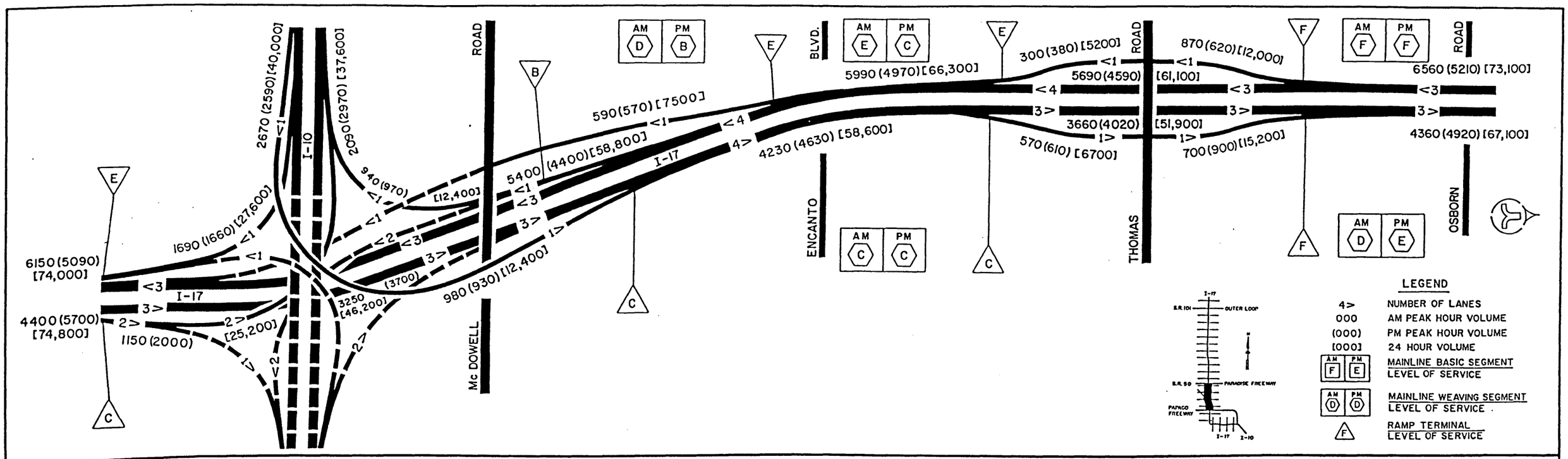
ANALYSIS OF 1988 TRAFFIC VOLUMES
7th AVENUE TO ADAMS STREET

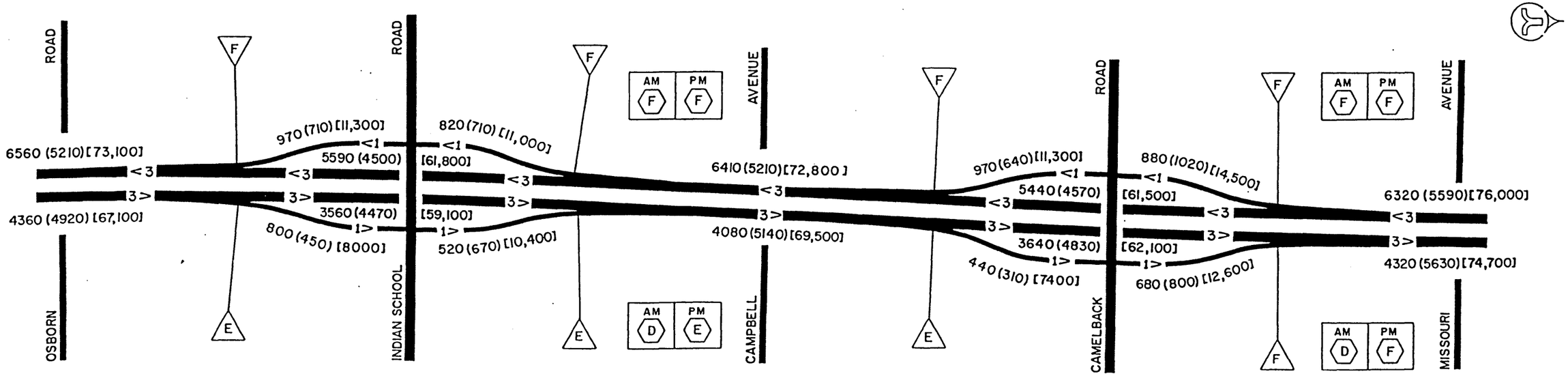
SCALE : NTS

FEBRUARY 1989

EXHIBIT 6

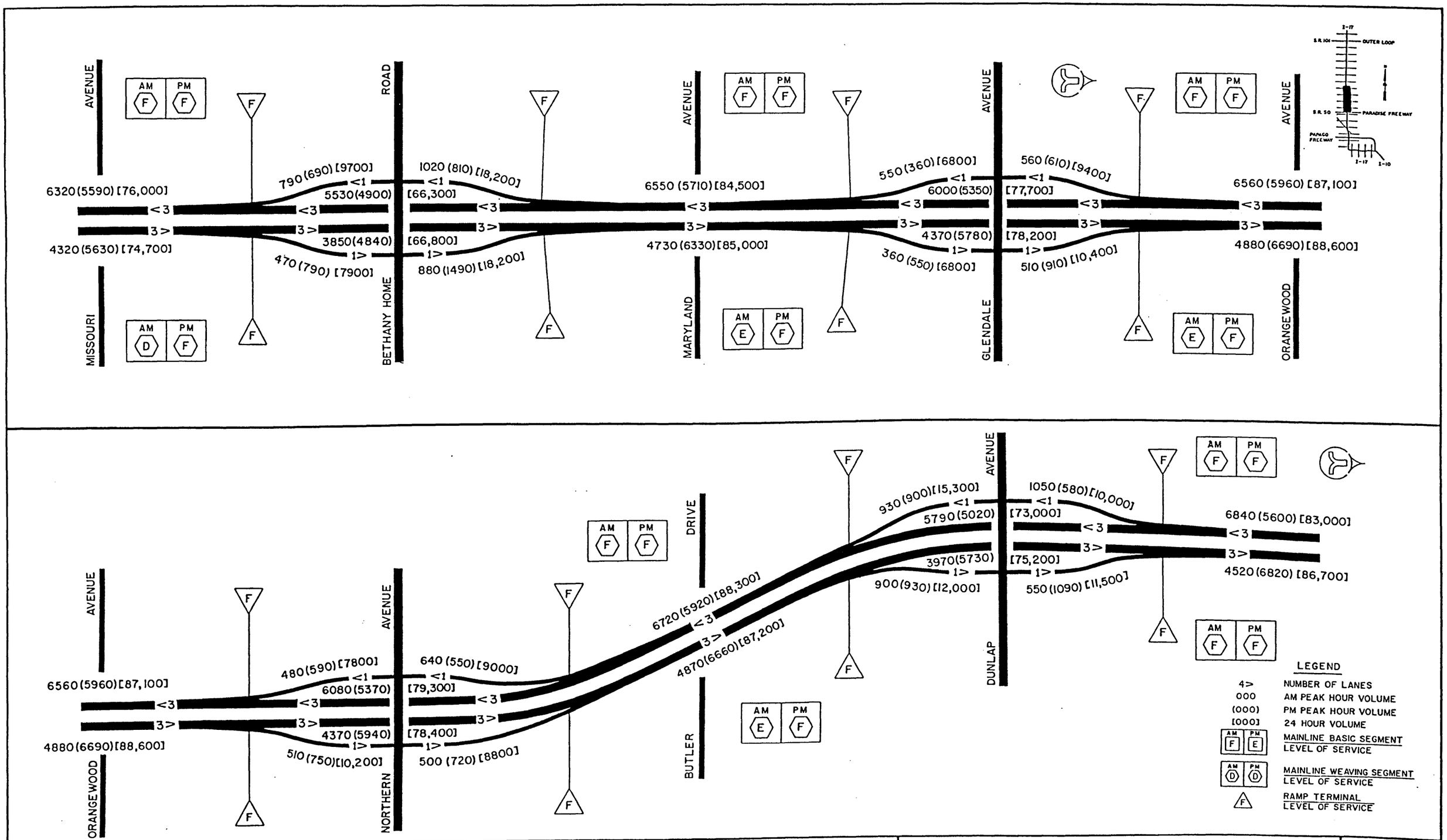
11205-3





JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ANALYSIS OF 1988 TRAFFIC VOLUMES PAPAGO FREEWAY TO CAMELBACK ROAD SCALE : NTS FEBRUARY 1989	EXHIBIT 7

11205-8



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

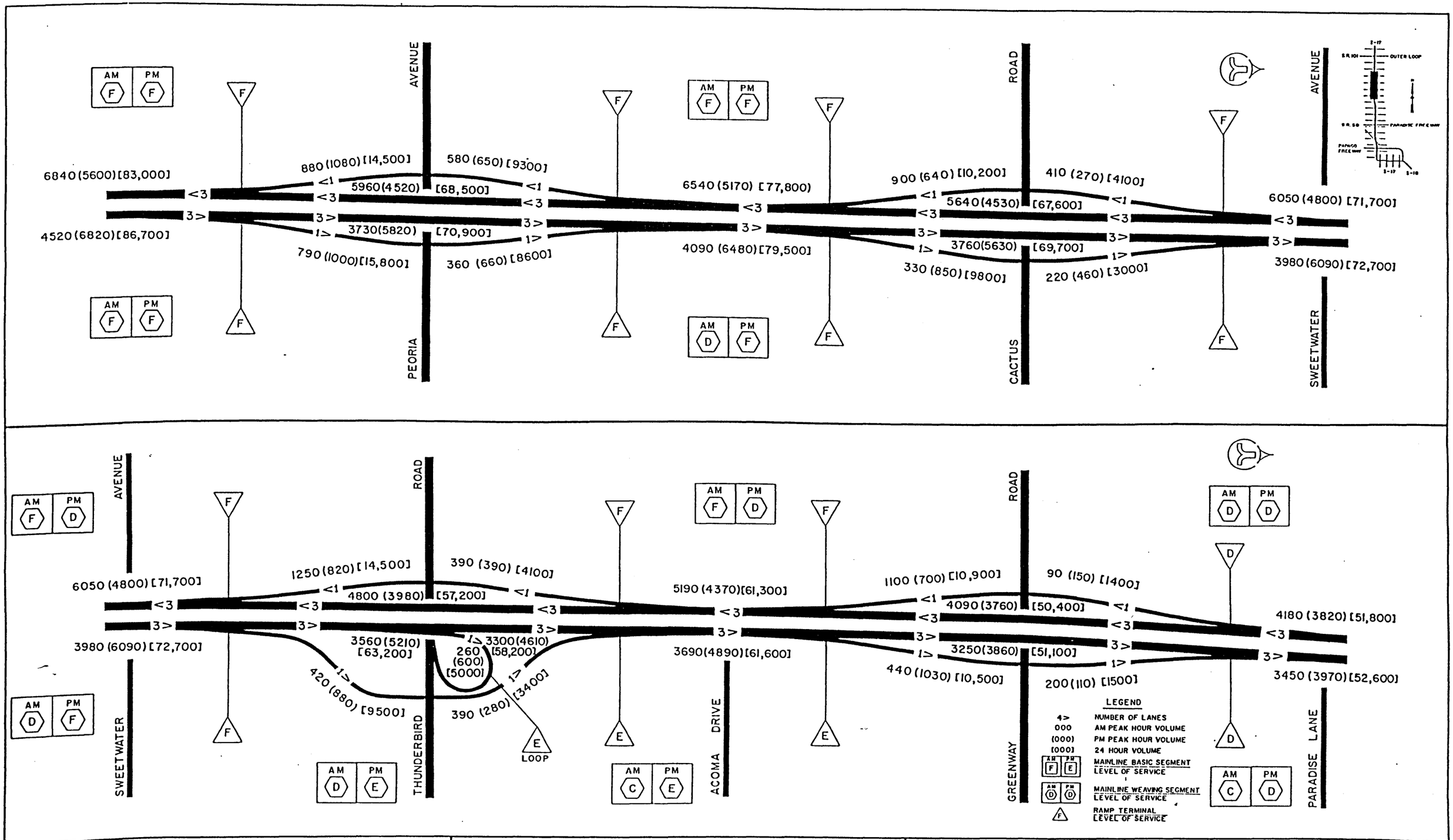
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF 1988 TRAFFIC VOLUMES
BETHANY HOME ROAD TO DUNLAP ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 8



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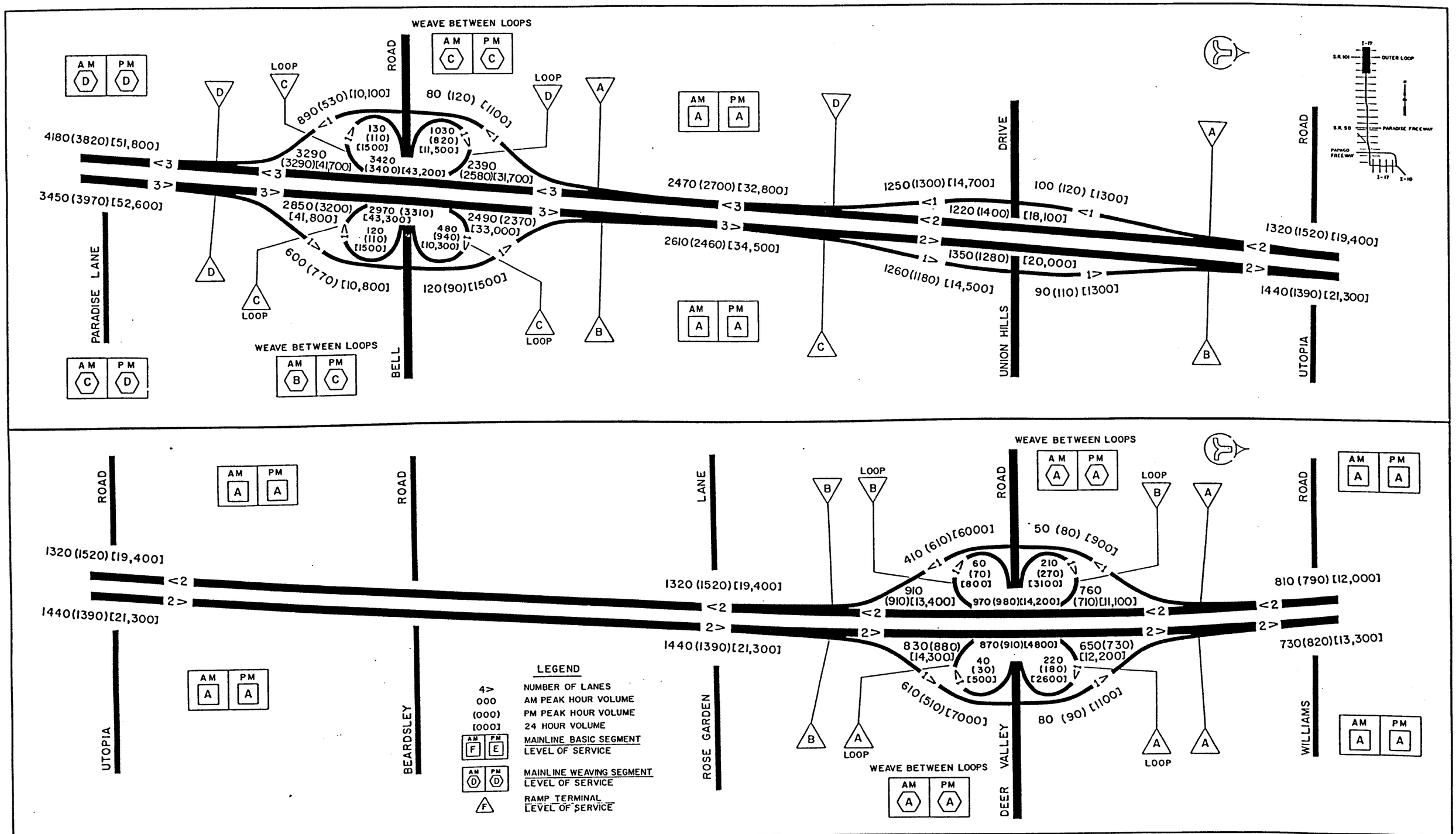
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF 1988 TRAFFIC VOLUMES
PEORIA ROAD TO GREENWAY ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 9



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF 1988 TRAFFIC VOLUMES
BELL ROAD TO DEER VALLEY ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 10

Freeway Analysis Procedures and Assumptions

The following assumptions were input to all freeway Level of Service analyses:

Design Speed	60 mph
Percent Trucks during Peak Hour	4 to 6 percent
Peak Hour Factor	0.95
Terrain	Level

Both Level of Service calculations and field observations verify that poor freeway operations occur on large portions of I-17 within the study area. For the most part, poor Levels of Service (E to F) occur primarily during morning and evening peak periods. However, there are locations experiencing poor midday operations. The extent of such operations and their undesirable side-effects such as accidents, greater user costs, and driver discomfort, should be of concern.

Level of Service (LOS) Conditions

Significant capacity problems occur on most segments of I-17 during the AM and PM peak periods. Several level of service problems associated with capacity are apparent: uninterrupted flow that exceeds mainline capacity; weaving maneuvers between entrance and exit ramps; and poor ramp terminal operations. Stagnation of traffic flows occur in both directions during the AM and PM peak periods along most segments of the freeway. There are few segments of the facility that operate at LOS E or better during peak periods.

As traffic in the right lane of the freeway approaches capacity, the merging and diverging maneuvers at ramp terminals cause operational breakdown on the freeway. In addition, the one-mile spacing of interchanges along I-17 results in the overlapping of the ramp merging and diverging maneuvers (weaving) which further denigrates the traffic operations (Level of Service) across all lanes of the freeway.

In the south sections of the corridor, between the Maricopa Interchange and the Papago Interchange, the directional distribution of traffic during the AM and PM peak periods is nearly equal. The mainline peak hour volumes range from 5,000 to 6,000 vehicles per hour in each direction. The Level of Service in this section is in the range of E-F during the peak periods because of high traffic volumes and the weaving maneuvers between the closely spaced interchanges. Traffic operations of the Maricopa Interchange will improve upon completion of the Papago Inner Loop.

Between the Papago Interchange and Thunderbird Road, there is an 55/45 directional distribution, southbound in the AM peak and northbound in the PM peak. Even with this directional distribution, virtually all segments of the freeway operate at LOS F in both directions during the AM and PM peak periods. These poor operating conditions are created by inadequate freeway capacity and exacerbated by the weaving maneuvers between the closely spaced interchanges. This most critical section of freeway is located within the narrowest right-of-way section (200 ft.)

In the north section between Thunderbird Road and Deer Valley Road, operating conditions are generally improved. The Level of Service ranges from LOS D north of Greenway Road to LOS A-C north of Bell

Road. North of Bell Road, the directional distribution of traffic reverses, with the heavier volumes northbound in the morning peak and southbound in the evening peak.

FREEWAY ACCIDENT EXPERIENCE

An important consideration in evaluating freeway operations is the accident experience of the facility. An evaluation of the accident rates and types was conducted in two steps. The first was to determine the variability in accident rates throughout the study area. The second step determined an overall characterization of accident types.

Accident Rate Methodology

Using computer-generated accident data and collision diagrams provided by the Arizona Department of Transportation, the accident history was analyzed for a three-year period from 1985 through 1987. The analysis included the following tasks:

1. Separate analysis sections were defined for determining accident rates. Section definitions were based on centering each interchange within a one-mile analysis section.

2. Summaries were provided listing accidents by number of vehicles (single vehicle, multi-vehicle), vehicle type(s) (truck, passenger car): severity (fatal or injury, property damage only): pavement condition (wet, dry) and light conditions (day, night).

3. Collision diagrams for the study years were reviewed to determine the accident type. Accident experience was separated into rear end, single vehicle, side swipe and miscellaneous accident types.

4. Accident rates for each study section were compared to statewide accident rates on urban freeways for the three year analysis period.

Accident Evaluation Results

Tables 1 and 2 summarize accident rates that were calculated for each analysis section. By inspecting the accident rates and types for each analysis section, the following conclusions can be drawn:

1. Throughout the study area, the accident rate for both directions is 2.06 accidents/MVM. This is 29 percent higher than the Arizona statewide rate of 1.60 accidents/ MVM. By direction, the northbound accident rate was 2.08 accidents/MVM for urban freeways while the southbound rate was slightly lower with a rate of 2.04 accidents/MVM.

2. In the northbound direction, most "poor" ratings were recorded in the southern portion of the project between the Maricopa interchange and Indian School Road. Southbound, most "poor" ratings occurred in the central to southern portion of the project area, between Cactus Road and Buckeye Road. These high accident rates may be partially attributed to

TABLE 1
I-17 NORTHBOUND
ACCIDENT RATES BY SECTION
YEARS 1985 TO 1987

MAJOR INTERCHANGE	MILEPOST - MILEPOST	TOTAL ACCIDENTS	ACCIDENT RATE (ACC/MVM)
I-10	194.02 to 194.50	17	0.53
16th Street	194.50 to 195.50	173	2.56
7th Street	195.50 to 196.50	202	2.96
7th Avenue	196.50 to 197.50	146	2.16
19th Avenue	197.50 to 198.50	127	1.90
Buckeye Road	198.50 to 199.50	210	3.16
Van Buren Street	199.50 to 200.50	154	2.31
McDowell Road	200.50 to 201.50	176	2.64
Thomas Road	201.50 to 202.50	165	2.47
Indian School Road	202.50 to 203.50	111	1.64
Camelback Road	203.50 to 204.50	115	1.68
Bethany Home Road	204.50 to 205.50	130	1.90
Glendale Road	205.50 to 206.50	128	1.87
Northern Road	206.50 to 207.50	121	1.79
Dunlap Road	207.50 to 208.50	121	1.84
Peoria Avenue	208.50 to 209.50	127	2.03
Cactus Road	209.50 to 210.50	193	3.22
Thunderbird Road	210.50 to 211.50	200	3.55
Greenway Road	211.50 to 212.50	59	1.17
Bell Road	212.50 to 213.50	22	0.56
Union Hills Drive	213.50 to 214.50	6	0.23
Beardsley Road	214.50 to 215.50	3	0.15
Deer Valley Road	215.50 to 216.50	7	0.40

TABLE 2
I-17 SOUTHBOUND
ACCIDENT RATES BY SECTION
YEARS 1985 TO 1987

MAJOR INTERCHANGE	MILEPOST - MILEPOST	TOTAL ACCIDENTS	ACCIDENT RATE (ACC/MVM)
I-10	194.02 to 194.50	11	0.34
16th Street	194.50 to 195.50	103	1.53
7th Street	195.50 to 196.50	125	1.83
7th Avenue	196.50 to 197.50	77	1.14
19th Avenue	197.50 to 198.50	124	1.85
Buckeye Road	198.50 to 199.50	90	1.36
Van Buren Street	199.50 to 200.50	164	2.46
McDowell Road	200.50 to 201.50	112	1.68
Thomas Road	201.50 to 202.50	221	3.31
Indian School Road	202.50 to 203.50	183	2.71
Camelback Road	203.50 to 204.50	162	2.37
Bethany Home Road	204.50 to 205.50	142	2.08
Glendale Road	205.50 to 206.50	145	2.12
Northern Road	206.50 to 207.50	150	2.22
Dunlap Road	207.50 to 208.50	203	3.09
Peoria Avenue	208.50 to 209.50	158	2.52
Cactus Road	209.50 to 210.50	120	2.00
Thunderbird Road	210.50 to 211.50	104	1.84
Greenway Road	211.50 to 212.50	93	1.85
Bell Road	212.50 to 213.50	113	2.89
Union Hills Drive	213.50 to 214.50	1	1.21
Beardsley Road	214.50 to 215.50	24	1.21
Deer Valley Road	215.50 to 216.50	6	0.34

the construction activity on portions of I-17 during the three year analysis period.

3. For both directions, rear-end accidents comprised 53 percent of all reported accidents. In the southbound direction, 55 percent of the accidents were rear-ends. This was slightly higher than 51 percent rear-end accidents recorded in the northbound direction.

In general, accidents cluster around interchanges. This is to be expected, considering that vehicle conflicts increase at, or near interchanges. In the case of the I-17 corridor, the peak period capacity constraints combined with the sub-standard entrance and exit ramp designs exacerbate vehicular conflicts. The high number of rear-end collisions indicate that the freeway congestion, high ramp volumes, and poor ramp terminal design is prohibiting drivers from making safe merge and diverge maneuvers. Ratings of the accident experience by analysis sections are shown on the evaluation exhibits in the next chapter.

FREEWAY EVALUATION RESULTS

The primary objective of Phase I efforts of the system operations and design study was to perform a detailed review of the geometric and operational characteristics of the I-17 freeway corridor. To simplify the following discussion, the study corridor was separated into three sections. Each of these sections, (south, central, and north) have unique design and operational characteristics. In addition to the generalized discussion of the description and evaluation of each section, detailed ratings are graphically portrayed.

SOUTH SECTION

The south section of I-17 begins at the Maricopa Interchange and ends at Thomas Road. I-17 is a 6-lane roadway with a 16-foot wide center median and 8-foot wide outside shoulders. Double faced concrete barrier separates the three north and southbound lanes allowing 7 feet of usable inside shoulder width. Adjacent to the outside shoulder there is a 2-foot curb and gutter section, providing a 10-foot usable shoulder. At the underpasses, the median barrier narrows and becomes flush with the center bridge pier. This allows approximately 7.25 feet of usable shoulder at these locations. From I-10 to west of 19th Avenue, the freeway is constructed on approximately 18 feet of fill. Side slopes range from 2:1 to 1-1/2:1 due to the changes in right-of-way widths which narrow from 300 feet to 280 feet.

West of 19th Avenue, at the Durango Curve, the north and southbound roadways separate into independent horizontal and vertical alignments. The northbound lanes descend to ground level while the southbound lanes remain on fill. North of the Durango Curve, the southbound profile descends to join the northbound alignment, at ground level. After the roadways join, the freeway continues north and becomes a depressed section for about 2.5 miles. Between Buckeye Road and Van Buren Street, the freeway profile is approximately 19 feet below ground level with 1-1/2:1, gunite protected side slopes. The right-of-way width in this segment is approximately 366 feet. Between Van Buren Street and McDowell Road the freeway cross section opens up to accommodate the system ramps of the Papago Interchange.

The south section has continuous 2-lane, one-way frontage roads on each side of the freeway beginning at 16th Street. The width of the frontage roads at the ramp merge have been reduced to one lane at selected interchanges, reducing the operational flexibility of the continuous frontage road system. Freeway ramps tie to the frontage roads and provide access to city cross streets and local properties adjacent to the freeway.

During 1988, successive portions of the Papago Interchange were opened to traffic. Construction of the four-level, fully directional interchange resulted in associated improvements to I-17 from Van Buren Street to Thomas Road. These improvements included improving cross sectional elements by widening the freeway for the new system ramps and rebuilding the McDowell Road, Grand Avenue and Thomas Road structures.

All ramps originally constructed in this section during the early 1960's are substandard when evaluated according to current design policy. The existing parallel design does not provide adequate acceleration or deceleration length for safe merge and diverge maneuvers. In the elevated section, in addition to the inadequate deceleration length, sub-standard vertical curve lengths at the ramp merge/diverge points (as short as 200 feet) yield inadequate

stopping sight distance. Also, excessive ramp grades (as steep as 6 percent) make it difficult for vehicles, especially trucks, to accelerate to a safe merging speed within the short distances provided.

With two exceptions, ramps added or modified since the original construction comply with current design policy. The two exceptions are the northbound Thomas Road exit ramp and the southbound Van Buren Street exit ramp. Each of these ramps has a diverge angle exceeding 5°. The Van Buren Street and Thomas Road ramp diverge angles are 8° 10' and 7° 51', respectively.

The evaluation of the south section is summarized below and the results are graphically detailed in Exhibits 11 through 15.

Geometric Features

- Horizontal Alignment though this section ranges between "good" and "poor". Segments near Seventh Street and in the Durango curve area are rated poor because of insufficient superelevation rates for the corresponding degree of curve.

- Vertical Alignments are rated "good" through this section. Only one segment of the freeway grade exceeds one percent. A 2.5 percent grade occurs southbound through the Durango curve.

- Stopping sight distance is "good" through the section except at the Durango curve. A two foot separation between the left lane and the median barrier provides inadequate horizontal sight distance in the southbound direction.

- Decision sight distance is adequate in the south section except in the depressed area between the Durango curve and Van Buren Street. Closed end abutments at the cross street structures provide insufficient sight distance to the exit ramps.

- Cross Section elements through most of the south section are "good" except in the Durango curve area and in the depressed section. Within the Durango Curve area, inadequate shoulder widths (two feet in some locations) provide insufficient stopping sight distance. In the depressed section, barrier curb and steep side slopes require "poor" ratings.

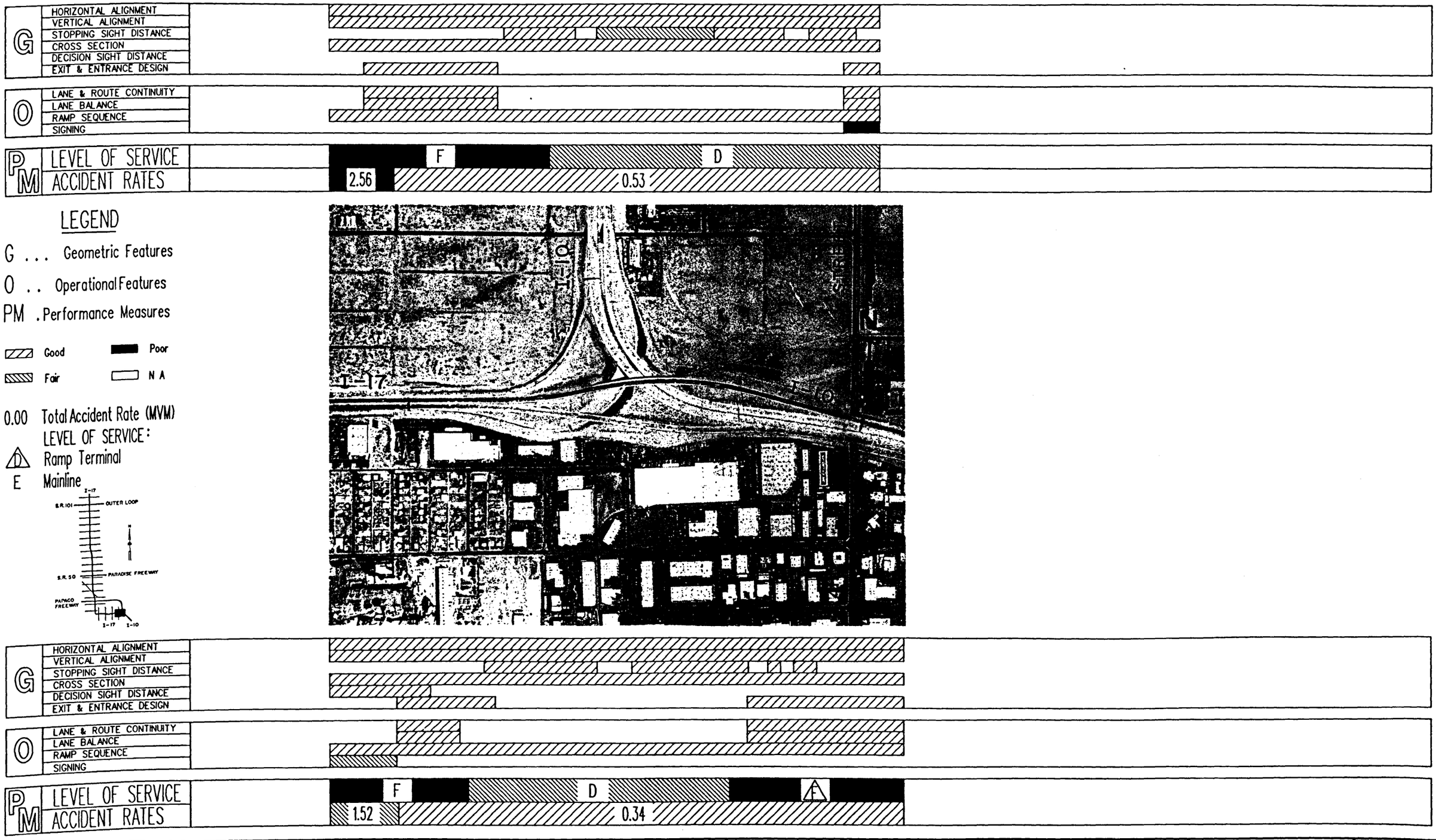
- Entrance and Exit design information was detailed in the general description of the south section limits. Most ramp terminals are rated "poor" through the section because of inadequate acceleration and deceleration lengths.

Operational Features

- Lane and route continuity is provided throughout this section.

- Lane balance criteria is achieved at all entrance and exit ramp locations.

- Ramp sequencing is adequate at all locations except northbound between the ramps at Grant Street and Adams Street and southbound between Grant Street and Durango Street. These closely spaced ramps create a "poor" rating.



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

INTERSTATE 17 CORRIDOR STUDY

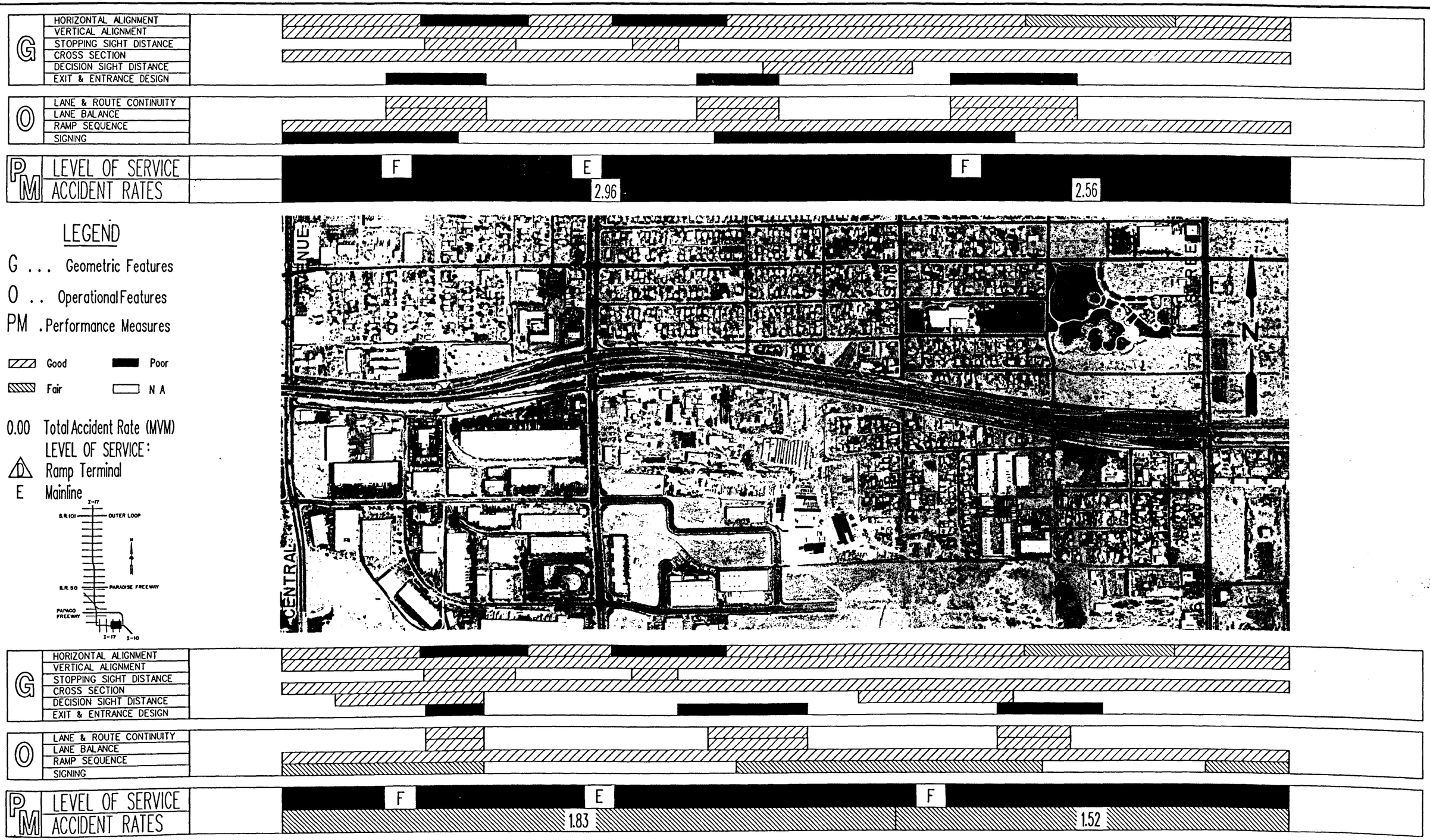
ANALYSIS OF EXISTING FREEWAY
MARICOPA INTERCHANGE TO 16th ST.

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT

11



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ARIZONA DEPARTMENT OF TRANSPORTATION

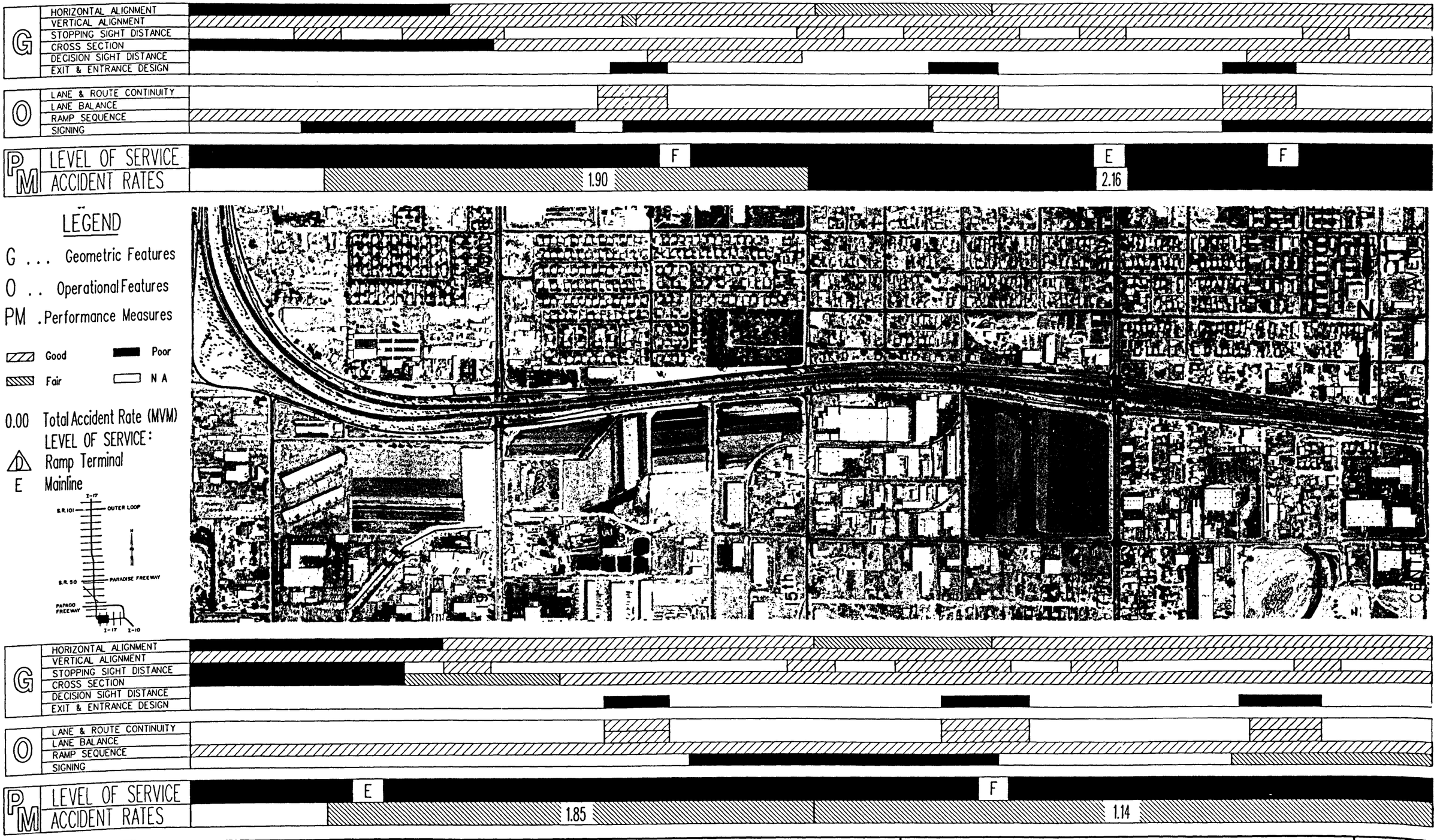
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
16th ST. TO 7th ST.

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 12



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

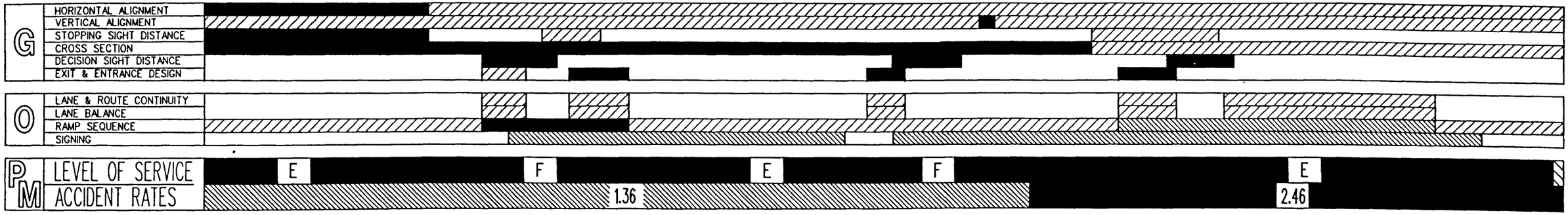
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
7th AVE. TO 19th AVE.

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 13



LEGEND

G . . . Geometric Features

O . . Operational Features

PM . Performance Measures

Good — Poor

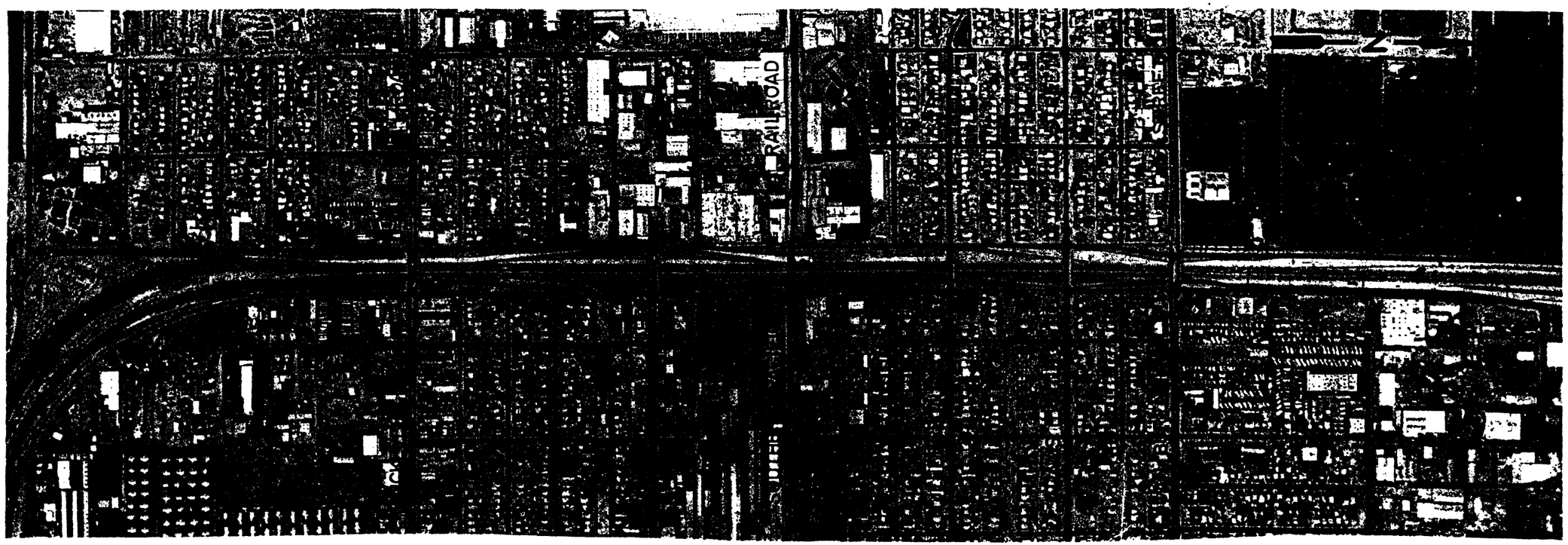
Fair — N A

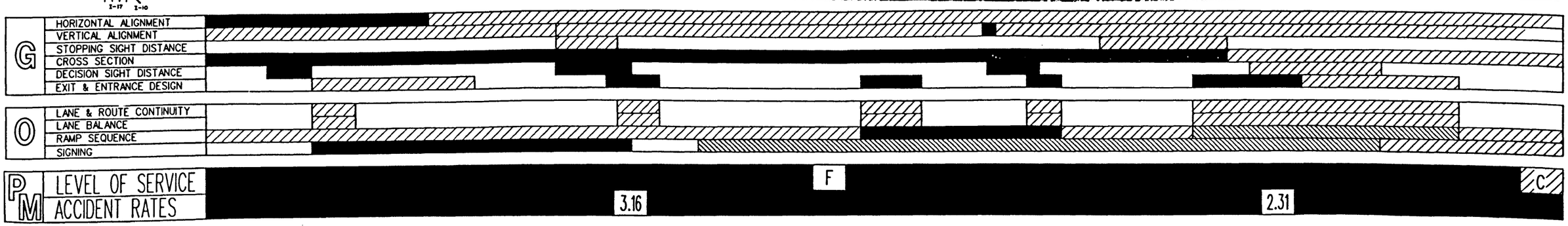
0.00 Total Accident Rate (MVM)

LEVEL OF SERVICE:

D Ramp Terminal

E Mainline





JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

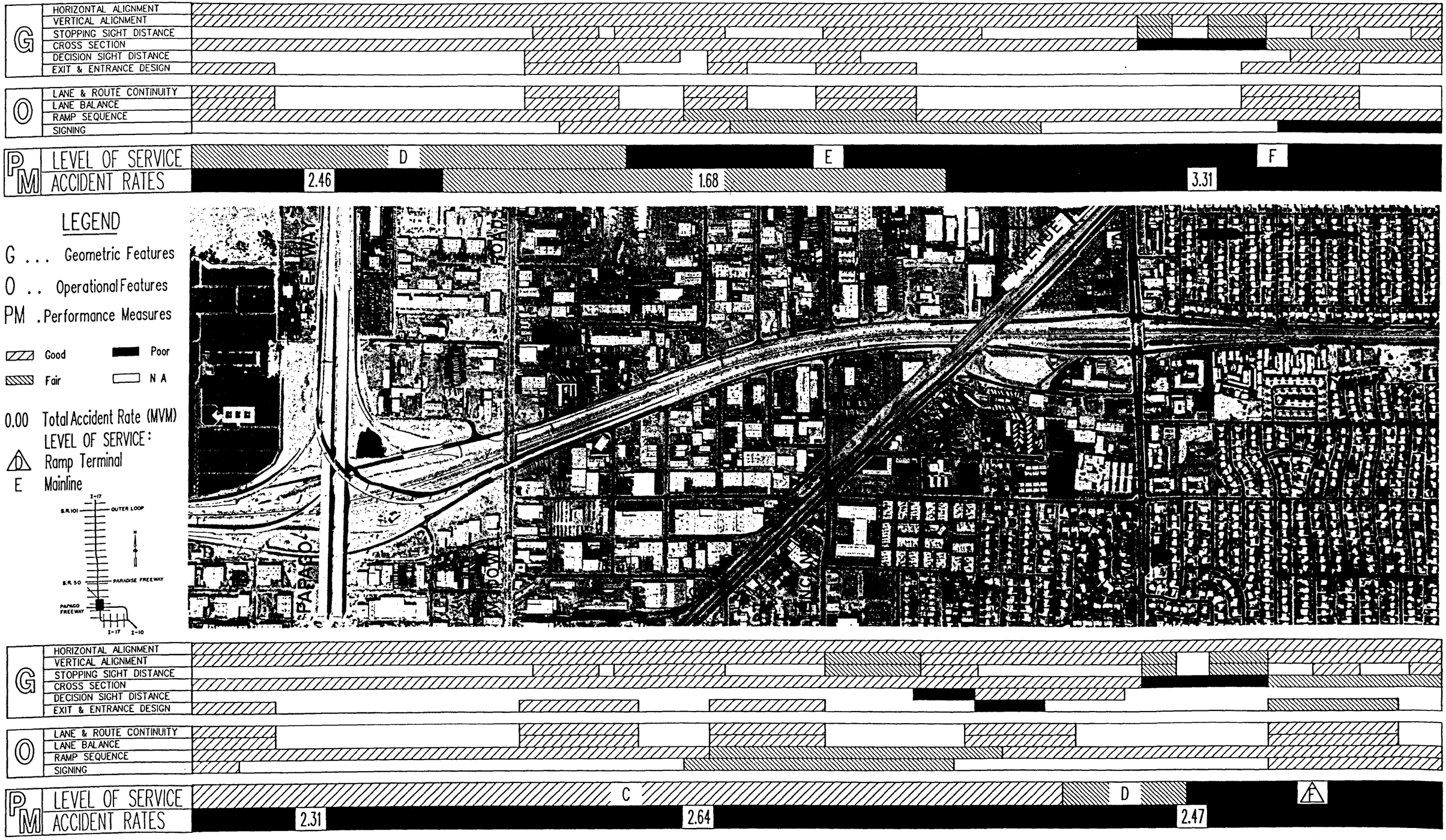
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
BUCKEYE TO ADAMS

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 14



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
PAPAGO (I-10) TO THOMAS

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 15

- Signing in this section rated between "fair" and "poor". Most locations, with a poor rating, exceed the criteria for message units. Lack of one mile advance signing southbound at Grant Street, Durango Street, and Seventh Avenue creates "poor" ratings for these locations.

Performance Measures

- Level of Service and traffic volumes for the south section are detailed in Exhibits 7 through 9. Level of service through most of the section is rated "poor" . Exceptions occur in the vicinity of the recently reconstructed interchanges with I-10.

- Accident rates in this section are generally "poor". Northbound, high rates occur through the entire section. A "fair" rating occurs at 19th Avenue. Southbound, accident rates are predominantly "fair", with "poor" locations occurring just north of Jefferson Street and South of Thomas Road. The accident rates within this section may have been higher than normal due to the construction of Maricopa and Papago interchanges.

CENTRAL SECTION

The central section begins at Thomas Road and ends at Dunlap Avenue. This section is the narrowest section within the corridor. Beginning at Thomas Road, typical section right-of-way widths are 200 feet and flare to a width of 400 feet at the one-mile cross street interchanges.

The cross section through this segment is also 6 six lanes wide with a 16-foot wide median and 8-foot wide right shoulder. A 2-foot wide curb and gutter runs along the right shoulder, while double faced concrete barriers separate northbound and southbound traffic. The median barrier narrows at the underpasses, providing a net median shoulder width of 7.25 feet. One-way, 2-lane frontage roads are located on each side of the freeway. A 12-foot wide buffer separates the freeway and frontage roads.

In this section, the freeway gradient is approximately 0.3 percent, rising gradually to the north. The profile undulates each mile as I-17 passes under the cross streets. To pass under the structures, the profile grade changes from a 2.5 percent downgrade to 2.5 percent upgrade. The profile grade changes are facilitated by relatively short crest and sag vertical curves. These vertical curves have an average length of approximately 600 feet.

In the depressed sections, gunite protected, 1-1/2:1 side slopes line the freeway. Barrier curb runs the length of the right shoulders. This curbing provides 1'-6" clearance between the edge of the right shoulder and the closed end abutments of the overcrossing structures.

Within the central section, the frontage road design effectively provides only one continuous lane, limiting the use of the frontage roads as a relief route for the mainline. Typically the frontage roads are 3 lanes wide at the cross road. The 3 lanes narrow to 2 lanes before splitting with one lane accessing the freeway and one lane continuing on. Immediately after the ramp diverge the frontage road widens to 2 lanes and then narrows to one lane in advance of the ramp merge. After the ramp joins, the frontage road widens to 3 or 4 lanes approaching the intersection.

The ramp design in the central section is similar to the design used in the south section. Nearly half of all ramps within this section are substandard when evaluated according to current design policy. Of those substandard ramps, more than 3/4 of them were entrance ramps. Inadequate acceleration lengths to complete the merge maneuvers is the predominant design deficiency.

Evaluation results for the central section are summarized below. Detailed ratings for the section are shown graphically in Exhibits 16 through 18.

Geometric Features

- **Horizontal alignment** in this section is predominantly tangential. Therefore, "good" ratings apply. An exception occurs between Northern Avenue and Dunlap Avenue. In this location the superelevation rate is insufficient for the corresponding degree of curve. This segment is rated "poor".

- **Vertical alignment** is "good" through this section. Profile grades of significant length range between approximately 0.2 percent and 0.4 percent.

- **Stopping sight distance** in this section is "good" except at locations where the freeway passes under the one-mile cross streets. At these locations, the stopping sight distance for the corresponding vertical curve length provides a design speed between 50 mph and 60 mph. A "fair" rating was assigned to these locations.

- **Decision sight distance** is "good" through most of central section. Less than the AASHTO recommended length of 1000 feet is available at the northbound exit to Dunlap Avenue. This location is rated "poor".

- **Entrance and exit design** information was detailed in the general description of the central section limits. Almost half of all ramps in this section are rated "poor". The most common deficiency is inadequate length provided to complete merge and diverge maneuvers.

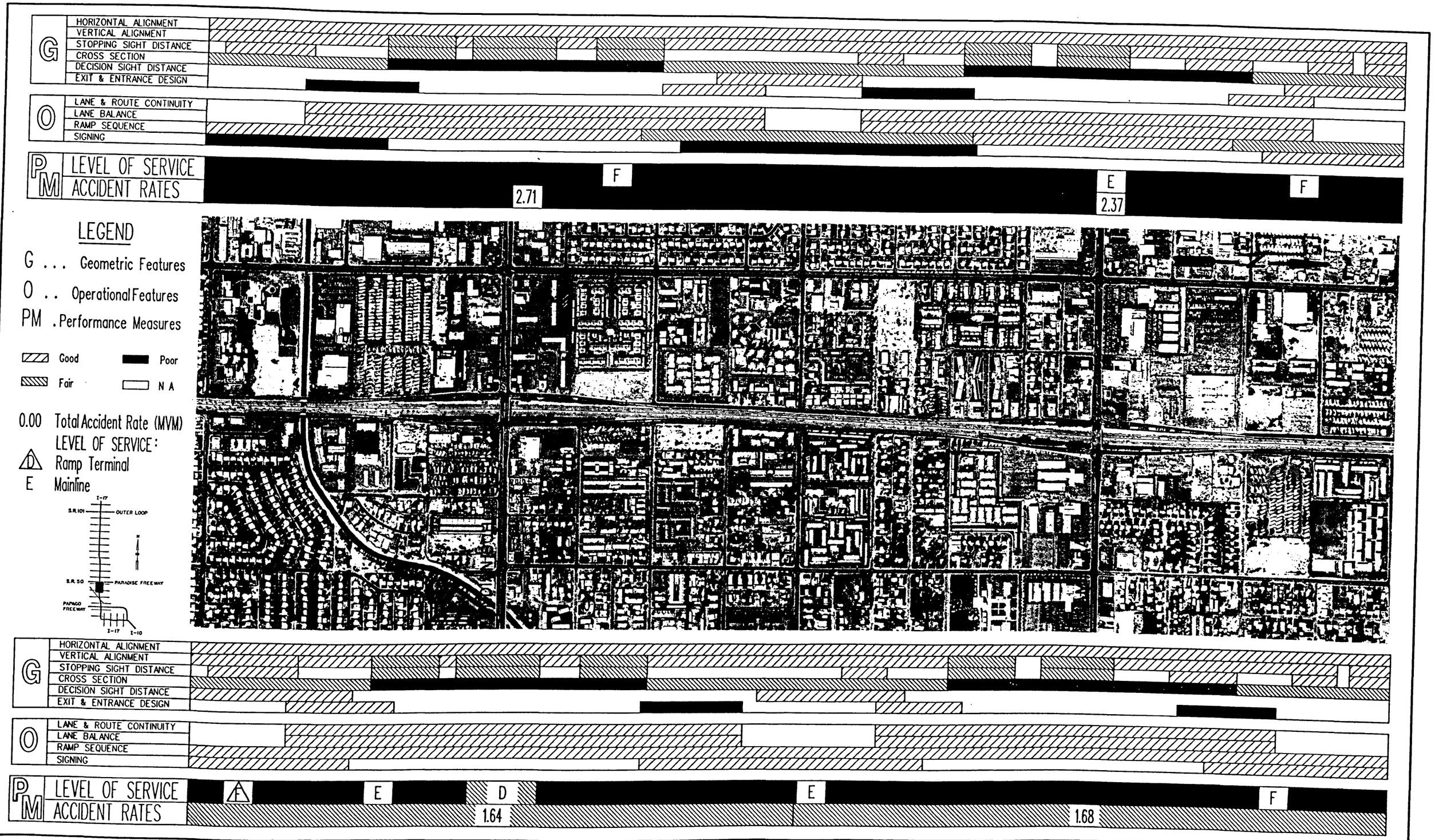
- **Cross section** elements in the central section rated "good" at virtually all locations. The exceptions occur in the depressed sections at the one-mile cross streets. The unprotected closed end abutments of the cross street structures create a "poor" rating.

Operational Features

- **Lane and route continuity** is provided throughout this section.

- **Ramp sequencing** is adequate at all locations within the section.

- **Signing** is adequate in the central section. The signing for the southbound exits to Indian School Road and Thomas Road does not meet the design criteria and was rated "poor".



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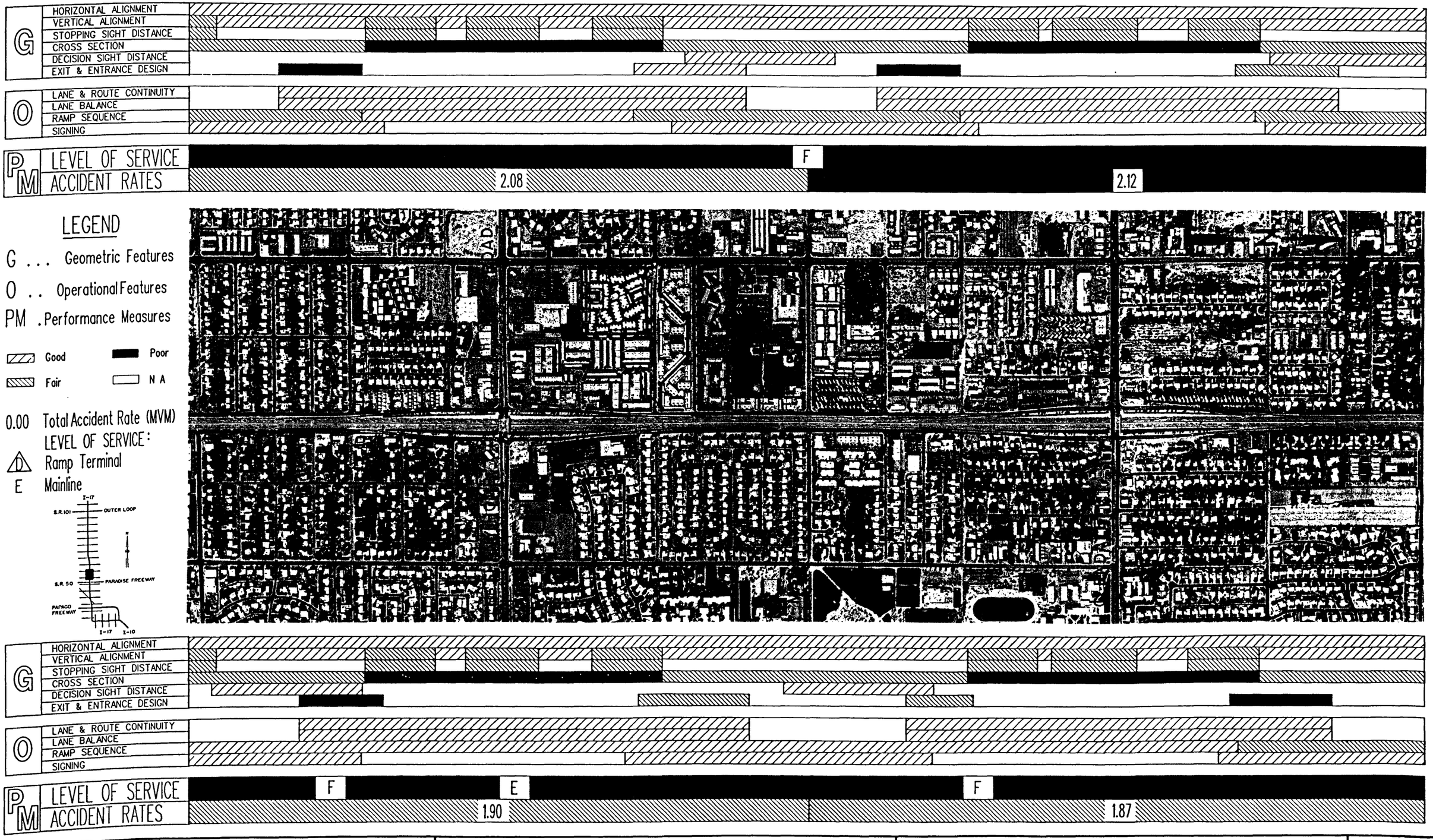
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
INDIAN SCHOOL TO CAMELBACK

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 16



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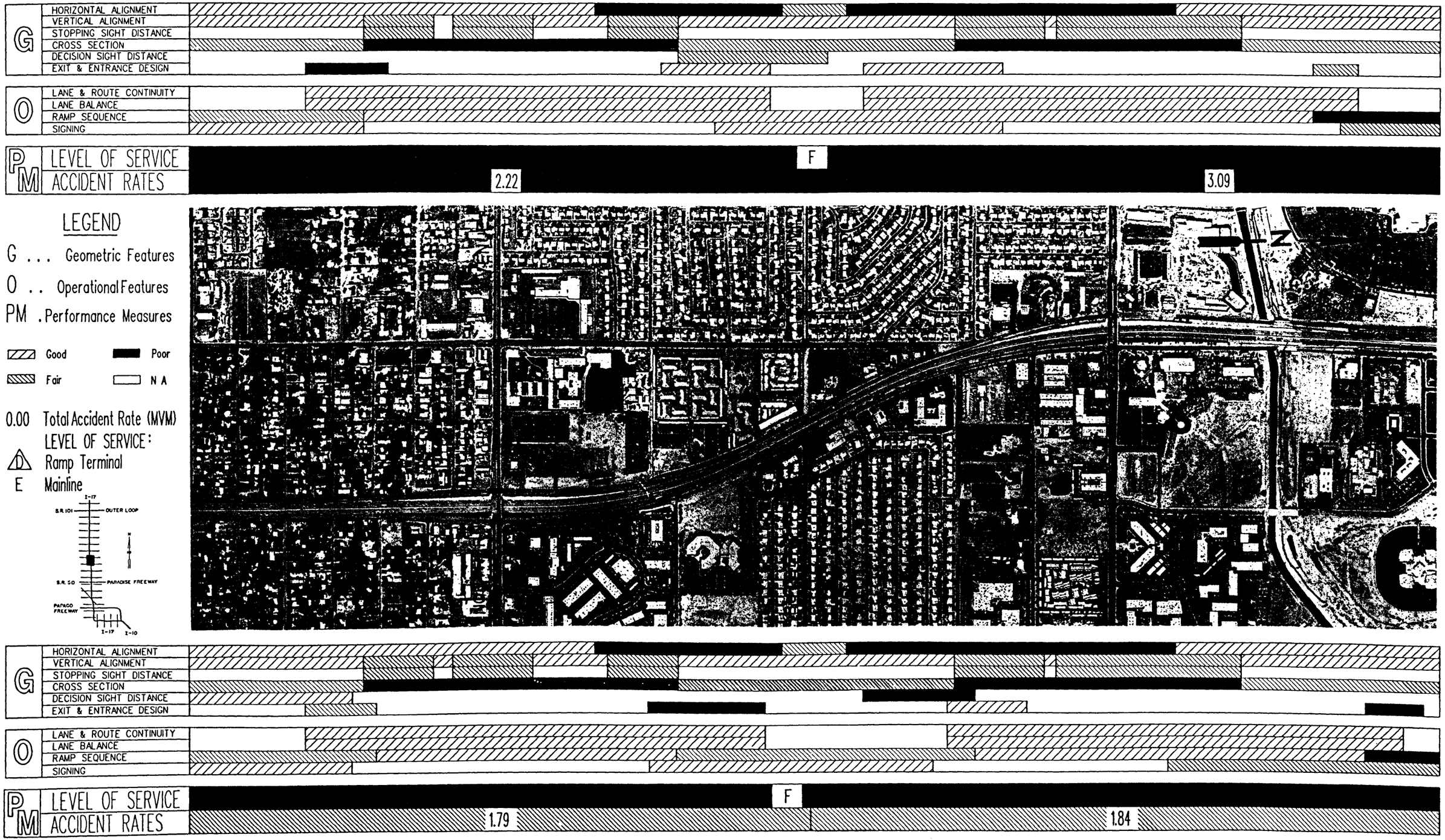
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
BETHANY HOME TO GLENDALE

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 17



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
NORTHERN TO DUNLAP

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 18

Performance Measures

- Level of service and traffic volumes for the central section are detailed in Exhibits 9 through 10. Level of service in this section rated "poor" in virtually all locations. Southbound I-17 operates at level of service "F" during both the AM and PM peak hour, while the northbound operates at level "D-E" during the AM peak hour and level of service "E-F" during the PM peak hour.

- Accident rates are "poor" in the southbound direction along the length of the central section except at Bethany Home Road. The highest accident rate in the southbound direction for the entire corridor (3.31 accidents/ MVM) occurs at Thomas Road. In the northbound direction, "fair" ratings were assigned to all sections.

NORTH SECTION

The north section of the project area begins at Dunlap Avenue and ends at Deer Valley Road. This section has minimum right-of-way widths of 280 feet. A significant change in design philosophy is evident when compared to the other two sections.

Although the basic cross sectional elements in this segment are similar to those in the south sections, the design of the north section is significantly different in two ways. The first is the freeway profile grade and the second is the interchange configuration. Beginning at Peoria Avenue, the freeway profile grade remains at a constant gradient of approximately 0.4 percent to the north while the intersecting cross streets pass under the freeway. This eliminates the rolling freeway profile and poor cross sections that are prevalent in the central section.

The second difference between the north and the south sections is the pronounced change in interchange design. The north section has two, four-quadrant cloverleaf interchanges and one partial cloverleaf interchange. The full cloverleaf interchanges are located at Bell Road and Deer Valley Road while the partial cloverleaf interchange is located at Thunderbird Road. Originally constructed with loop ramps in the northeast and southeast quadrants, the southeast quadrant entrance loop ramp has been removed.

The change to rural-type interchanges provides better entrance and exit ramp designs in general, with two exceptions. First, the full and partial cloverleaf interchange ramps were constructed without C-D roads. Without C-D roads, merge and diverge maneuvers must take place directly on the freeway. The short weaving sections decrease the mainline level of service and increases the accident potential. The second exception occurs between Dunlap Avenue and Peoria Avenue. Ramps between these interchanges are closely spaced due to the location of the Arizona Canal. Merge and diverge influence areas overlap and cause operational problems.

Between Dunlap Avenue and Peoria Avenue, the median width expands from 16 feet to 60 feet and the right shoulder widths increase from eight to ten feet. The curb and gutter adjacent to the right shoulder has been eliminated. The original six lane section tapered to four lanes at Thunderbird Road. In 1972, a full diamond interchange was constructed at the Greenway Road grade separation. More recently, a median closure project has extended the six lane

section three miles to Union Hills Drive. Other improvements associated with the Outer Loop construction are currently under way near Utopia Road.

Evaluation results for the north section are summarized below. Detailed ratings for the section are shown graphically in Exhibits 19 through 22.

Geometric Features

- Horizontal alignment is "good" through this predominantly tangent section.

- Vertical alignment is "good" within this section. The profile reaches a maximum grade of approximately 0.4 percent.

- Stopping sight distance is rated "good" throughout entire north section.

- Decision sight distance requirements are exceeded throughout the north section. Therefore, "good" ratings apply. The improvement of the decision sight distance is due to the change in the interchange design with the cross street passing under the facility and the flat grade of the mainline.

- Entrance and exit design in this section varies from standard tapered design to full cloverleaf design. All but one of the tapered ramps are rated "good". The exception occurs at the northbound entrance at Dunlap Avenue, where 25:1 taper rate exceeds the design criteria and is rated "poor". Cloverleaf designs at Thunderbird Road, Bell Road and Deer Valley Road do not meet current design criteria for freeways. These locations are also rated "poor".

- Cross section elements through the entire north section are rated "good". The level profile and wider right-of-way widths associated with the rural design distinguish the north section from the other two sections.

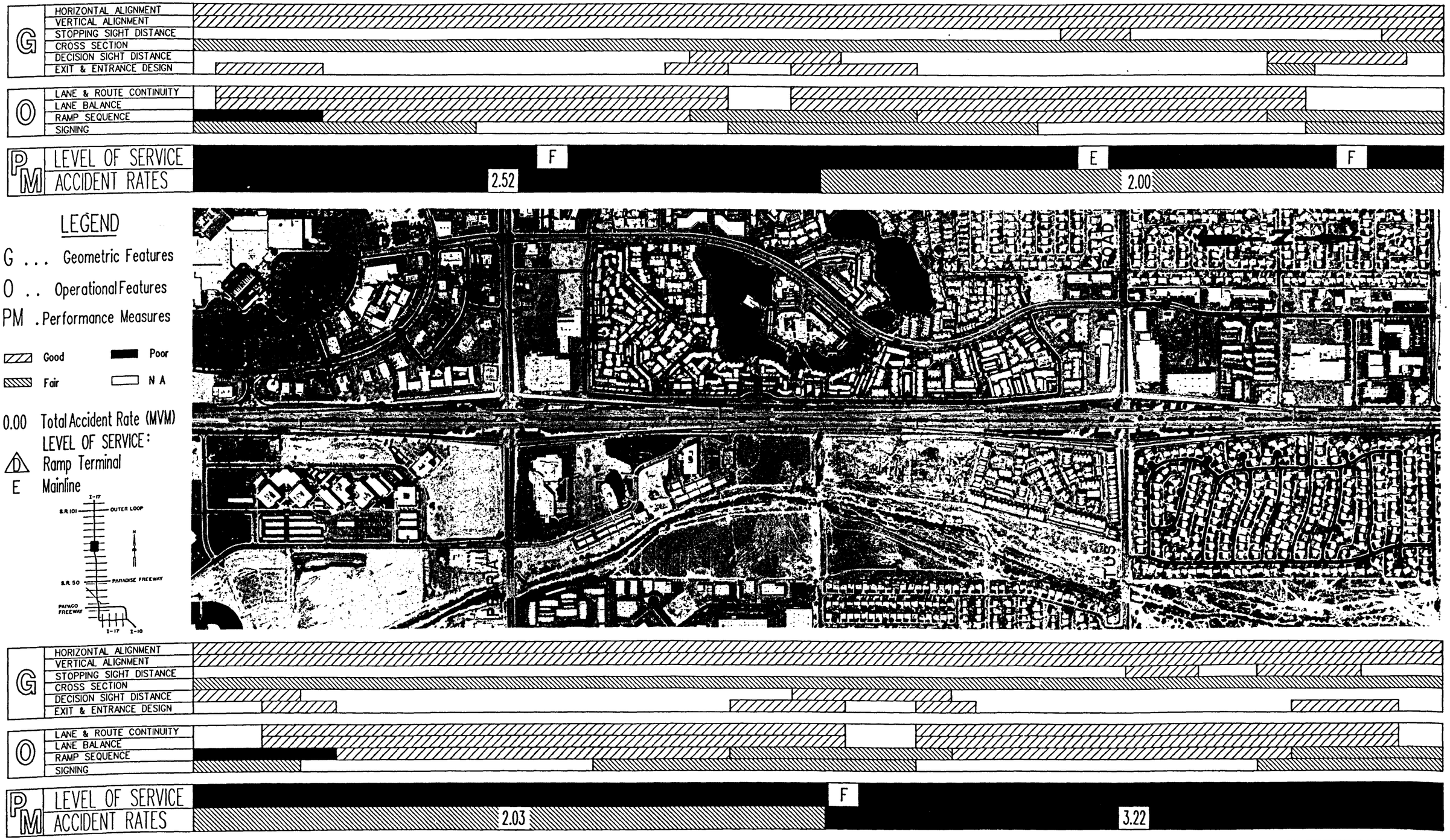
Operational Features

- Lane and route continuity is provided throughout this section.

- Lane balance criteria is achieved at all entrance and exit ramp locations.

- Ramp spacing is poor in both directions between Dunlap Avenue and Peoria Avenue. The southbound exit to and the northbound entrance from Dunlap were located in advance of the canal, decreasing the mainline spacing.

- Signing is adequate throughout the north section. Sign panel design criteria is exceeded northbound approaching Deer Valley Road and has been rated "poor".



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

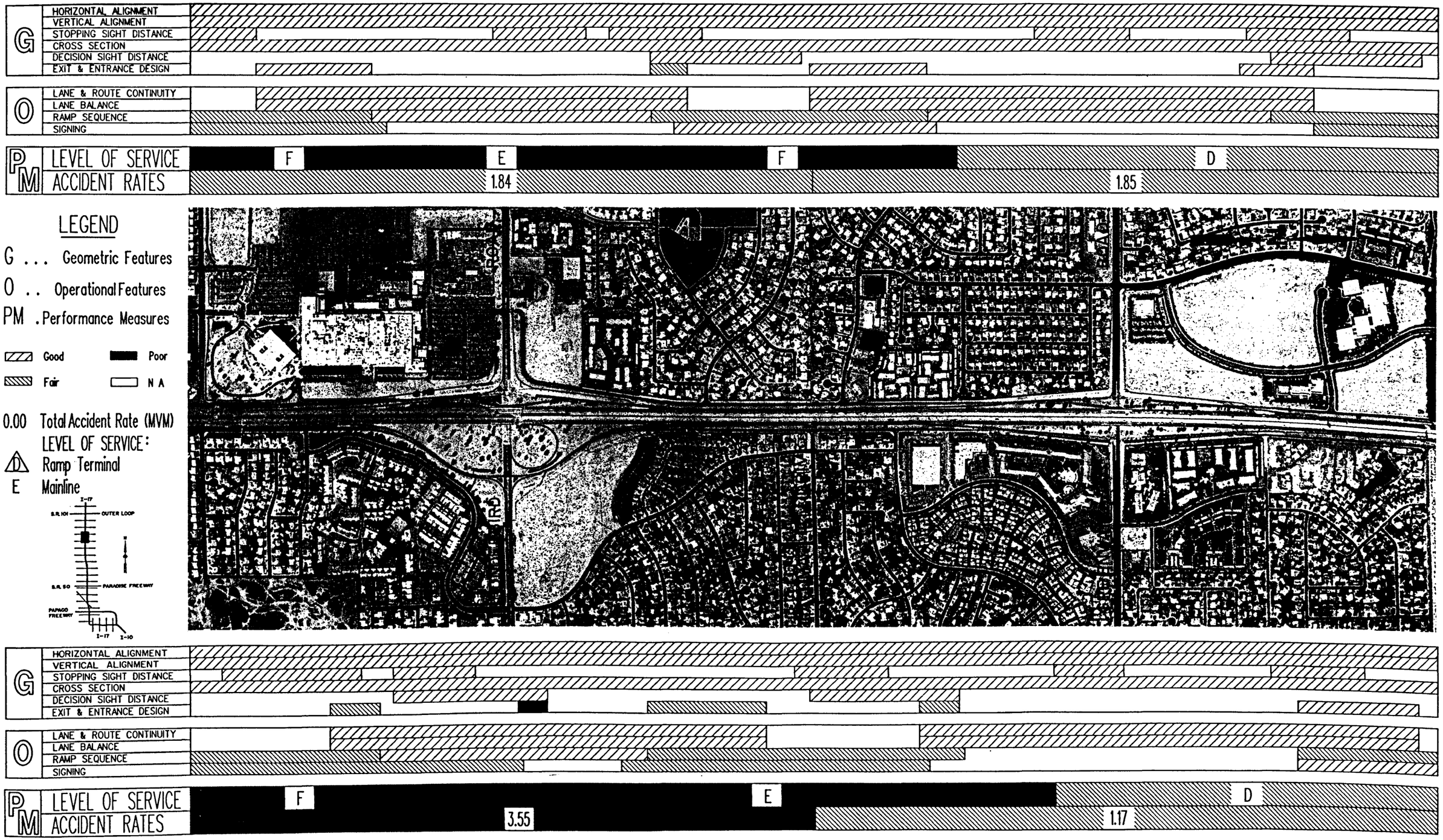
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
PEORIA TO CACTUS

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 19



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
THUNDERBIRD TO GREENWAY

SCALE 0 400 1000

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EXHIBIT 20

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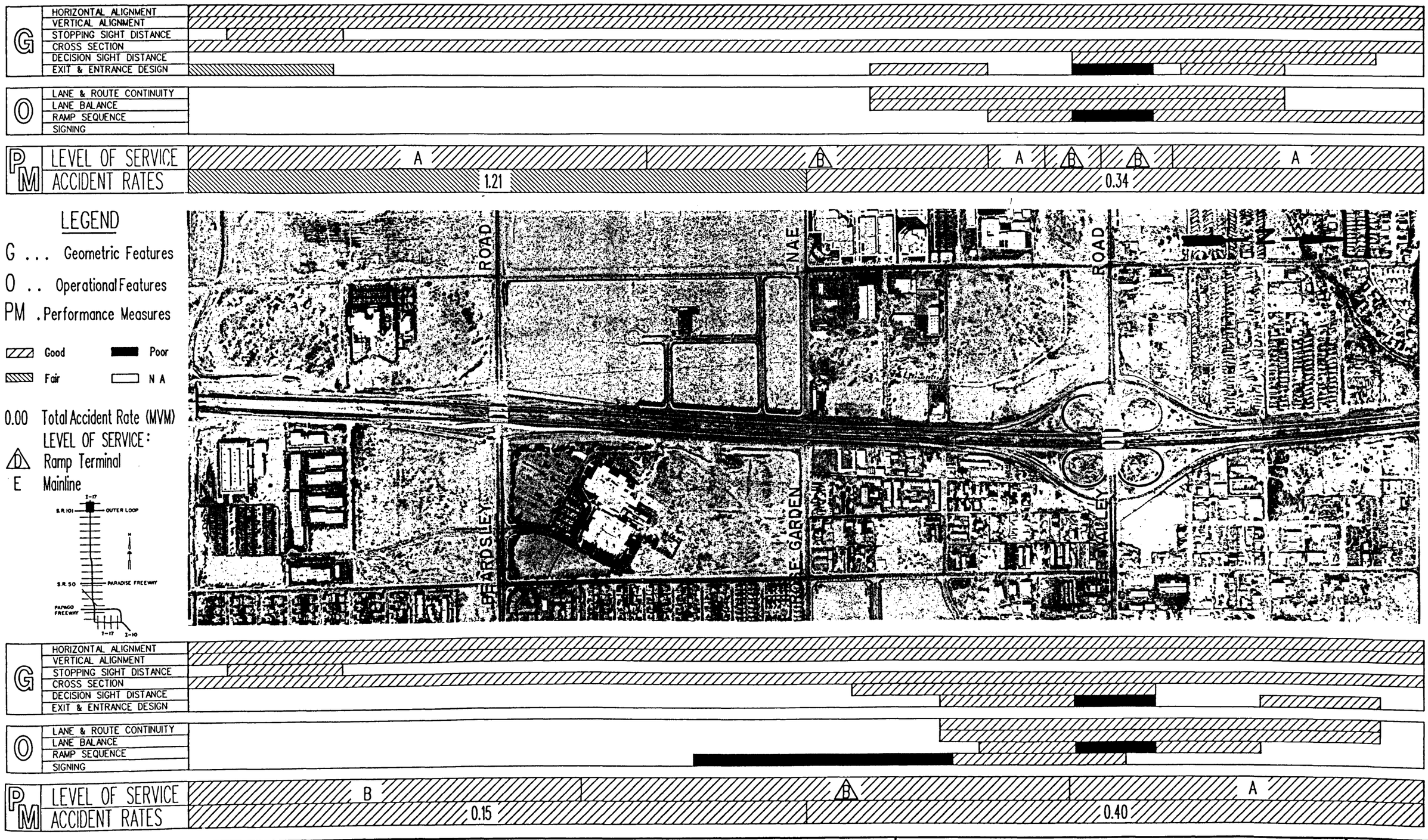
INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
BELL TO UNION HILLS

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 21



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INTERSTATE 17 CORRIDOR STUDY

ANALYSIS OF EXISTING FREEWAY
BEARDSLEY TO DEER VALLEY

SCALE 0 400 1000

FEBRUARY 1989

EXHIBIT 22

Performance Measures

- Level of Service is "poor" in both directions between Peoria Avenue and Greenway Road. The level of service improves from Greenway Road to the north limit of the project.

- Accident rates northbound at Thunderbird Road are the highest in the entire study area. The accident rate at Thunderbird Road is 3.55 accidents/MVM, or 2.2 times the Arizona state-wide average of 1.60/MVM for urban freeways. This high rate may be attributed to the short weave length between loop ramps at Thunderbird Road. The northbound entrance loop ramp has since been removed. The accident rate at Cactus Road in the northbound direction is 3.22, making this 2-mile stretch of roadway extremely hazardous.

In the southbound direction, "poor" ratings occur at Peoria Avenue and Bell Road. Accident rates drop below the statewide average northbound beyond Thunderbird Road and in the southbound direction north of Bell Road.

LONG RANGE PLANNING FRAMEWORK

The primary considerations in developing long range freeway rehabilitation plans are to correct existing design and operational deficiencies while accommodating future traffic demand.

Prior sections of this report detailed the freeway performance and evaluation results. The evaluation results reveal significant design and operational deficiencies. While recognizing these evaluation results, future traffic demand should be considered along with physical constraints within the freeway corridor.

FUTURE TRAFFIC DEMAND

The Maricopa Association of Governments Transportation Planning Office (MAGTPO) provided the basis for determining future traffic forecasts. The MAGTPO 2010-34 transportation network model computer plots were reviewed to determine 24 hour average weekday traffic volumes. The MAGTPO also provided Selected Link computer plots. The selected link assignments were used to evaluate origin and destination volumes on a ramp by ramp basis. They were also used to determine average trip lengths within the I-17 corridor.

Year 2010 Forecasts

Based on the 24-hour average weekday traffic volumes, year 2010 peak hour forecast volumes were calculated. Values of K=8 percent and D=55/45 were used (where K is defined as the percentage of 24 hour volumes occurring during the peak hour and D is defined as the directional distribution). Lane requirements, based on 1600 vehicles/hour/lane were also calculated for each one mile segment. Exhibit 23 shows year 2010 mainline 24-hour volumes and calculated lane requirements for each one mile segment. System basic lane requirements, consistent with AASHTO recommendations, are also shown.

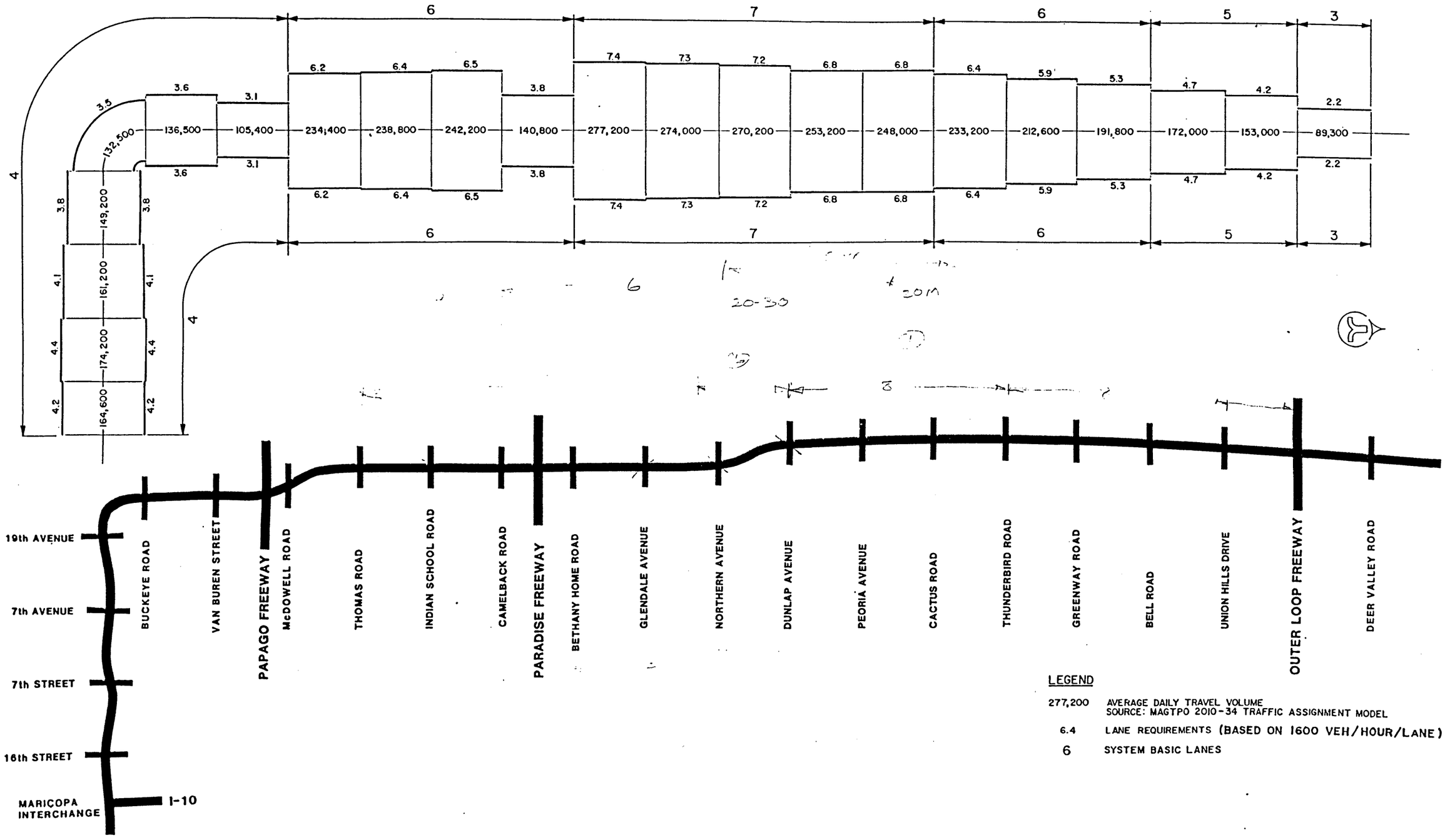
Year 2010 forecasted traffic volumes are detailed further in Exhibits 24 through 29. These diagrams show AM peak, PM peak and 24-hour volumes. The freeway facility shown, includes the present and programmed number of lanes and programmed improvements, including the Paradise Freeway.

In general, daily traffic demand increases from the north to the south, reaching a maximum of 277,000 vehicles between Bethany Home Road and Glendale Avenue. A significant reduction occurs at the Paradise Interchange and volumes continue to decrease to 234,000 approaching the Papago Freeway.

In contrast to the somewhat pronounced directional distribution and high demand in the central and north sections, the south section, from the Papago Interchange to the Maricopa Interchange, yields a relatively equal directional distribution. A maximum of 174,000 vehicles are forecasted between 7th Street and 16th Street. It is interesting to note that year 2010 forecasts in the south section are only approximately 10 percent higher than 1988 traffic volumes. Completion of the Papago Inner Loop is expected to offer relief to the south section as vehicles will be able to more directly access the central city.

Selected Link Analysis

The selected link analysis was used to determine the origin and/or destination of traffic at a specific point on I-17. For example, a selected link on I-17 southbound, south of the Outer Loop, in effect creates an origin at this location. This is depicted graphically in Exhibit 30. From this origin, the selected link



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

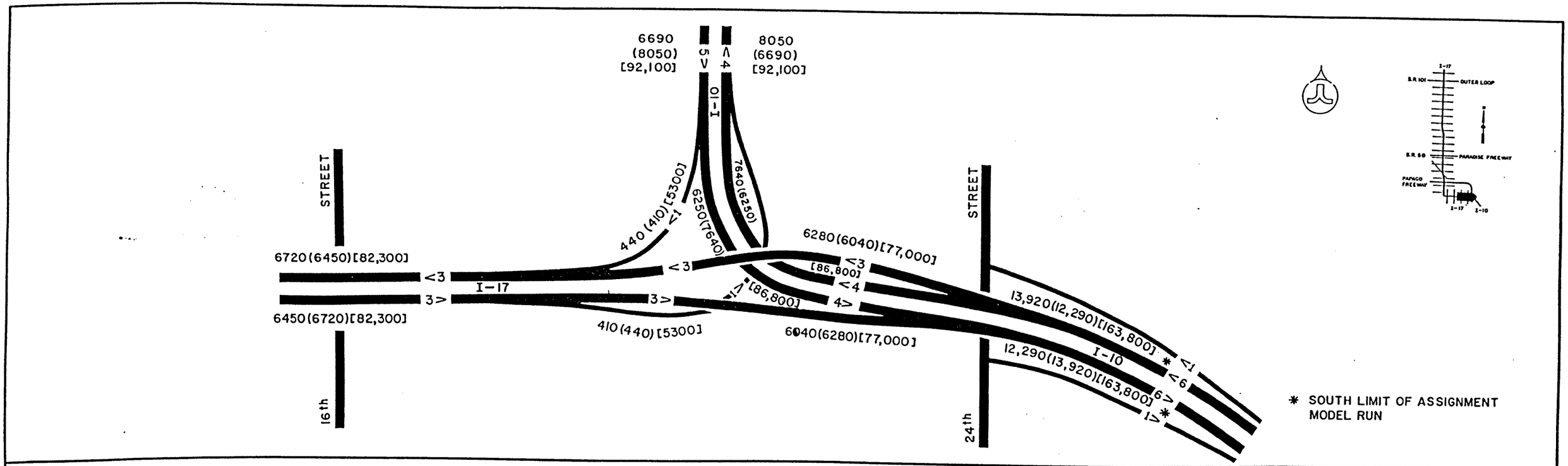
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 MAINLINE 24 HOUR TRAFFIC VOLUMES AND LANE REQUIREMENTS

SCALE : NTS

FEBRUARY 1989

EXHIBIT 23



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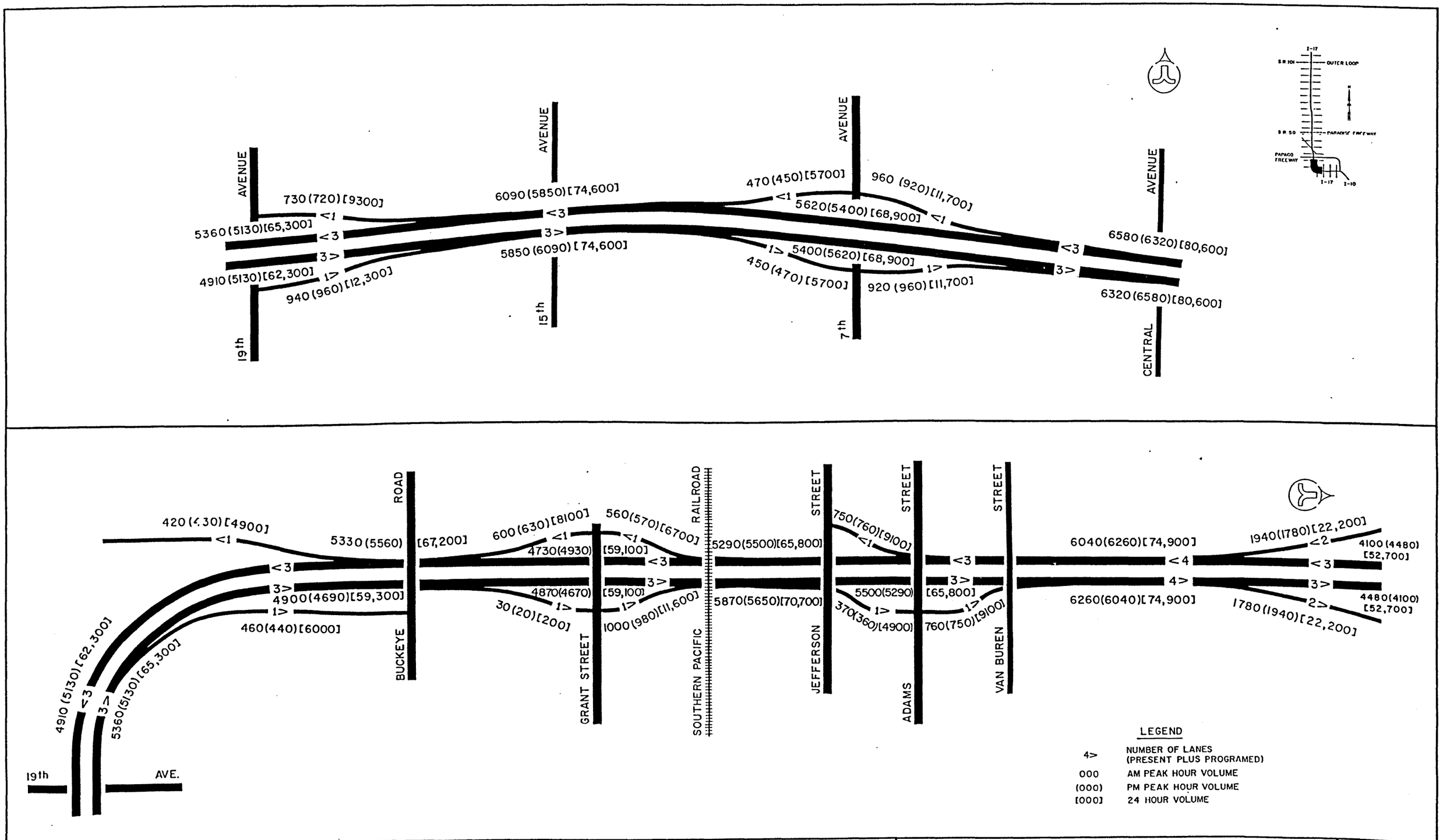
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 FORECASTED TRAFFIC VOLUMES
MARICOPA INTERCHANGE TO 7th STREET

SCALE : NTS

FEBRUARY 1989

EXHIBIT 24



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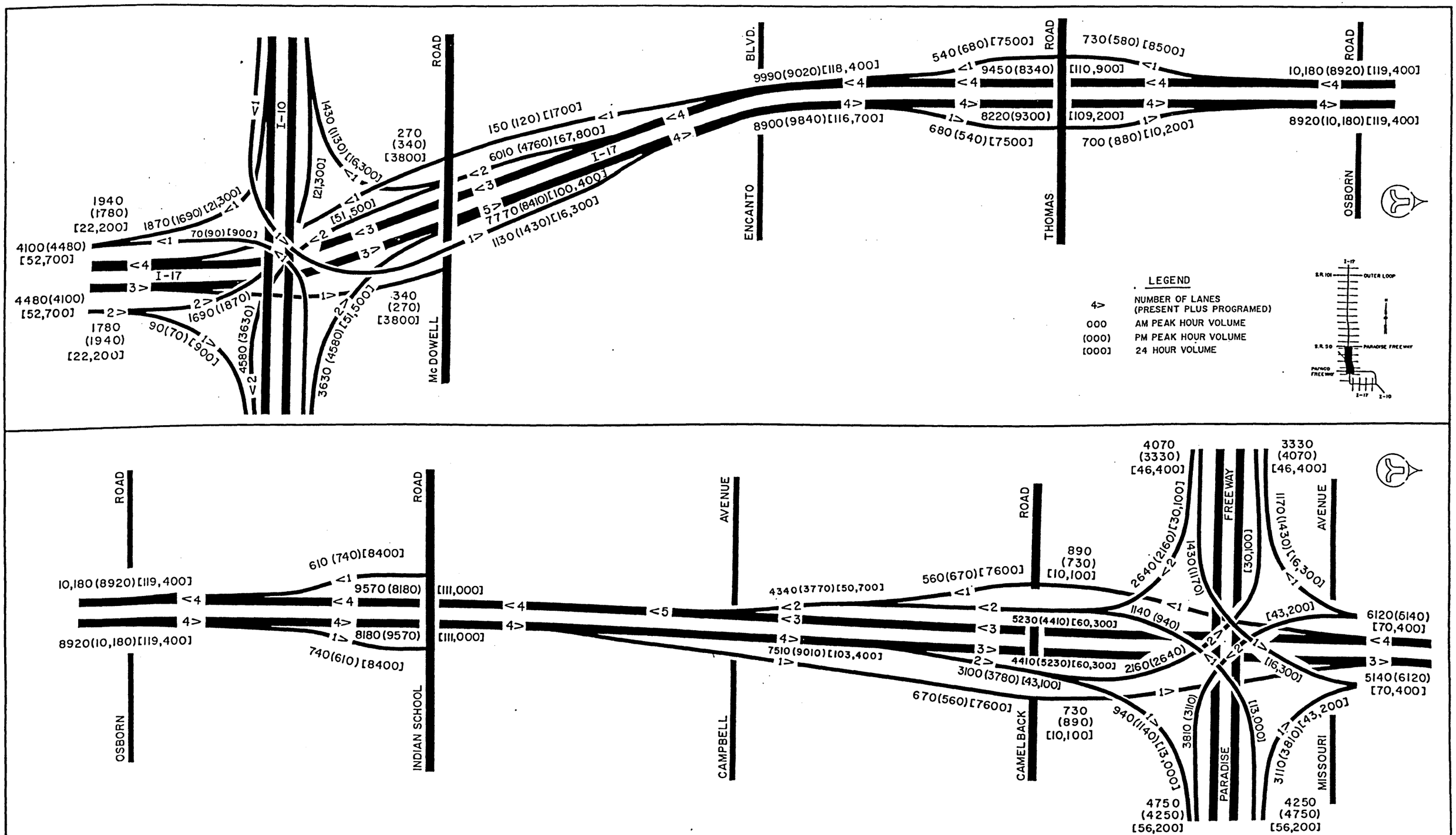
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 FORECASTED TRAFFIC VOLUMES
7th AVENUE TO ADAMS STREET

SCALE : NTS

FEBRUARY 1989

EXHIBIT 25



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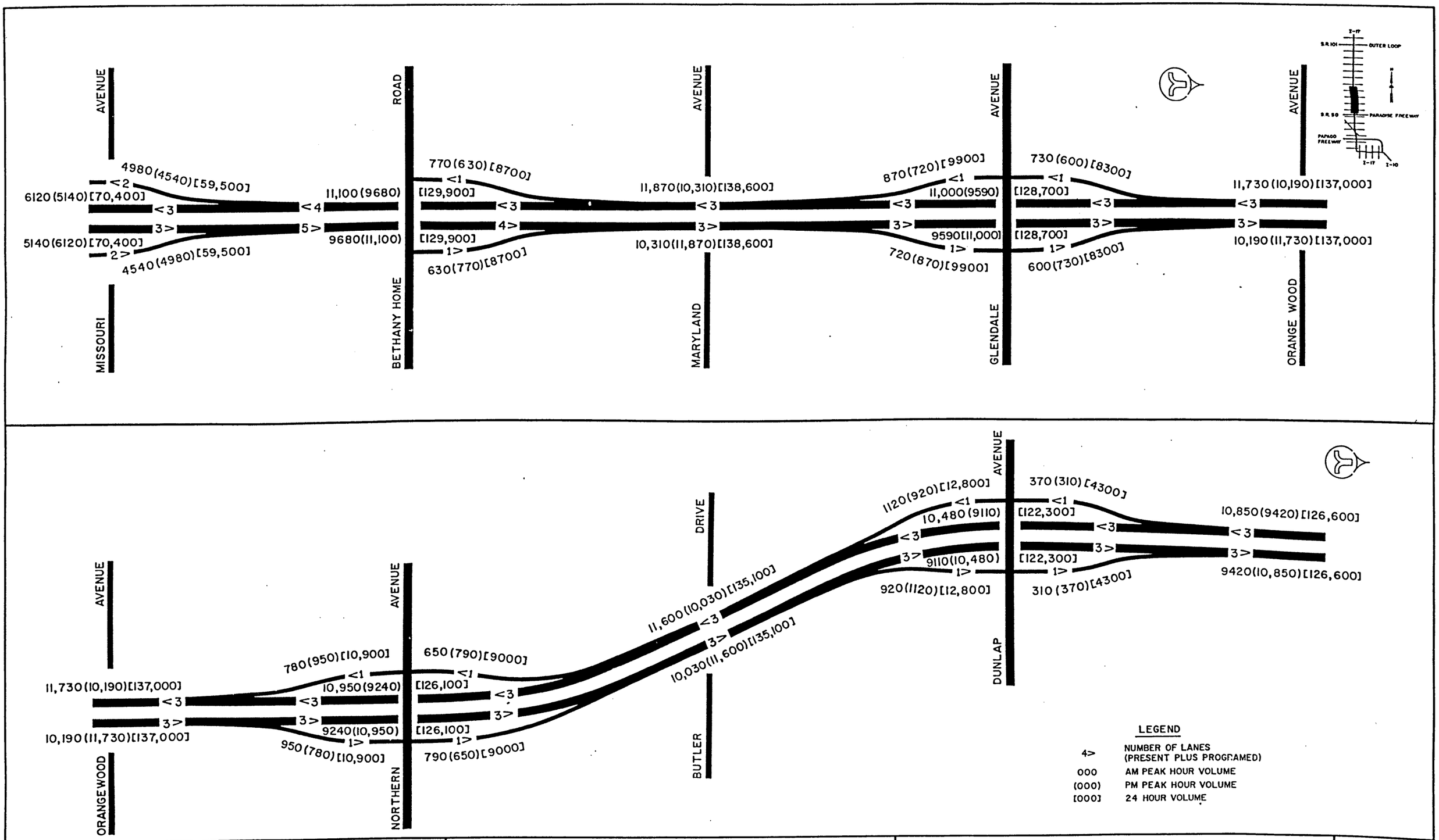
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 FORECASTED TRAFFIC VOLUMES
PAPAGO FREEWAY TO CAMELBACK ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 26



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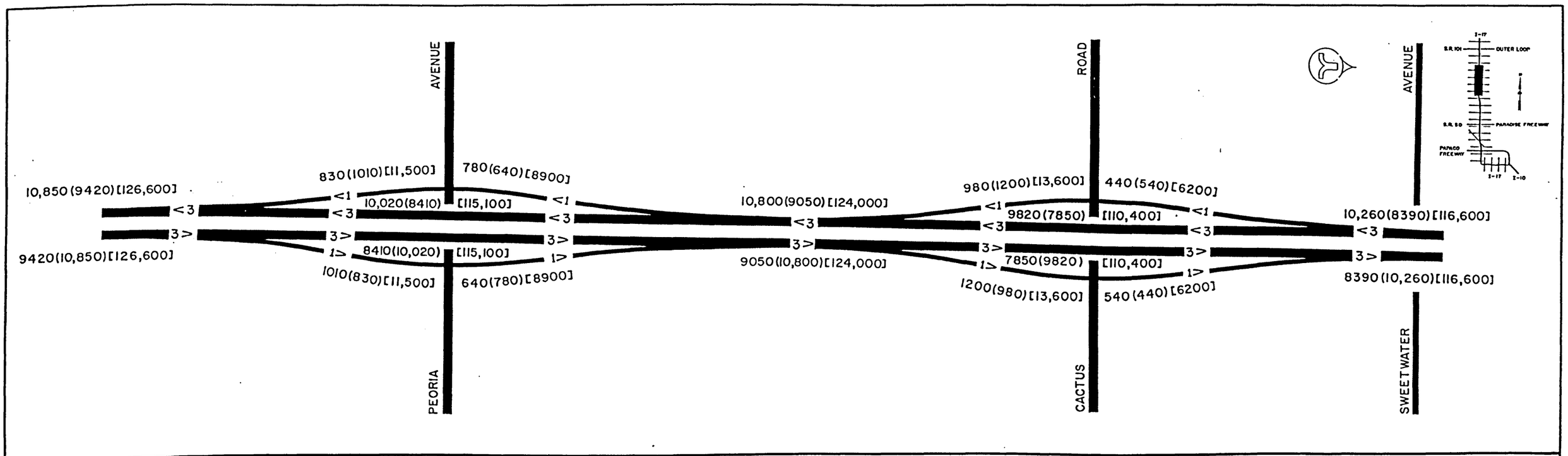
INTERSTATE 17 CORRIDOR STUDY

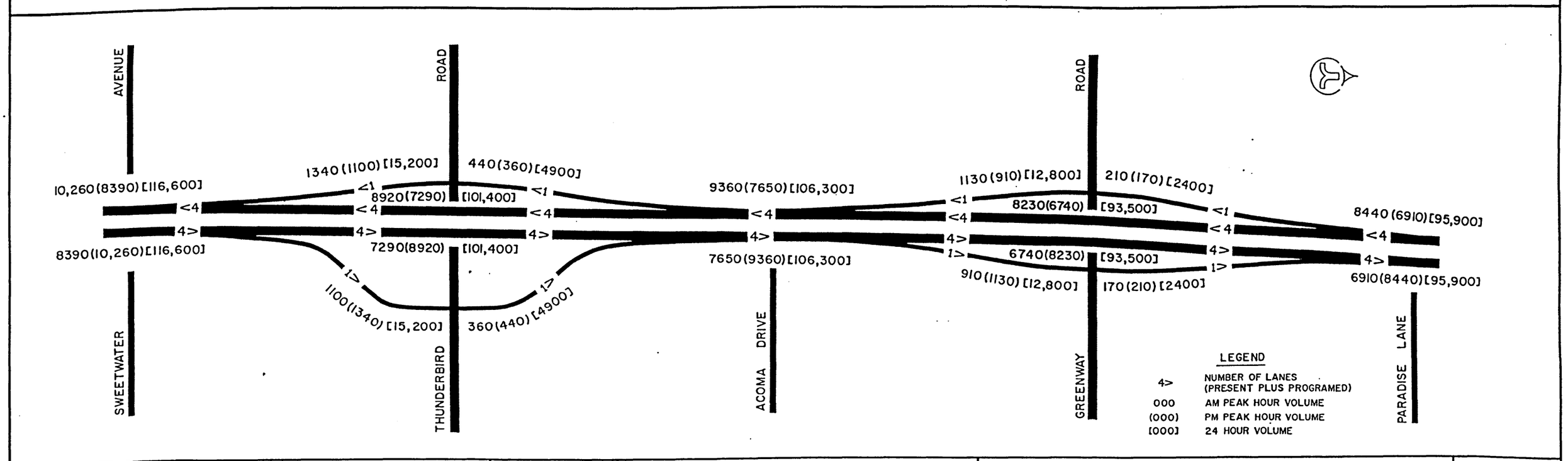
YEAR 2010 FORECASTED TRAFFIC VOLUMES
BETHANY HOME ROAD TO DUNLAP AVE.

SCALE : NTS

FEBRUARY 1989

EXHIBIT 27





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ARIZONA DEPARTMENT OF TRANSPORTATION

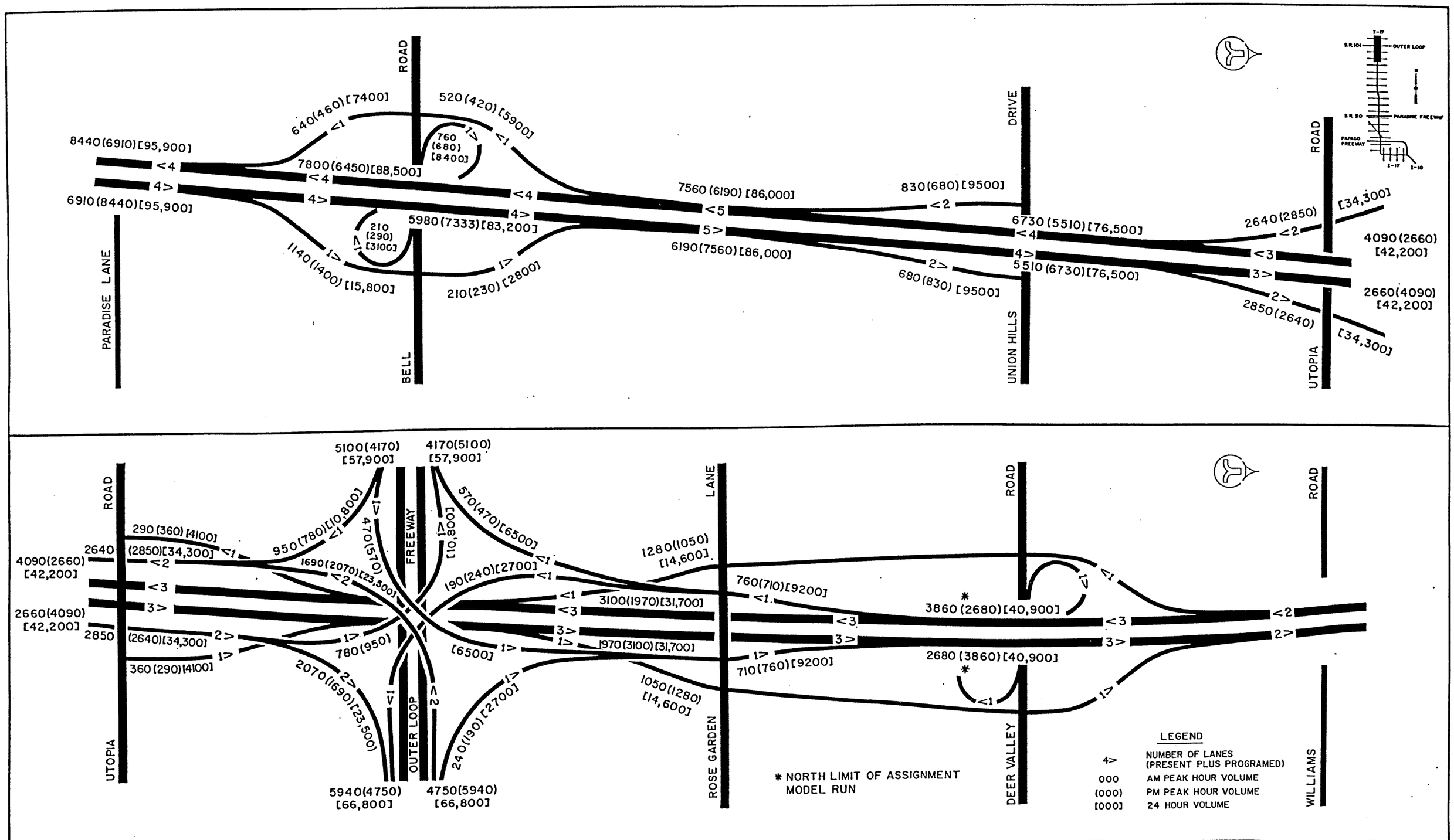
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 FORECASTED TRAFFIC VOLUMES
PEORIA AVE. TO GREENWAY ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 28



JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 FORECASTED TRAFFIC VOLUMES
BELL ROAD TO DEER VALLEY ROAD

SCALE : NTS

FEBRUARY 1989

EXHIBIT 29

assignment identifies all destinations of the traffic passing through this location. The analysis was also used to determine trip lengths. The average trip length in the I-17 corridor within the study area is approximately 6.6 miles, for the forecast year.

Selected link analyses were performed for various locations on I-17 and the results are shown in Exhibits 30 through 33. At each location two analyses were performed. The first identifies traffic volumes that would use either a local access facility or an express facility that terminates at the Paradise Freeway only. The second analysis indicates the increase in traffic volumes on an express facility that would access the Paradise freeway and also connect back to I-17.

Traffic demand on an express facility increases significantly as the origin location is shifted south on I-17. One-way, 24-hour volumes on an express facility connecting only with the Paradise Freeway range from approximately 18,000 vehicles south of the Outer Loop, to nearly 36,000 vehicles when the origin is located south of Thunderbird Road. With a connection from the express facility returning to I-17, travel demand ranges increase to approximately 30,000 to 65,000 vehicles between the same limits.

The basic trend, as indicated by the results of the selected link analysis, may justify an express facility. Direct connections to the Paradise Freeway appear viable to accommodate the heavy demand from the north to the east. By providing connections to I-17 south of the Paradise Interchange, even more drivers would be able to utilize and benefit from the express facility. Further detailed studies will help to define the limits of the express facility.

PHYSICAL CONSTRAINTS

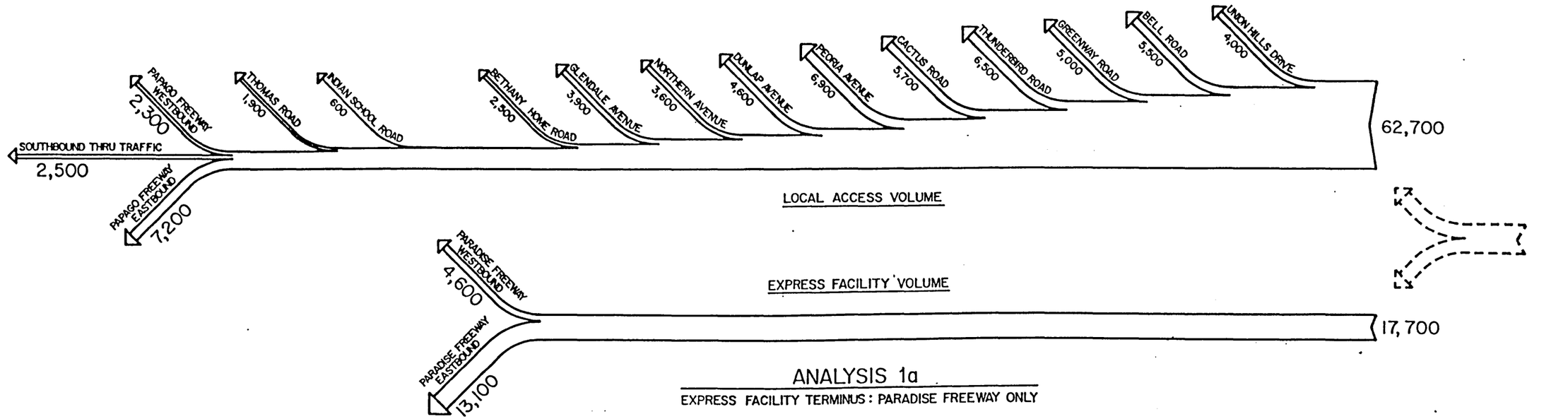
In addition to future traffic demand, physical constraints must be reviewed when developing long range alternative concepts. The confined right-of-way and highly developed areas adjacent to the I-17 corridor create challenges in developing an operationally viable improvement plan.

In addition to minimizing conflicts with existing and proposed land uses, a goal of the improvement plan is to provide an operationally balanced corridor. The balanced system concept is one that promotes transportation improvements to provide a uniform level of service and operation, on a systemwide basis. Therefore, the proposed improvement concepts for the I-17 corridor should be compatible with the interconnecting transportation network.

Right-of-Way

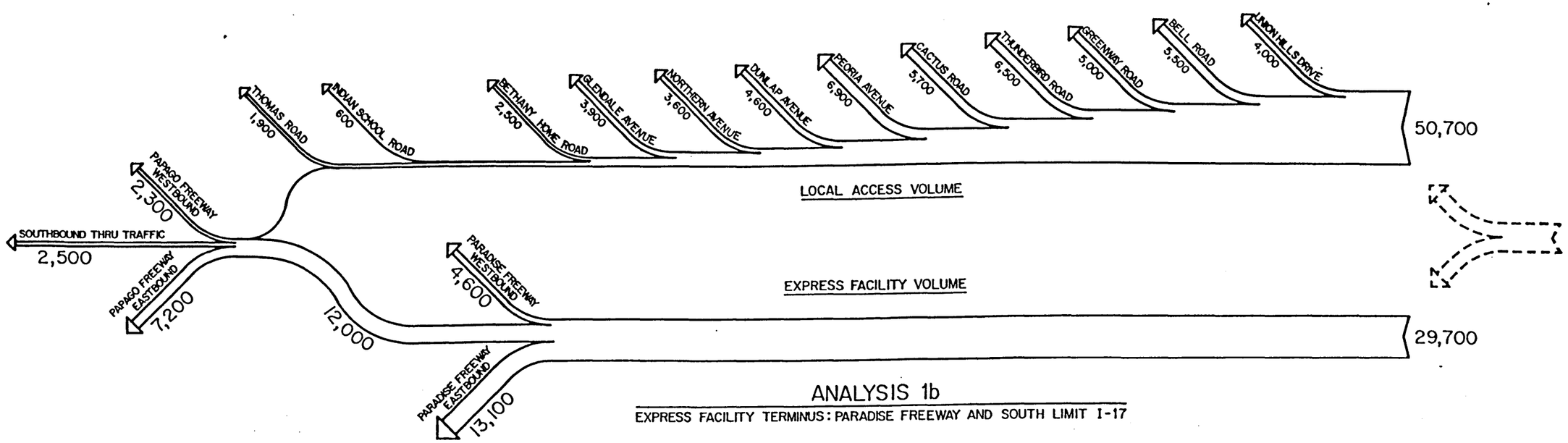
As previously referenced, Exhibit 2 depicts right-of-way widths for the corridor. It should be noted that the portion of I-17 forecasted to serve the highest traffic volumes has the narrowest right-of-way section.

In the section south of the Papago Interchange, the lack of development adjacent to the freeway and wider right-of-way creates more improvement opportunities than in other sections. Because this segment is expected to experience a lower increase in traffic demand, proposed improvements will require less extensive construction efforts to meet forecasted traffic requirements. Improvements in the depressed section between the Durango curve and the Papago Interchange will, however, require the use of retaining walls.



ANALYSIS 1a

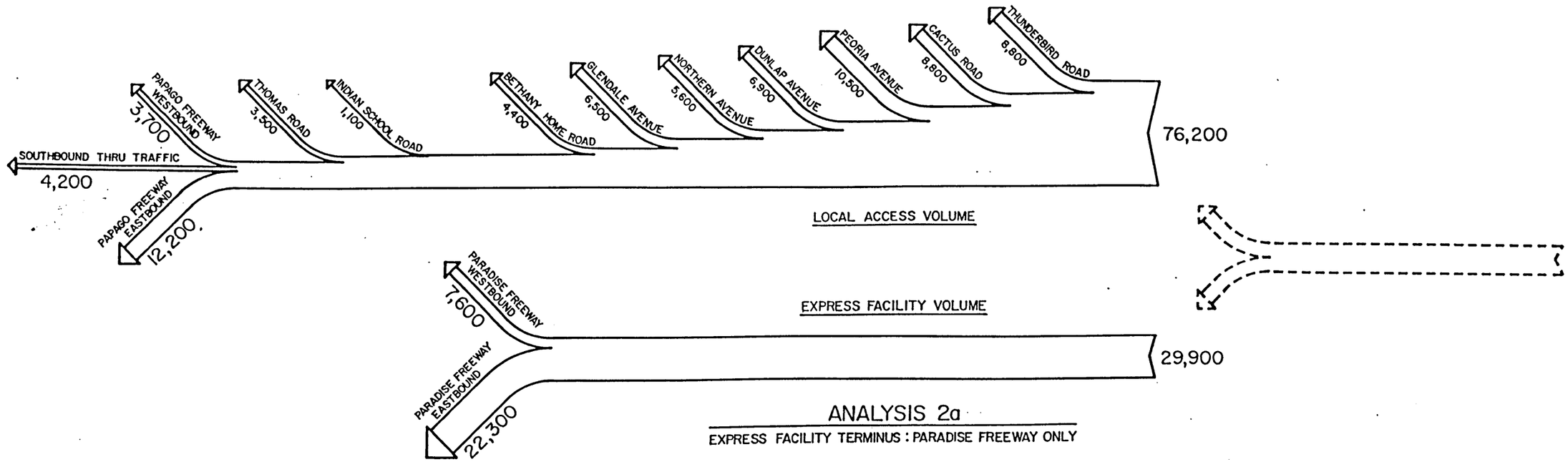
EXPRESS FACILITY TERMINUS: PARADISE FREEWAY ONLY



ANALYSIS 1b

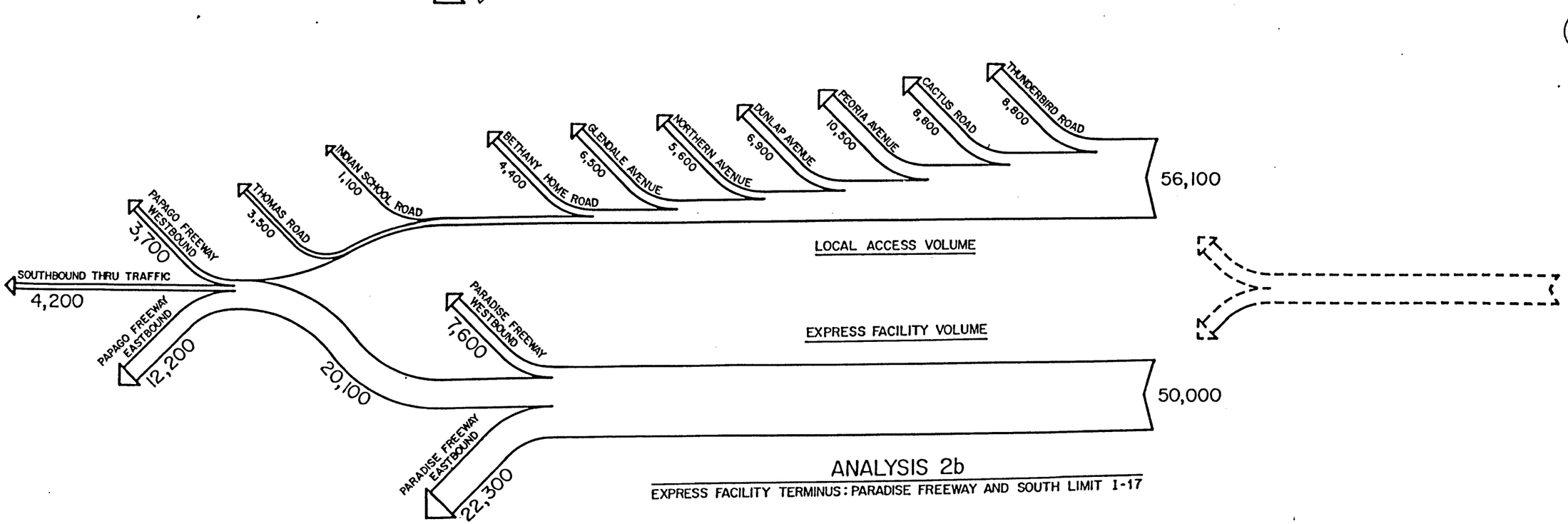
EXPRESS FACILITY TERMINUS: PARADISE FREEWAY AND SOUTH LIMIT I-17

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	YEAR 2010 SELECTED LINK ANALYSIS ORIGIN : I-17 SOUTH OF OUTER LOOP SCALE : NTS FEBRUARY 1989	EXHIBIT 30



ANALYSIS 2a

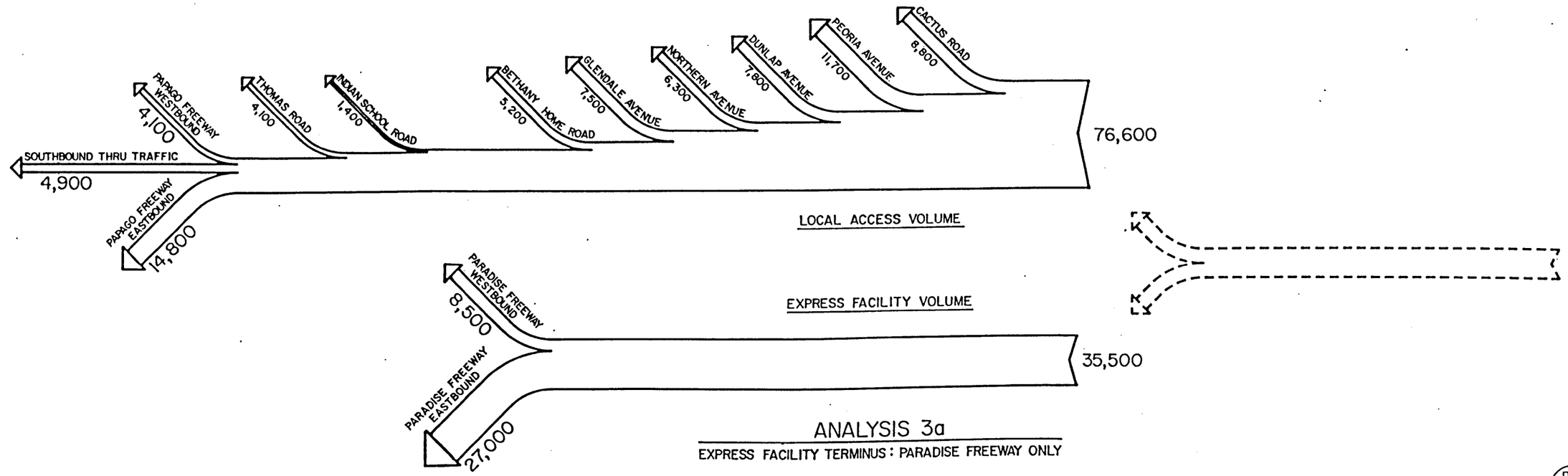
EXPRESS FACILITY TERMINUS : PARADISE FREEWAY ONLY



ANALYSIS 2b

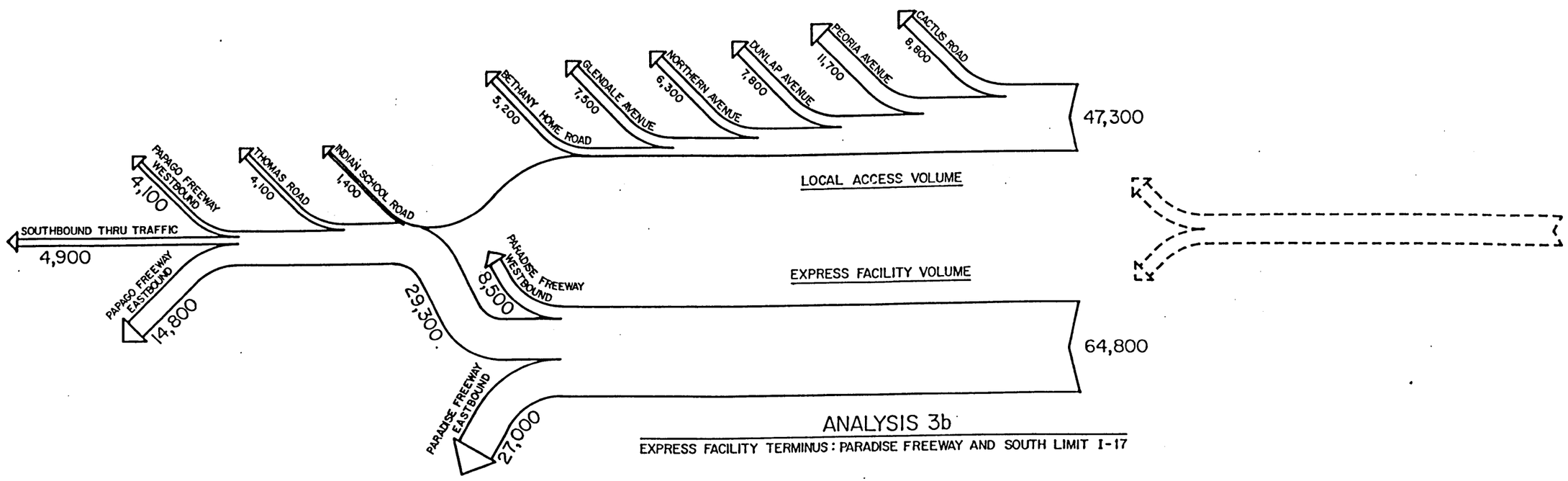
EXPRESS FACILITY TERMINUS: PARADISE FREEWAY AND SOUTH LIMIT I-17

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	YEAR 2010 SELECTED LINK ANALYSIS ORIGIN : I-17 SOUTH OF GREENWAY SCALE : NTS FEBRUARY 1989	EXHIBIT 31



ANALYSIS 3a

EXPRESS FACILITY TERMINUS: PARADISE FREEWAY ONLY



ANALYSIS 3b

EXPRESS FACILITY TERMINUS: PARADISE FREEWAY AND SOUTH LIMIT I-17

JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION

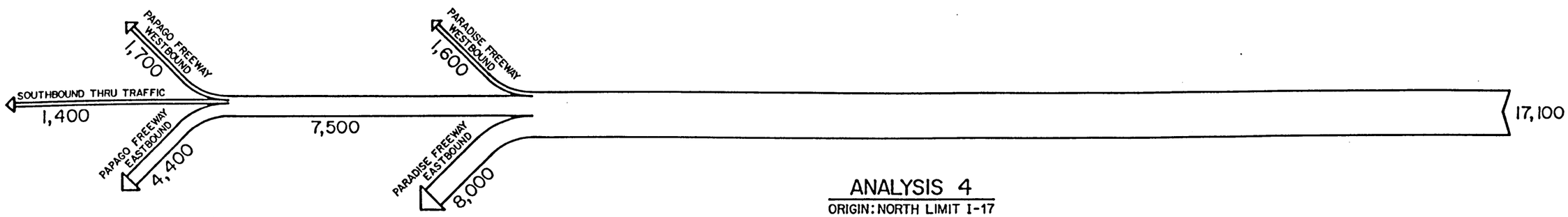
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 SELECTED LINK ANALYSIS
ORIGIN : I-17 SOUTH OF THUNDERBIRD

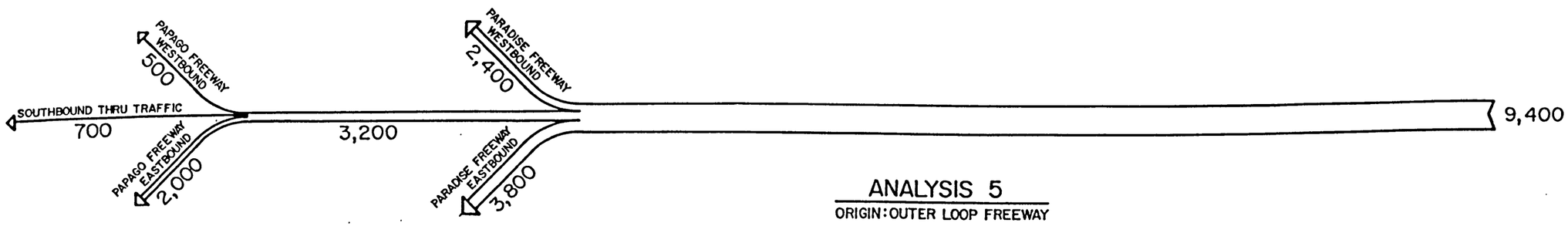
SCALE : NTS

FEBRUARY 1989

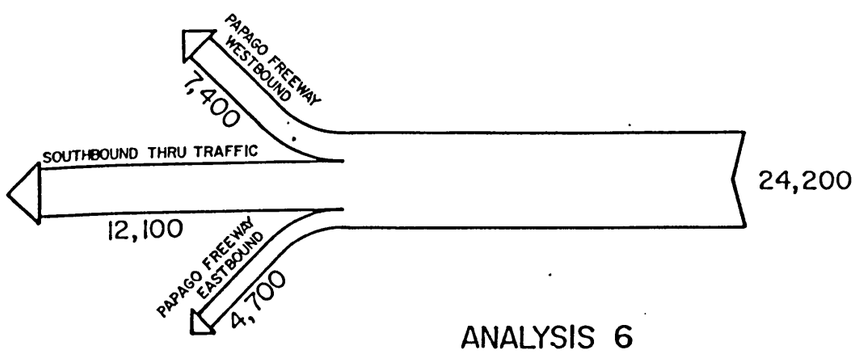
EXHIBIT 32



ANALYSIS 4
ORIGIN: NORTH LIMIT I-17



ANALYSIS 5
ORIGIN: OUTER LOOP FREEWAY



ANALYSIS 6
ORIGIN: PARADISE FREEWAY

JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

YEAR 2010 SELECTED LINK ANALYSIS
ORIGINS : I-17, OUTER LOOP, PARADISE

SCALE : NTS

FEBRUARY 1989

EXHIBIT
33

The minimum 200-foot right-of-way between Thomas Road and Dunlap Avenue is a significant constraint when developing long range improvement concepts. Improvement plans in this segment will concentrate on minimizing impacts to the densely populated residential areas and variety of commercial properties that are adjacent to I-17.

In segments north of Dunlap Avenue, minimum right-of-way widths increase by between 40 feet and 48 feet on both sides of the freeway centerline. Even with the increase in widths, constraints such as the Metro Center Shopping Mall, the Cave Creek Drainage Wash, and mid-rise office and hotel complexes add to the complexity in developing long range improvement concepts.

Freeway Systems

Providing a balanced regional transportation network requires that improvement concepts for I-17 must work in concert with other elements of the freeway network. It is especially important that the long range improvement plans are compatible with the remainder of the system.

As mentioned previously, there are currently two system interchanges with I-17. Both of these interchanges are with I-10. In the future, completion of the Outer Loop will include a fully directional interchange with I-17 at the present location of Beardsley Road. This connection will provide direct freeway access for the northwest and northeast areas of the city. Long range plans must be compatible with the programmed construction of the Outer Loop Freeway and associated traffic patterns.

The proposed Paradise Freeway will play a significant role in the network and will have a substantial impact on the operation of I-17. Assignment model forecasts and selected link analyses indicate the significant traffic demand from the north along I-17 to the east on the Paradise Freeway. Alternative interchange schemes at the Paradise will significantly influence the variation and magnitude of traffic patterns on I-17.

Should the Paradise Freeway not interchange directly with I-17, increased demand on the interchanges south of the Paradise on I-17 could create serious operational deficiencies in the network. Because of the high projected demand, I-17 improvement schemes must be developed in a way that are compatible with the Paradise/I-17 Interchange alternatives and phased implementation.

LONG-RANGE IMPROVEMENT CONCEPTS

One objective of this study is to examine possible alternatives by which the existing facility might be expanded to accommodate significantly larger volumes (nearly doubling the capacity) in the future. Seven schemes evolved as depicted cross-sectionally in Exhibits 34 and 35: from (Scheme A) the highest capacity representing an expanded freeway with continuous collector-distributor (C-D) roads plus frontage roads; to (Scheme G) a somewhat lower capacity corridor with a freeway and high-type frontage roads.

In a review meeting with The Arizona Department of Transportation, ADOT, an additional alternative was suggested for design and operational analysis. This scheme, Alternative H, is depicted in Exhibit 43 and is an adjunct to Scheme G, however, this concept may require less ROW.

In essence there are three broad categories of alternatives presented: (1) mainline freeway with continuous C-D roads, flanked by frontage roads (variations are Schemes A, B and C); (2) mainline freeway with an express roadway, flanked by frontage roads (variations are Schemes D and E); and (3) a facility consisting of a mainline freeway, flanked by high-type frontage roads. (variations F, G and H.)

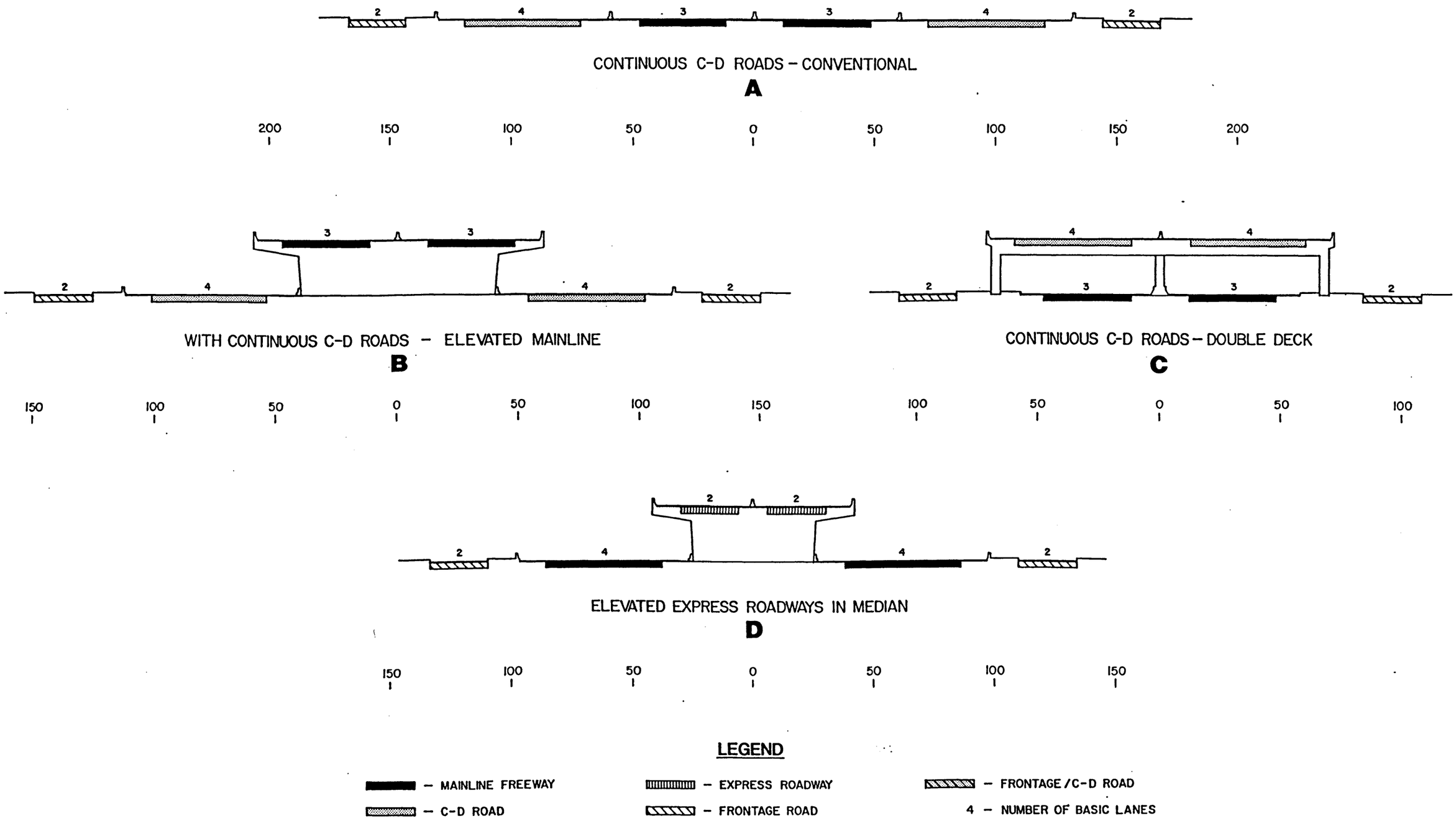
The conceptual alternatives are depicted in Exhibits 36 through 43. Each of these exhibits has five elements which describe that concept in increasing detail from left to right. The overall conceptual I-17 system configuation and basic number of lanes are shown in the first diagram, on the far left of each exhibit. Second, the typical ramp pattern and lane arrangements are shown. The third element on each exhibit is the general right-of-way requirements for a typical mile. The final diagrams show exit ramp geometry in conjunction with the geometry of other roadways (mainline, frontage roads, etc.), resulting right-of-way requirements, and locations of the representative cross-sections, which are shown on the far right of each exhibit.

SCHEME A

The first alternative, as shown by the typical section in Exhibit 34, is a corridor consisting of a core (mainline) freeway flanked by continuous C-D roads, plus a pair of one-way frontage roads. The system configuration, as depicted in Exhibit 36, indicates lane arrangements varying in four segments. The first segment maintains a conventional freeway section south of the Papago Freeway with 4-plus-4 basic lanes and local 2-lane frontage roads. Between the Papago Freeway and the Paradise Freeway, a 3-lane C-D road is introduced, providing 6 basic lanes in each direction. North of the Paradise Freeway to Cactus Road, the C-D road is increased to provide an overall freeway section of 4-3-3-4, plus 2-lane frontage roads. The final segment to the Outer Loop Freeway is reduced to a 3-3-3-3 section, with continuing frontage roads.

Interconnections between the core roadways and C-D roadways (referred to as transfer roadways) would be spaced three miles apart, either as individual pairs, or double pairs (basketweaves). Each exit transfer roadway would direct traffic to three cross street destinations while each entrance transfer roadway would collect traffic from three cross streets.

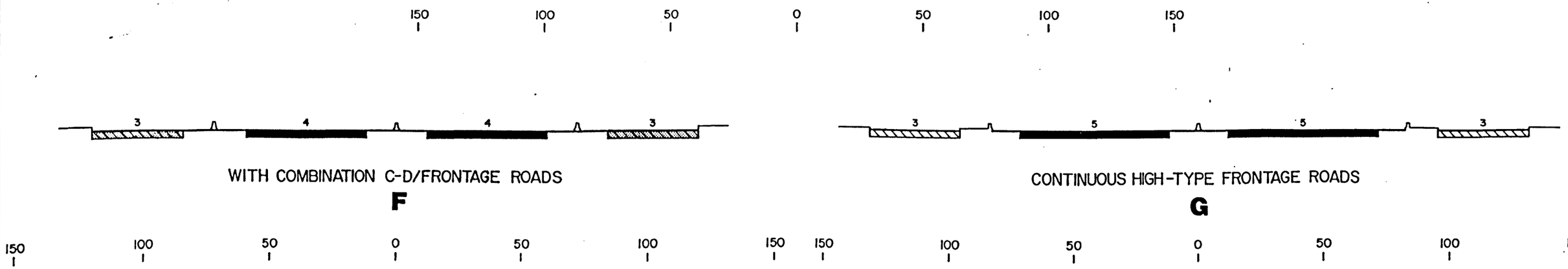
The one-mile ramp spacing along the C-D road produces repetitive 1800-foot weaving sections every mile, but provides high capacity signalized intersections at the cross streets. Ramp geometry and positioning require right-of-way widths from 192 feet to 240 feet, as measured from the centerline to the outer limits.



JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS TYPICAL MINIMUM CROSS-SECTIONS SCHEMES A THROUGH D SCALE : NTS FEBRUARY 1989	EXHIBIT 34

ELEVATED EXPRESS ROADWAY ON EACH SIDE

E

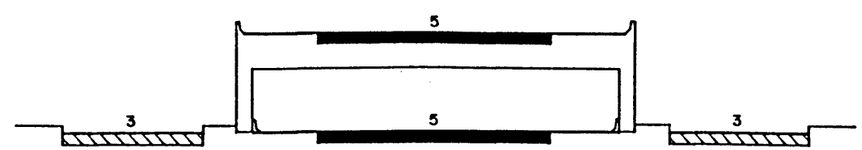


WITH COMBINATION C-D/FRONTAGE ROADS

F

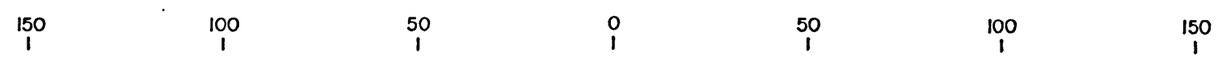
CONTINUOUS HIGH-TYPE FRONTAGE ROADS

G



CONTINUOUS HIGH-TYPE FRONTAGE ROADS – DOUBLE DECK

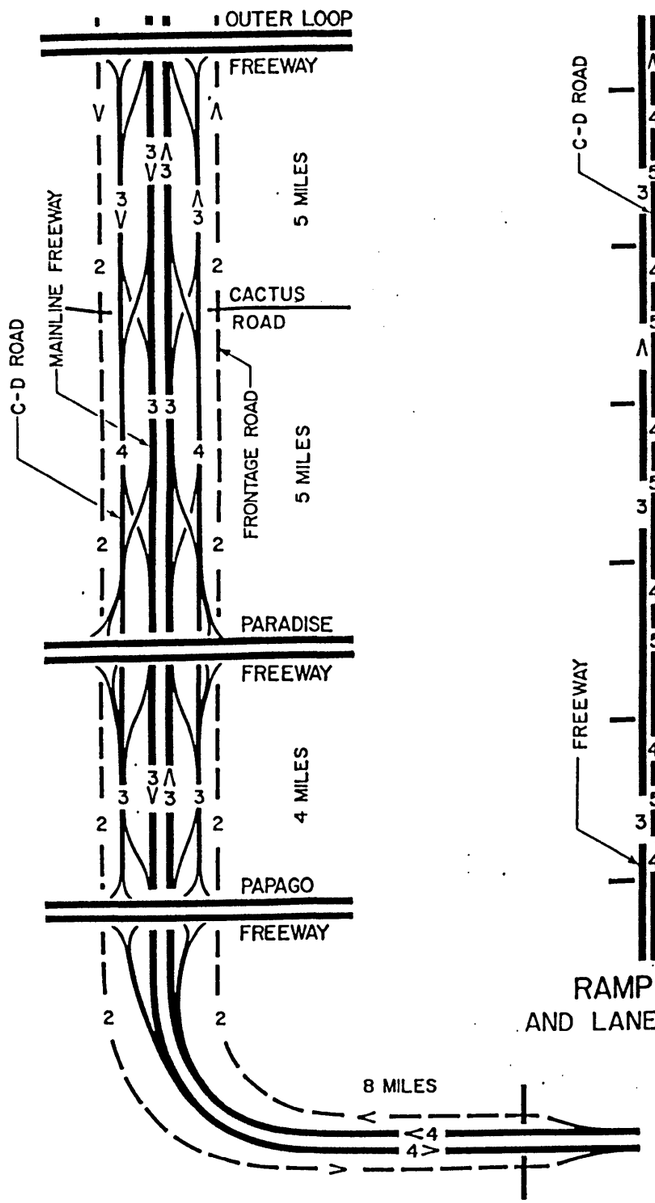
H



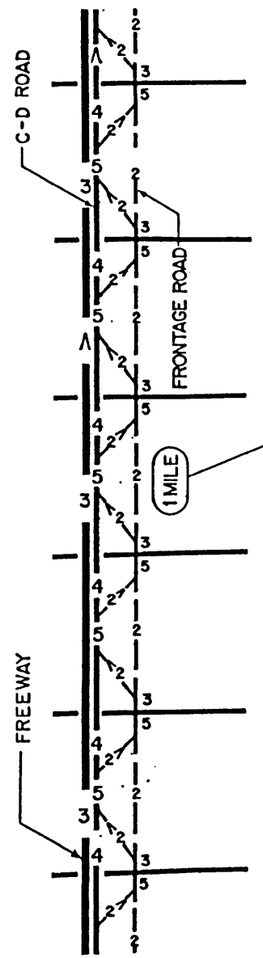
LEGEND

- MAINLINE FREEWAY
- C-D ROAD
- EXPRESS ROADWAY
- FRONTAGE ROAD
- FRONTAGE/C-D ROAD
- 4 – NUMBER OF BASIC LANES

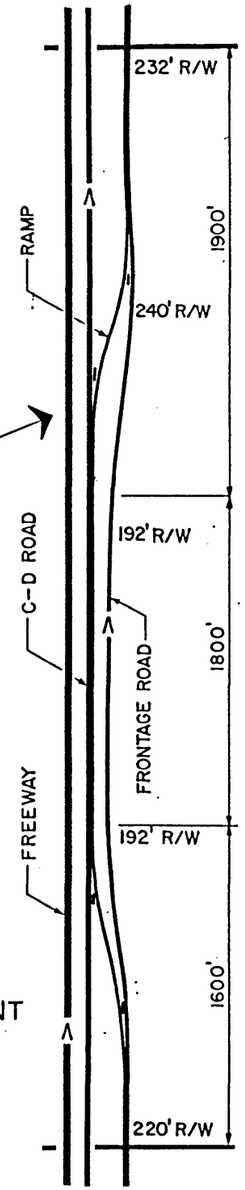
JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS TYPICAL MINIMUM CROSS-SECTIONS SCHEMES E THROUGH H SCALE : NTS FEBRUARY 1989	EXHIBIT 35



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

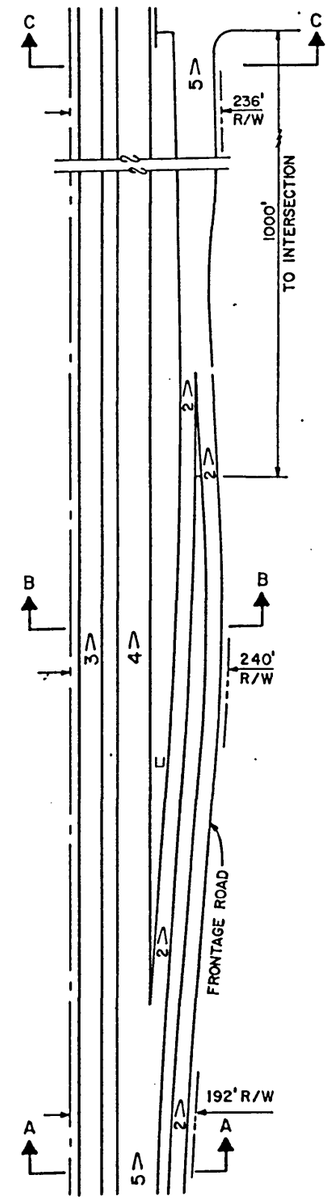


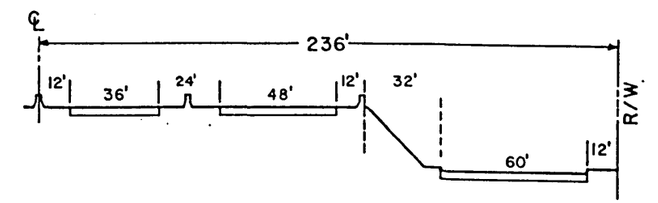
RAMP PATTERN
AND LANE ARRANGEMENT



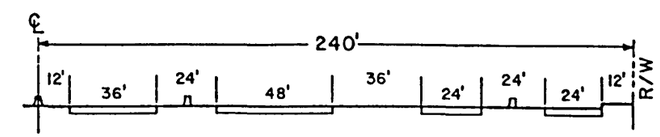
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

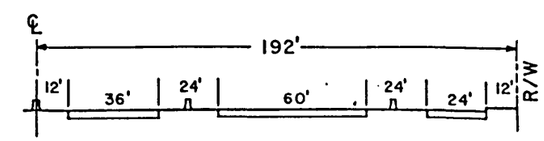




SECTION C-C



SECTION B-B



SECTION A-A

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME A CONTINUOUS C-D ROADS - CONVENTIONAL SCALE : NTS FEBRUARY 1989	EXHIBIT 36

SCHEME B

As shown by a typical section in Exhibit 34, Scheme B, is of the same general form as the continuous C-D road system in Scheme A. The major difference is that the mainline freeway is elevated and cantilevered to compress the overall cross-section and reduce the required right-of-way. Also, the system configuration, as indicated in Exhibit 37, is adjusted and simplified. The 4-mile segment between the Paradise Freeway and the Papago Freeway is arranged to operate as a conventional freeway with 4 basic lanes on the freeway and 3 basic lanes on the frontage road, in each direction. South of the Papago Freeway, 3 basic lanes on the freeway and 3 basic lanes on the frontage road are maintained in each direction. Between the Paradise Freeway and the Outer Loop Freeway, a continuous C-D roadway system, identical to Scheme A, is utilized.

The ramp pattern and lane arrangement for the section north of the Paradise Freeway are the same as for Scheme A, as well as the configuration of roadways for a typical mile. The right-of-way, however, is 18 feet narrower on each side of the corridor, due to the positioning of the elevated mainline structure.

SCHEME C

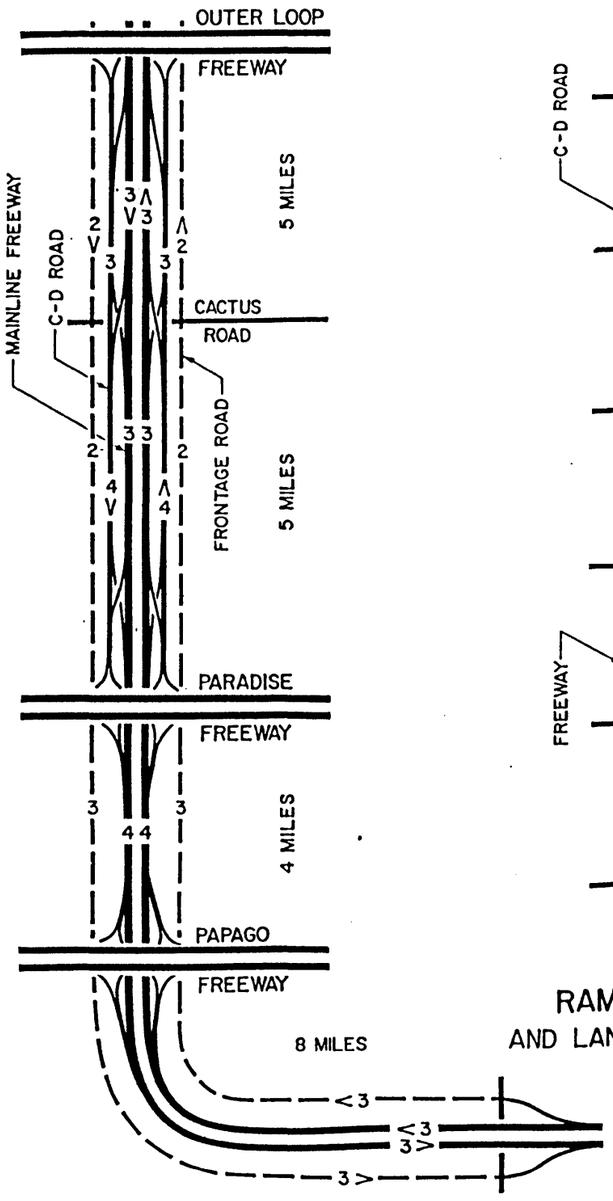
The next alternative, Scheme C, is represented by the typical section in Exhibit 34 and is of the same general form as the continuous C-D road system utilized in Scheme B. The system configuration of using two traveled ways (freeway mainline and high-type C-D roads) south of the Paradise Freeway and three traveled ways (freeway mainline, C-D road and frontage road) north to the Outer Loop Freeway is identical to Scheme B, as shown in Exhibit 38. However, the elevated structure in this case is a double-deck arrangement, with the C-D road on the upper level. A reversed arrangement, with the C-D road located on the lower level was also reviewed. This arrangement was considered less desirable because the maximum outriggered bent dimension just beyond the nose of the ramp would have required a 110-foot span.

Ramps are positioned at one-mile intervals as in Schemes A and B. Lane arrangements are also the same and the configuration of roadways within a typical mile are similar to the previous scheme. Right-of-way is significantly less than in previous alternatives, requiring between 132 and 182 feet; or reductions of about 40 and 60 feet on each side of the corridor when compared with Schemes A and B.

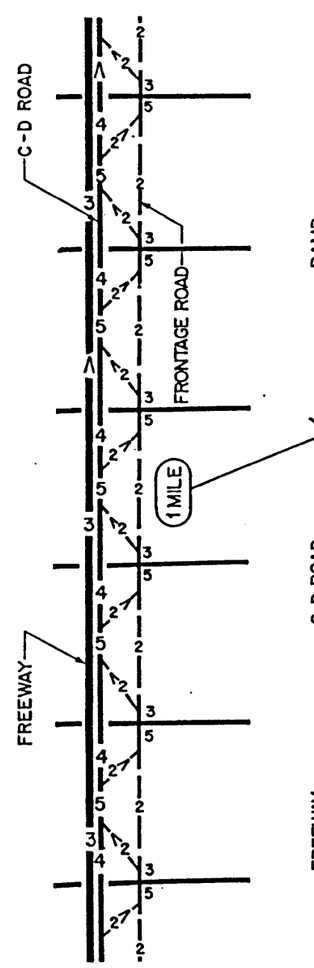
SCHEME D

The typical section in Exhibit 34 representing Scheme D, is another form of high-capacity facility, in this case utilizing an elevated express roadway in the median. The system configuration, as shown in Exhibit 39, indicates a separate 2-lane facility in each direction between Thunderbird Road and the Paradise Freeway. This express facility provides a continuous run over this length with no connecting ramps. The two terminals would be arranged to provide the driver with a choice of either using the mainline freeway or the express facility. The assignment projections and selected link analyses clearly show a high demand for express travel over this length. A 2-lane or possibly a 3-lane express roadway could be justified based on demand.

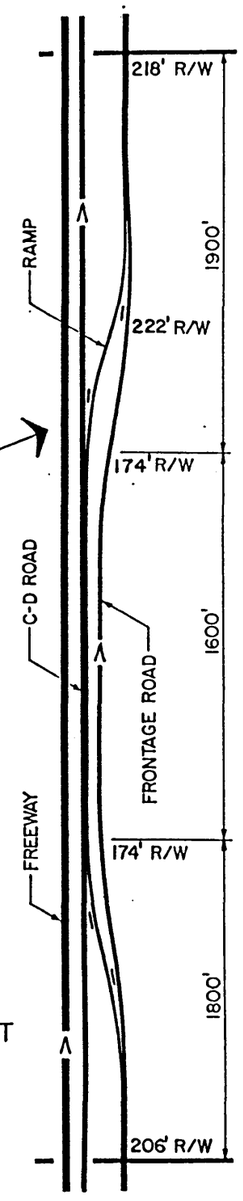
Because no transfer roads are provided, as in previous C-D road schemes, an operationally advantageous 2-mile ramp spacing arrangement is possible. This pattern tends to improve levels of service and minimizes right-of-way requirements. The 2-mile ramp spacing does not eliminate or reduce access. It continues to provide traffic interchanges at each cross street via greater



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

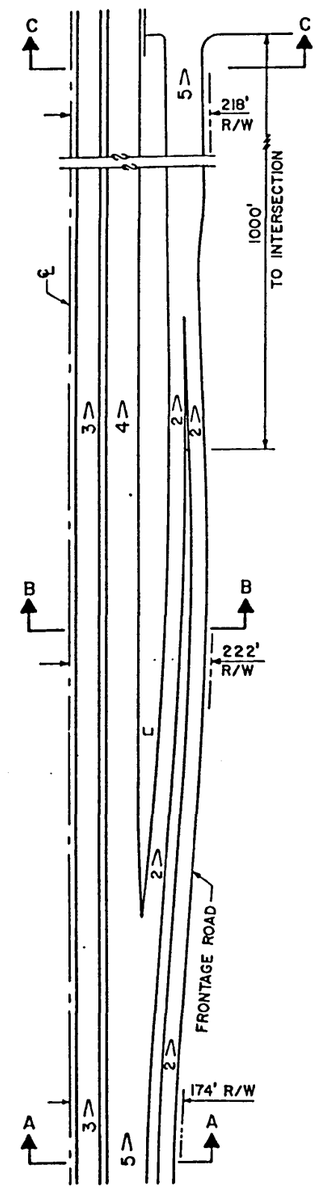


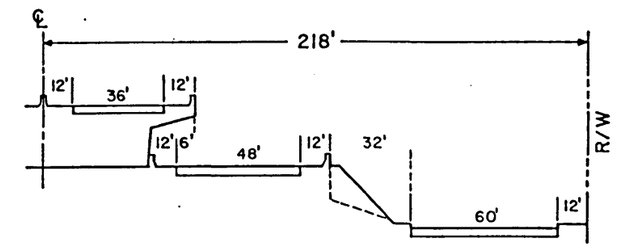
RAMP PATTERN
AND LANE ARRANGEMENT



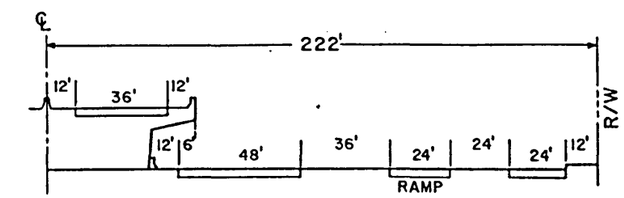
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

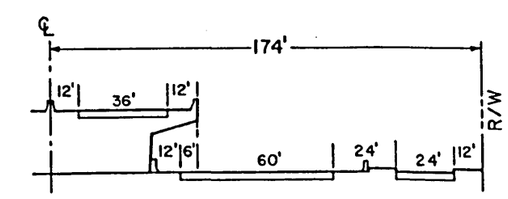




SECTION C-C

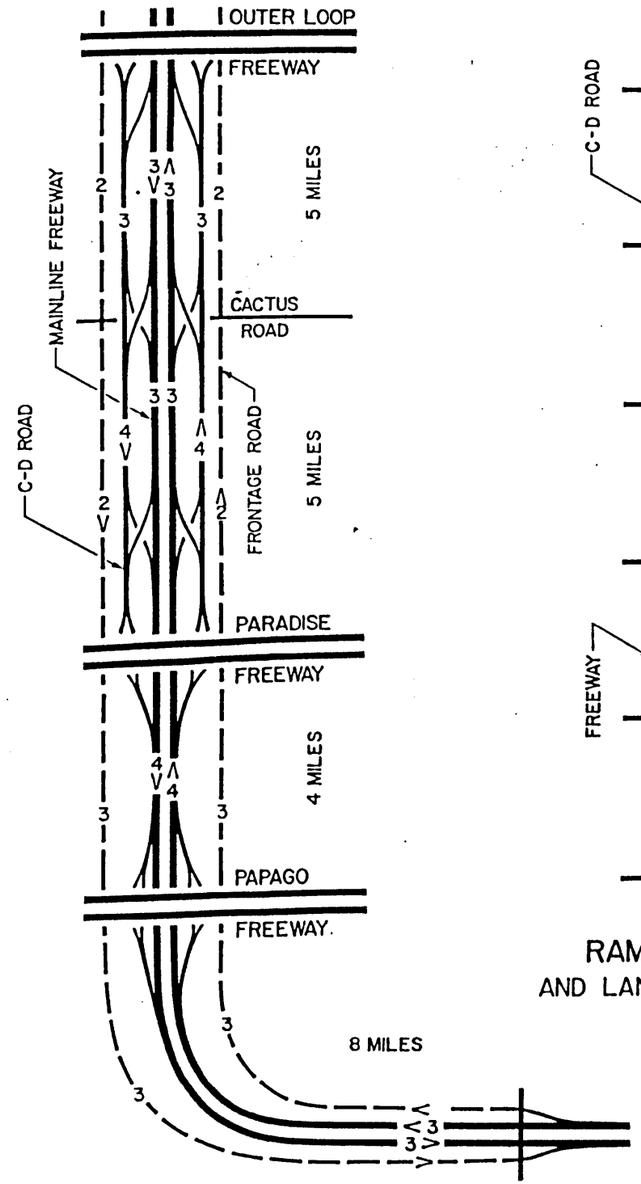


SECTION B-B

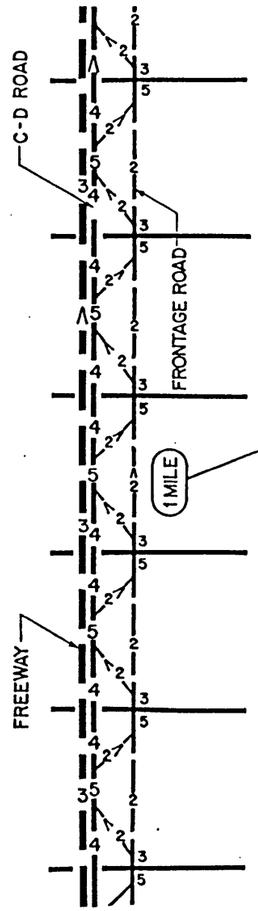


SECTION A-A

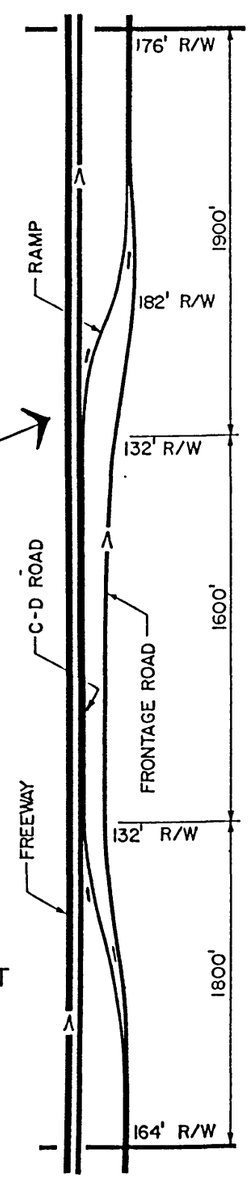
JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME B WITH CONTINUOUS C-D ROADS - ELEVATED MAINLINE SCALE : NTS FEBRUARY 1989	EXHIBIT 37



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

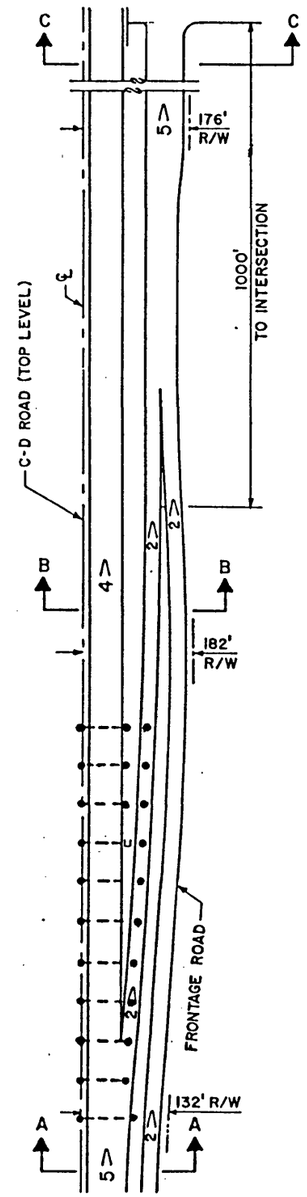


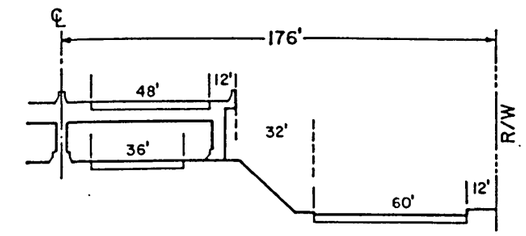
RAMP PATTERN
AND LANE ARRANGEMENT



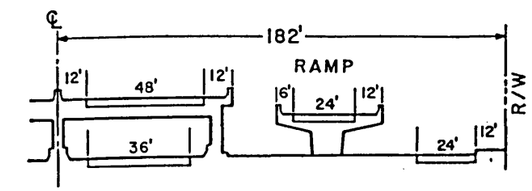
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

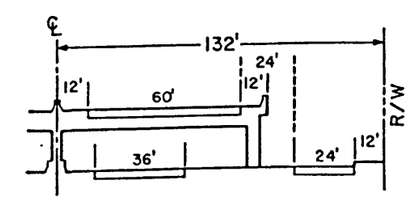




SECTION C-C

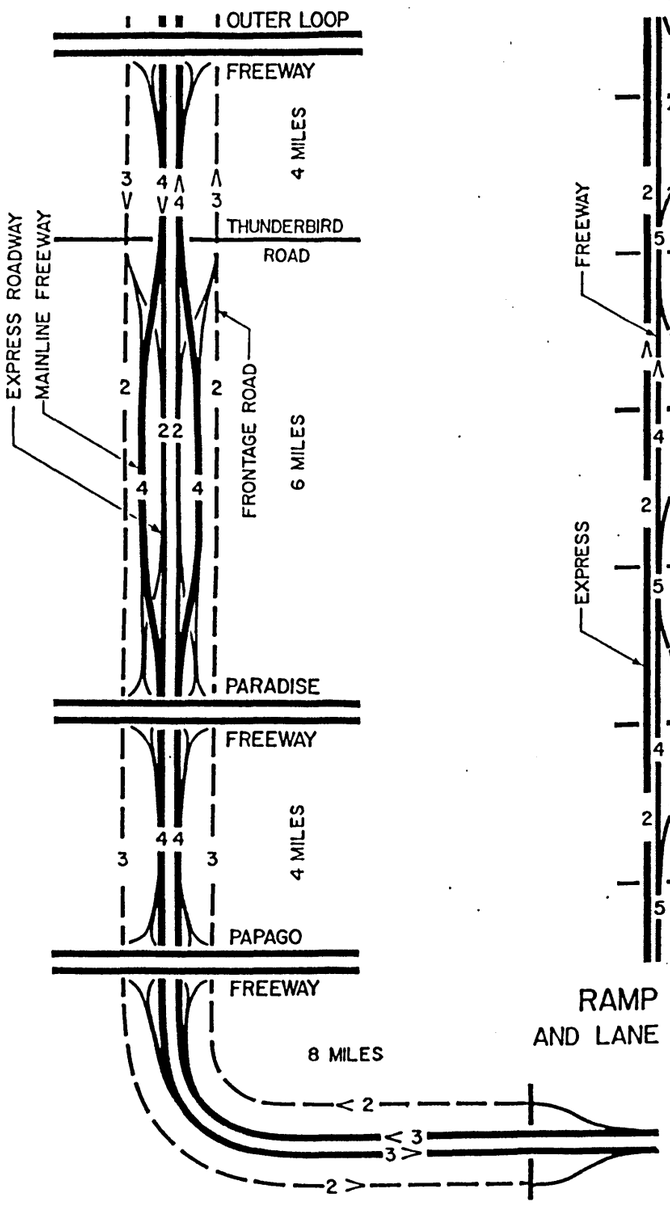


SECTION B-B

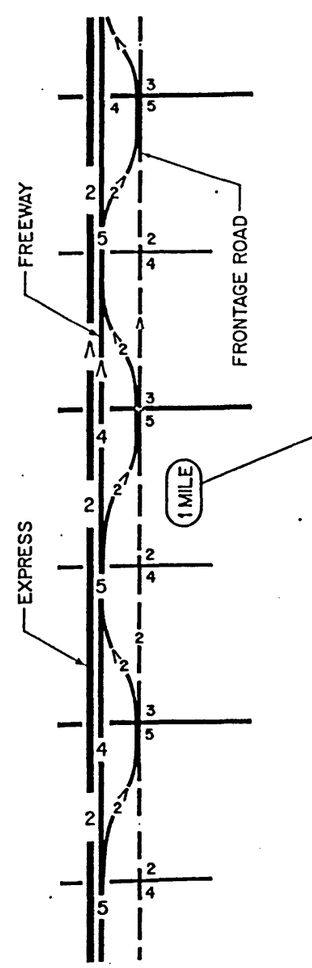


SECTION A-A

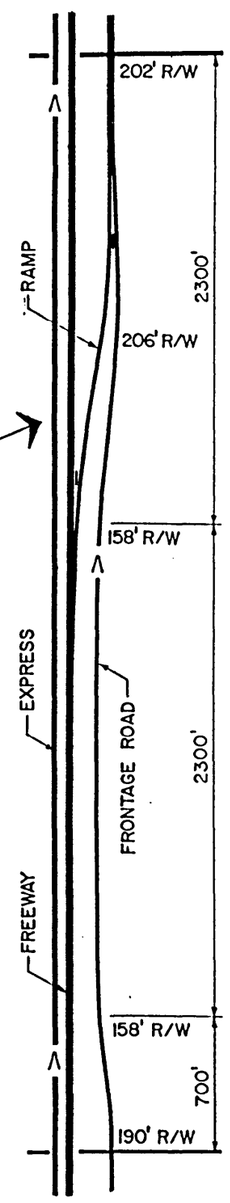
JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME C CONTINUOUS C-D ROADS - DOUBLE DECK SCALE : NTS FEBRUARY 1989	EXHIBIT 38



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

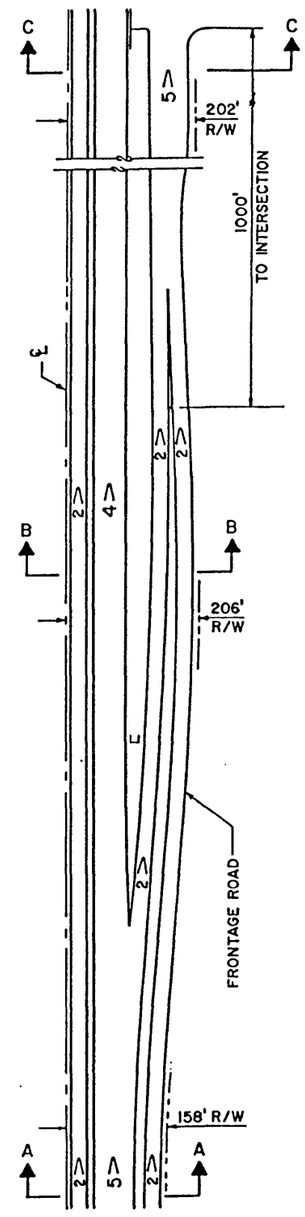


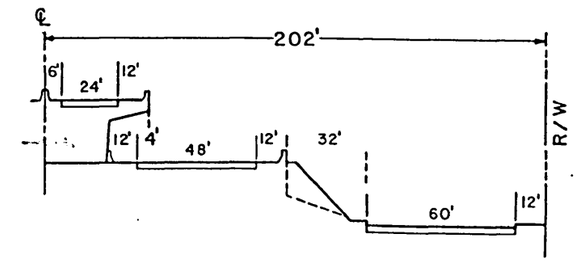
RAMP PATTERN
AND LANE ARRANGEMENT



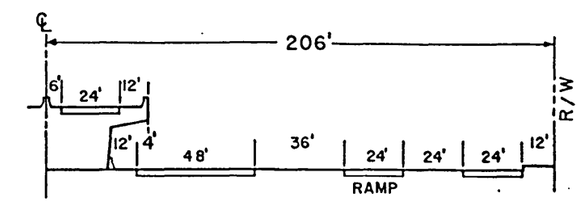
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

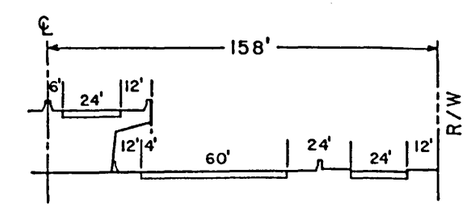




SECTION C-C



SECTION B-B



SECTION A-A

JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

ALTERNATIVE CONCEPTS - SCHEME D
ELEVATED EXPRESS ROADWAYS IN MEDIAN

SCALE : NTS

FEBRUARY 1989

EXHIBIT
39

utilization of the frontage road. Greater lengths of the narrower portion of right-of-way result in the typical mile of facility. Right-of-way widths range from 158 feet to 206 feet in the area of the exit ramps.

SCHEME E

Scheme E, represented by the typical section in Exhibit 35, is another variation of a freeway with express roadways. The system configuration, as shown Exhibit 40, is identical to the previous scheme. The major difference is in the cross-sectional treatment, where the express roadways are positioned on each side of the freeway mainline instead of in the median. The express portion of the facility, 2 lanes in each direction, extends between Thunderbird Road and the Paradise Freeway. South of the Paradise Freeway, the corridor consists of a conventional freeway with high-type, continuous frontage roads.

The ramp pattern, utilizes a 2-mile spacing. Ramp geometry entails a grade-separated crossing with the express roadway. In this scheme the express roadways assume curvilinear portions in conjunction with ramp crossings; however, a 60-mph alignment can be readily provided. Between ramps, the 146 foot right-of-way under this scheme is less than that of Scheme D. However, this scheme requires approximately 16 feet more right-of-way at the ramps widest location.

SCHEME F

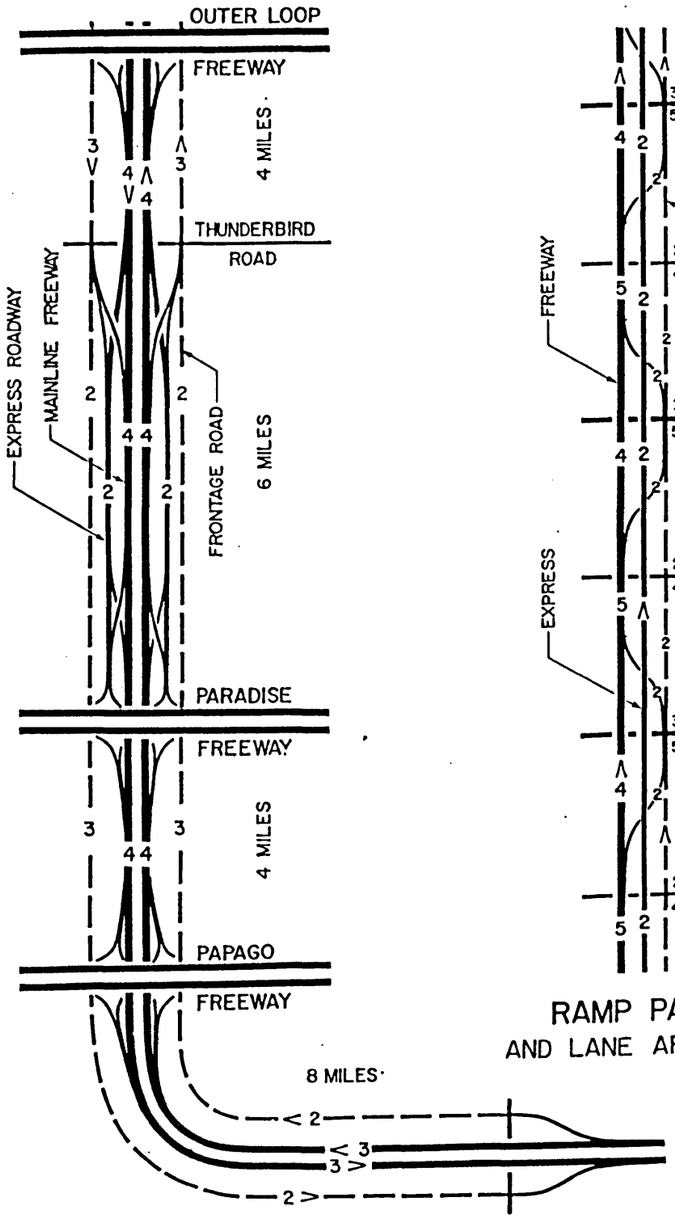
Represented by typical section in Exhibit 35, Scheme F utilizes two traveled ways in each direction. As shown in Exhibit 41, the system configuration consists of mainline freeway and frontage road south of the Papago Freeway. Between the Papago Freeway and the Paradise Freeway, 4 basic mainline freeway lanes and 2 basic C-D/frontage road lanes are provided. North of the Paradise Freeway, 4 and 3 lanes are indicated for the mainline freeway and the combination C-D/frontage road, respectively.

As in the pevious C-D schemes, ramps are actually transfer roadways spaced 3 miles apart. A transfer roadway thus serves 3 crossstreets. At every cross street, a C-D bypass is utilized passing over or under the cross street at the same level as the mainline freeway. The continuation of the frontage road also serves as a ramp at each cross street, allowing (along with the C-D bypass) complete through and interchange movements. 2-mile transfer spacing roads is also feasible and would provide similar levels of service along the facilities, but more right-of-way would be required.

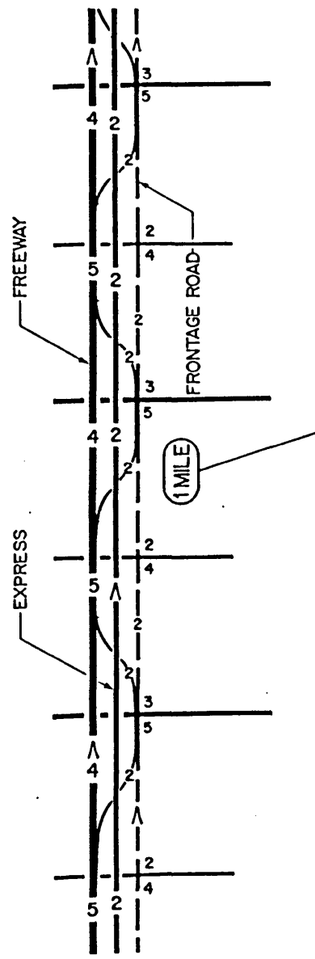
SCHEME G

Another variation utilizing only two traveled ways in each direction is represented by the typical section in Exhibit 35. As shown in Exhibit 42, the system configuration of Scheme G consists of a conventional freeway with continuous one-way frontage roads along the entire length of the facility. The frontage roads, however, have high-type, arterial characteristics throughout. In terms of basic lanes, they vary from 2 lanes on the south to 3 lanes north of the Papago Freeway. The mainline freeway varies from 3 basic lanes in each direction south of the Papago Freeway to 4 basic lanes between the Papago Freeway and Paradise Freeway. North of the Paradise Freeway, 5 basic lanes are provided.

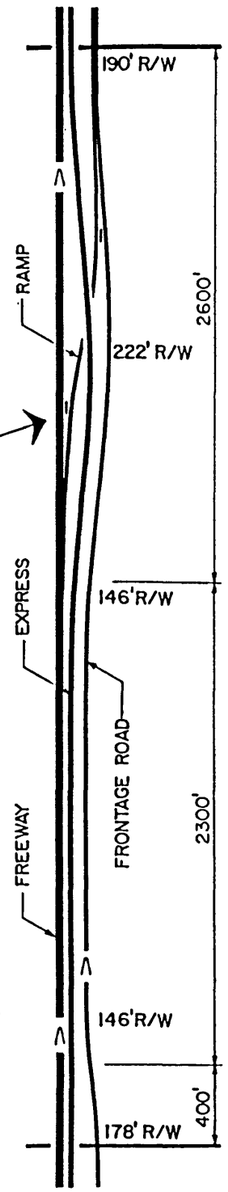
To minimize right-of-way requiements and to improve the quality of operation, ramp spacings for part of the facility are designated at 2-mile intervals. Consistent with previous schemes, traffic interchanges are still provided at each cross street. At critical



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

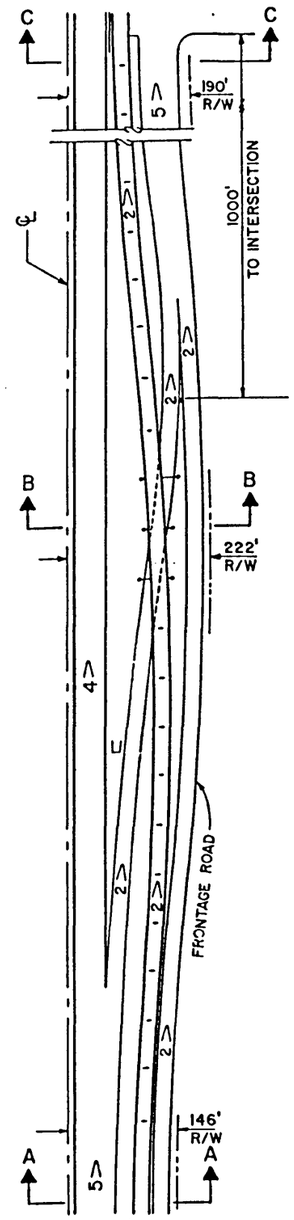


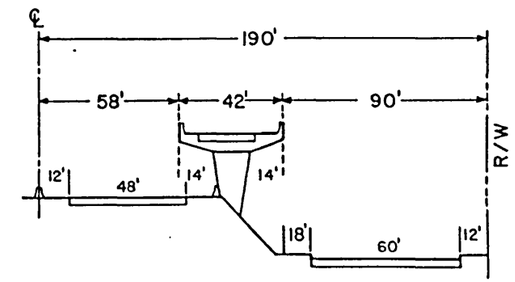
RAMP PATTERN
AND LANE ARRANGEMENT



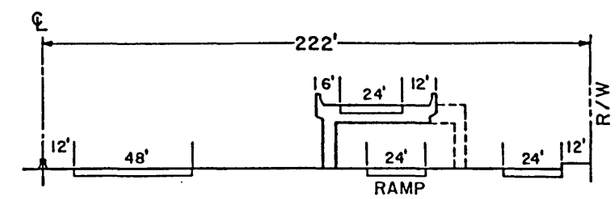
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

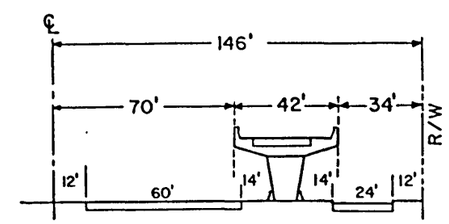




SECTION C-C

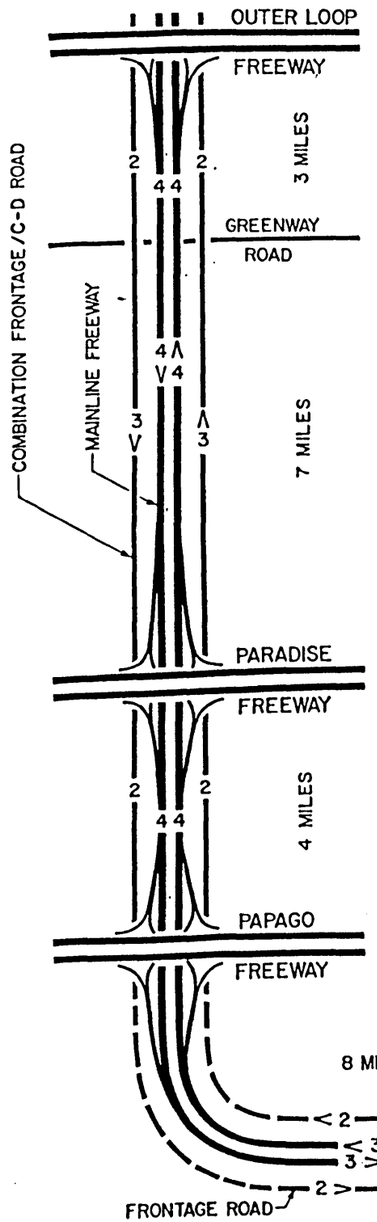


SECTION B-B

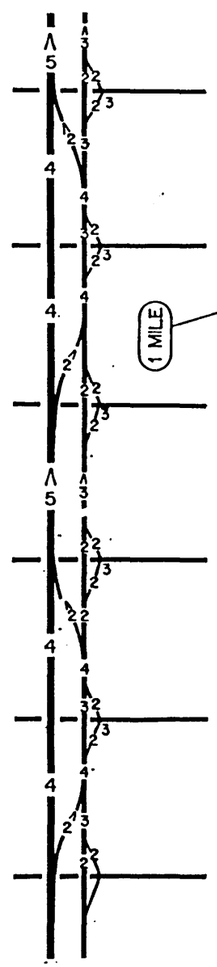


SECTION A-A

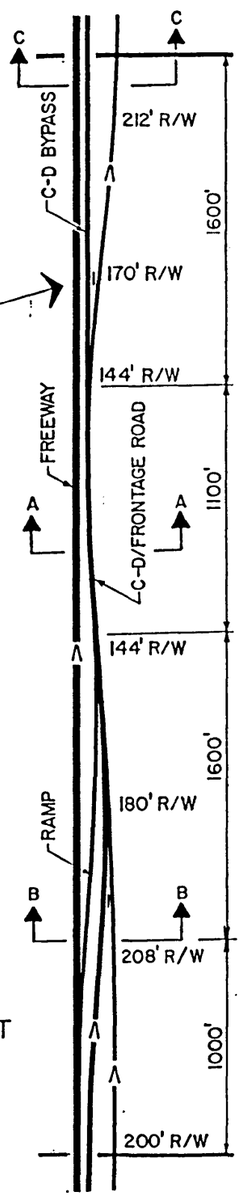
JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME E ELEVATED EXPRESS ROADWAY ON EACH SIDE SCALE : NTS FEBRUARY 1989	EXHIBIT 40



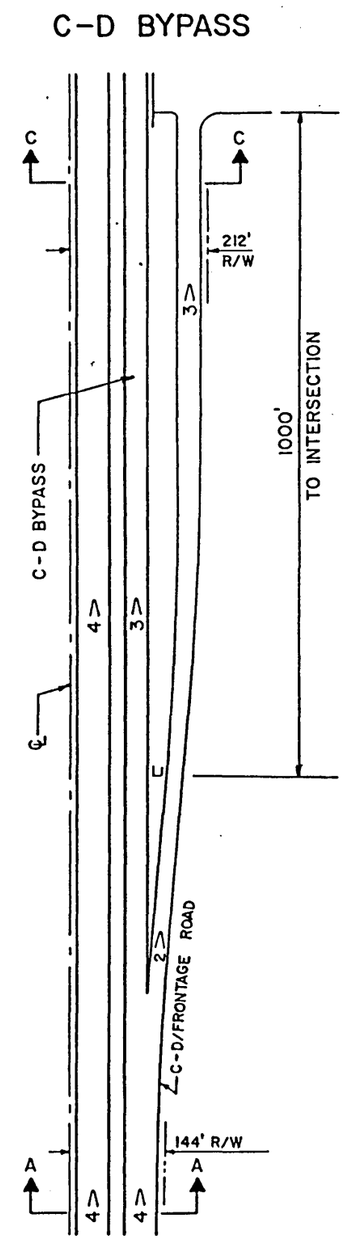
SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

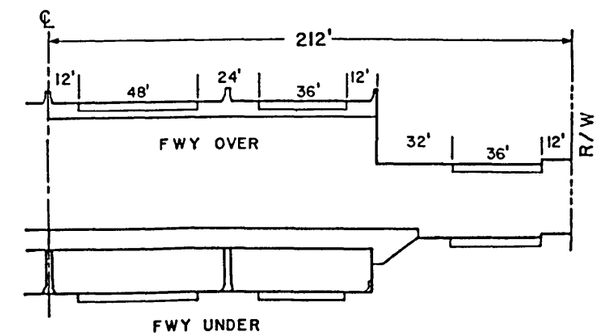


RAMP PATTERN
AND LANE ARRANGEMENT

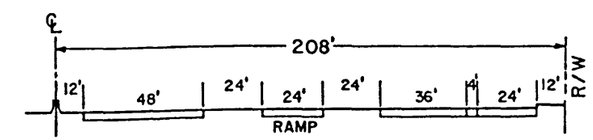


RIGHT-OF-WAY
TYPICAL MILE

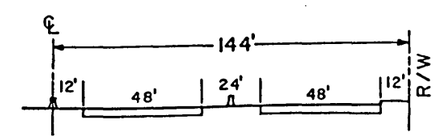




SECTION C-C

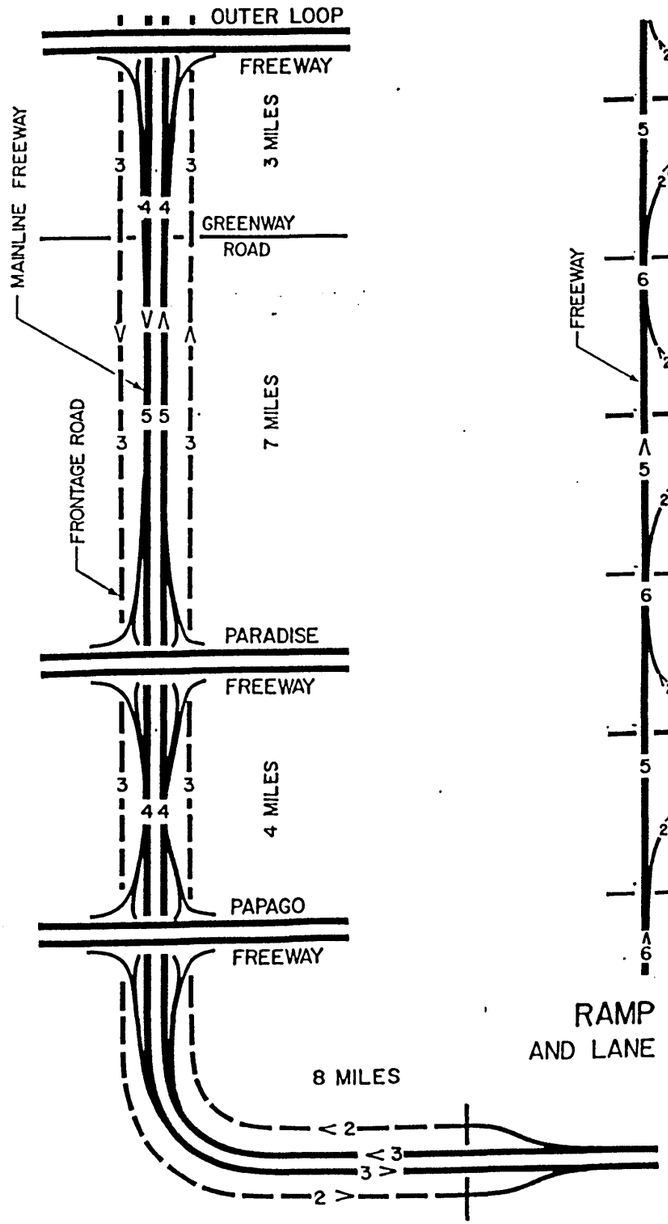


SECTION B-B

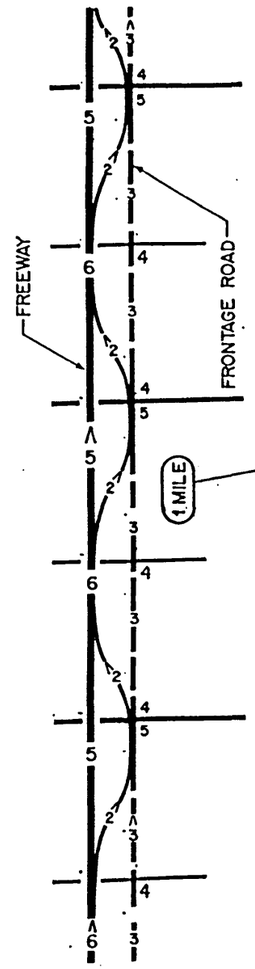


SECTION A-A

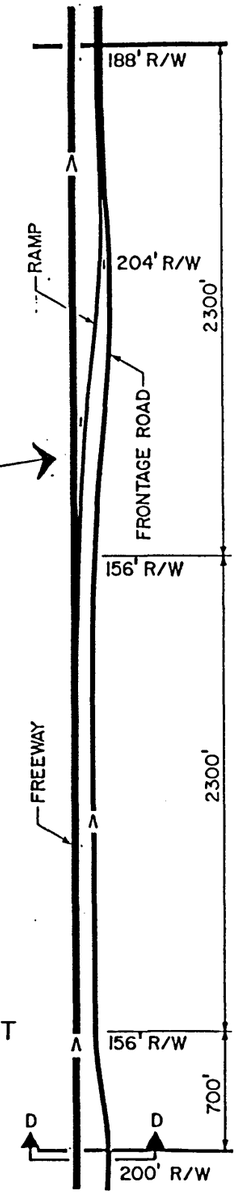
JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME F WITH COMBINATION C-D / FRONTAGE ROADS SCALE : NTS FEBRUARY 1989	EXHIBIT 41



SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

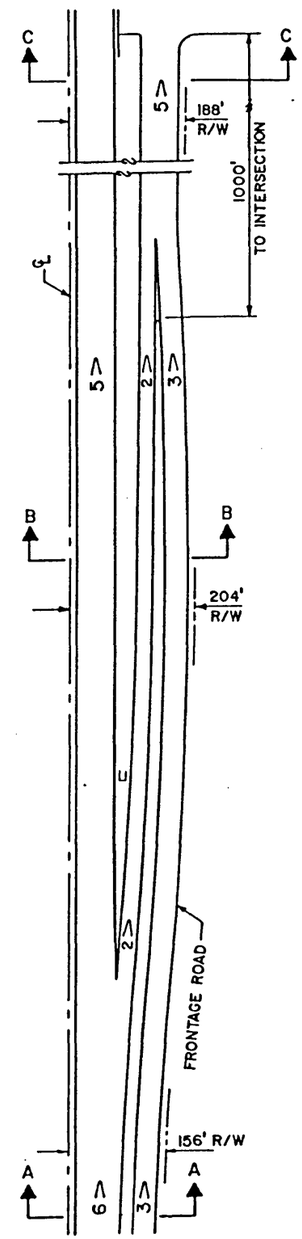


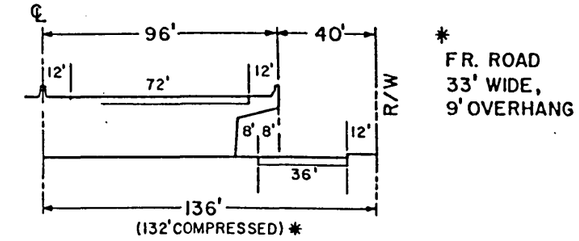
RAMP PATTERN
AND LANE ARRANGEMENT



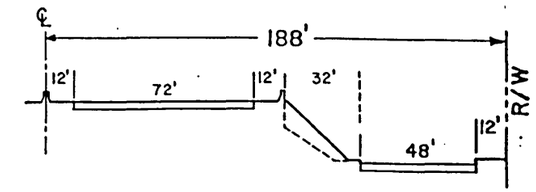
RIGHT-OF-WAY
TYPICAL MILE

RAMP GEOMETRY

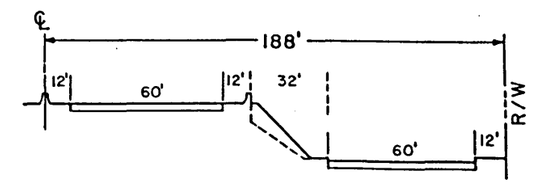




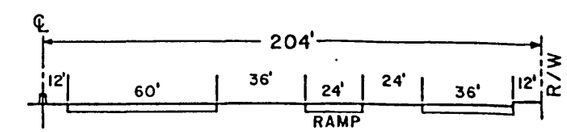
SPECIAL SECTION A-A



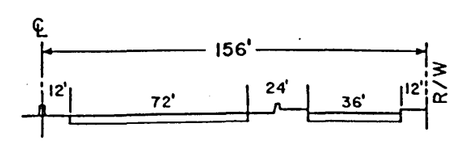
SECTION D-D



SECTION C-C



SECTION B-B



SECTION A-A

JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

ALTERNATIVE CONCEPTS - SCHEME G
CONTINUOUS HIGH-TYPE FRONTAGE ROADS

SCALE : NTS

FEBRUARY 1989

EXHIBIT
42

interchanges are still provided at each cross street. At critical right-of-way locations along the facility, a portion of the freeway proper may be elevated to compress the required width from 156 to 136 feet, as indicated in the special section A-A.

SCHEME H

The last alternative, represented by the typical section in Exhibit 35, is a variation of the previous alternative. Since an attempt has been made to minimize right-of-way progressively within each alternative category, Scheme H represents the most compact arrangement. This is accomplished by double decking the mainline freeway, with each level separately accommodating one-way traffic. The system configuration, as shown in Exhibit 43, consists of freeway roadways with continuous high-type frontage roads along the entire length of the facility. The number of basic lanes is identical to Scheme G, with the maximum in each direction located between the Paradise Freeway and Greenway Road. In this section 5 basic freeway lanes and 3 basic frontage road lanes are provided.

Interchanging traffic is handled at each cross street with ramps spaced at 2-mile intervals. One-mile ramp sequencing is not practical in this case due to inadequate weaving sections of approximately 1,000 feet. The short weaving sections are formed by the extra long ramps necessitated by the vertical difference of the elevated double-deck facility.

Between the Papago Freeway and Dunlap Avenue only nominal right-of-way taking would be needed. Between Dunlap Avenue and the Outer Loop Freeway, corridor improvements, for the most part, would fit within the existing right-of-way. Ramp geometry is shown for one-half of a representative diamond interchange. Different treatment may be noted for the lower and upper levels of the freeway.

Because of a continuous roof effect over the lower freeway roadway, special signing would be necessary, with some raising of the superstructure to accommodate single-line, 3-foot high sign panels.

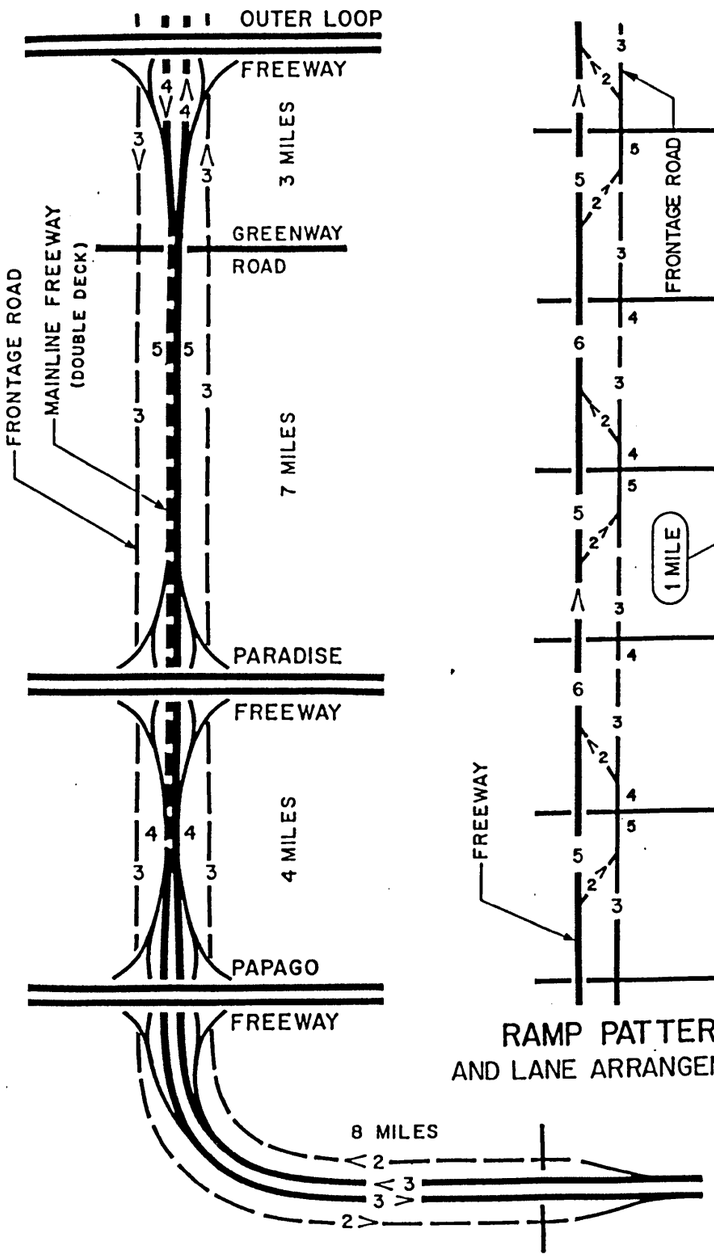
RAMP AND TRANSFER ROAD SPACING

Presently, interchanges along the existing I-17 corridor are located at one-mile intervals. This spacing is maintained in the alternative improvements with C-D roads, Schemes A, B and C. Transfer roads, however, are spaced at 3-mile intervals, with each transfer road from mainline freeway to C-D road serving three interchanges. In Schemes D and E, which have express roadways, a two-mile interchange sequence is indicated as a means of further simplifying the plan and reducing right-of-way. In Scheme F where the second travelled way in each direction is a combination C-D/ frontage road, the interconnecting ramps in essence are transfe roadways and are spaced at 3-mile intervals. Each one-mile cross street is served from the C-D road by a ramp from the frontage road portion of the second travelled way (Exhibit 41). In Scheme G, which employs a high-type frontage road in addition to the mainline freeway, interchanges could be advantageously spaced at 2-mile intervals as previously proposed in Schemes D and E.

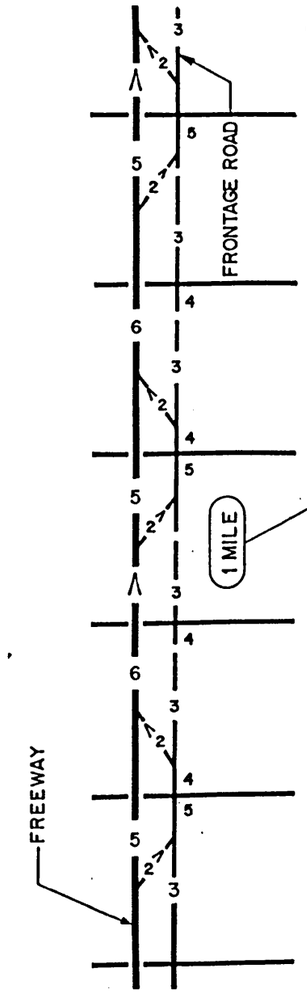
Analysis has been accomplished in relation to the one-mile versus two-mile interchange spacing. Exhibit 44 shows the geometrics over a two-mile or more length of freeway for one-mile spacing and for three-mile spacing, including apportionment of longitudinal dimensions, number of lanes, and representative design hour traffic volumes. These volumes are generally respresentative of mainline and ramp volumes along much of the corridor.

For the one-mile spacing, (upper diagram) lengths of weaving sections on the freeway are 1900 feet long for a 1600-vph weave; for the two-mile spacing (lower diagram) lengths of weaving

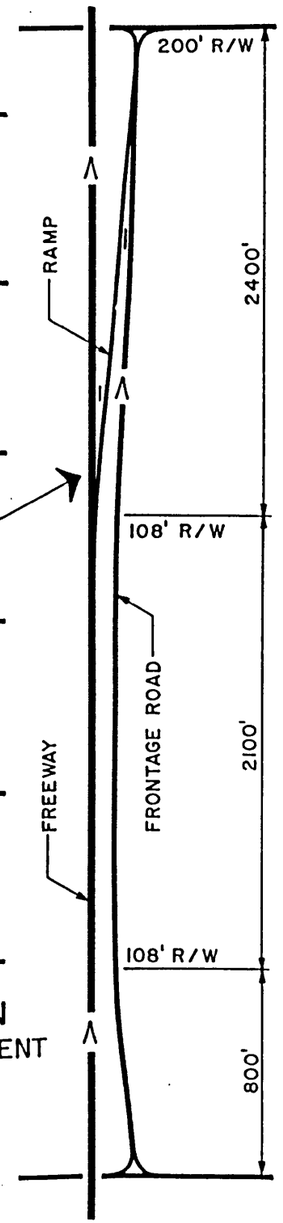
RAMP GEOMETRY



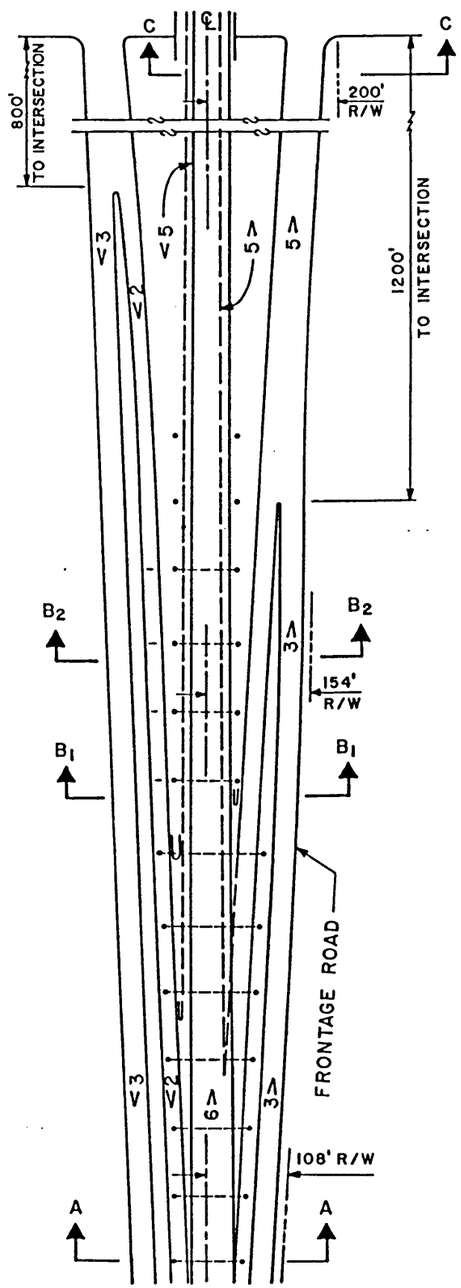
SYSTEM CONFIGURATION
AND BASIC NO. OF LANES

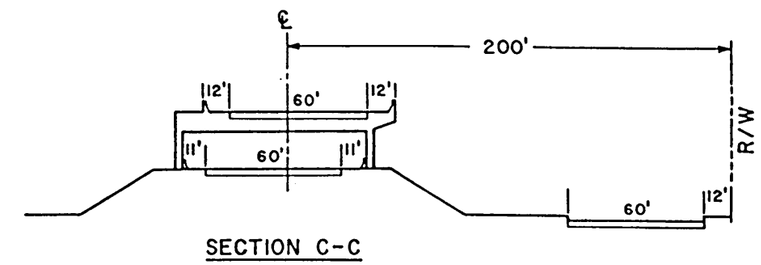


RAMP PATTERN
AND LANE ARRANGEMENT

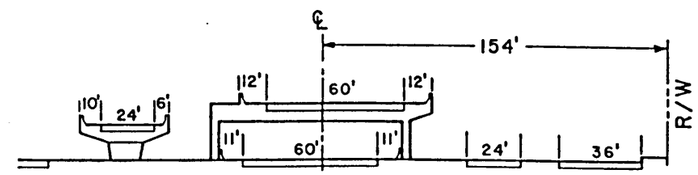


RIGHT-OF-WAY
TYPICAL MILE

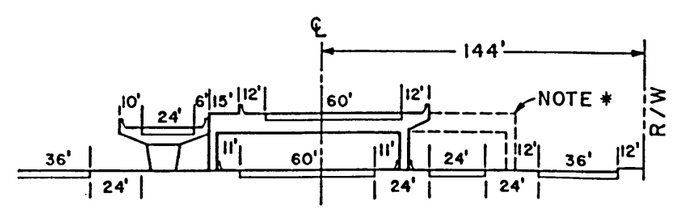




SECTION C-C

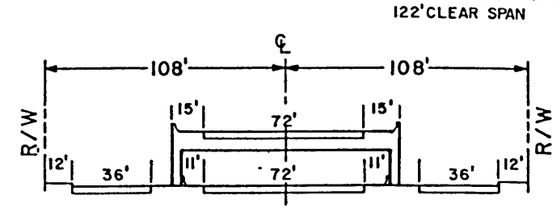


SECTION B_2-B_2



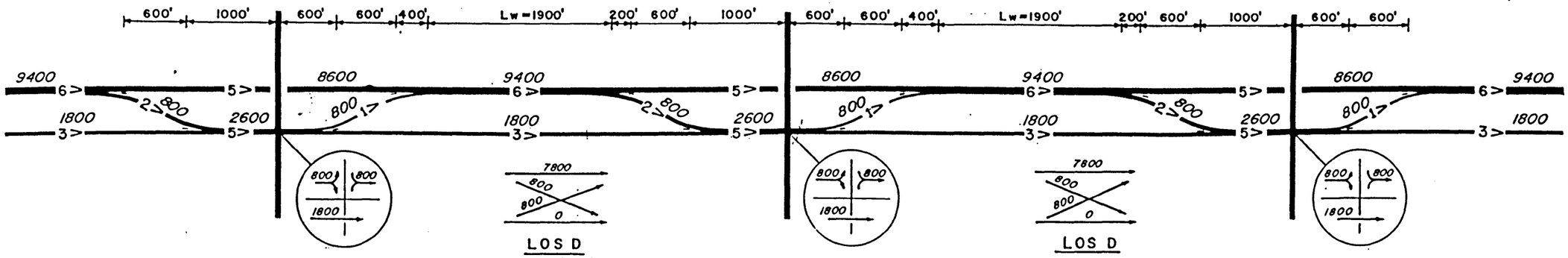
SECTION B_1-B_1

* NOTE
PREVIOUS BENT (OUTRIGGERED)
122' CLEAR SPAN

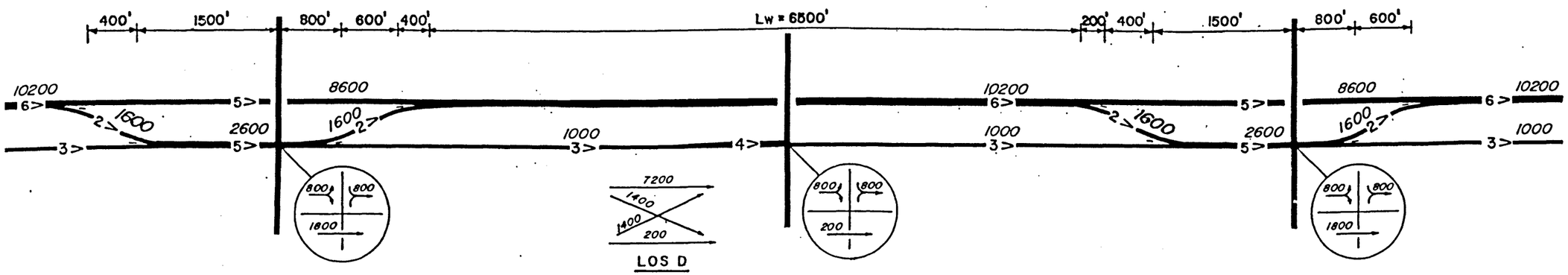


SECTION A-A

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ALTERNATIVE CONCEPTS - SCHEME H CONTINUOUS HIGH-TYPE FRONTAGE ROADS - DOUBLE DECK MAINLINE SCALE : NTS FEBRUARY 1989	EXHIBIT 43



ONE-MILE RAMP SPACING



TWO-MILE RAMP SPACING

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ANALYSIS OF ALTERNATIVE RAMP SPACING CONVENTIONAL FRONTAGE ROAD SCALE : NTS FEBRUARY 1989	EXHIBIT 44

R1

sections are 7200 feet long for 2800 vph weave. The levels of service are D in each case, same as for overall flow on the mainline; however, besides being substantially shorter, there are twice as many weaving sections on the freeway with one-mile than 2-mile spacing. As indicated in the exhibit, the total freeway volume is greater between the interchanges with the two-mile ramp spacing than with the one-mile spacing. Both yield the same level of service. Since the total corridor traffic is the same the frontage road traffic between the interchanges is less with the two-mile spacing.

Another aspect is the relative difference in right-of-way requirements between the plans. Potential right-of-way requirements are considerably less with the 2-mile spacing because of the greater flexibility to shift ramps longitudinally. The one-mile spacing, on the other hand, does not lend itself to ramp repositioning because weaving sections on the freeway might be shortened beyond an already near-minimum length.

Transfer road spacing on Scheme F, which utilizes a combination C-D/frontage road, are shown at three-mile intervals. These also could be spaced at two-mile intervals. The comparison of the two arrangements are analyzed in Exhibit 45. Weaving effects and levels of service do not differ much on the mainline freeway. Weaving sections along the C-D/frontage road produce similar levels of service. The major difference is the number of ramp-sequence segments produced along the C-D/frontage road. There would be four in the 3-mile spacing scheme and five in the 2-mile spacing scheme. Because of this, the 2-mile spacing arrangement would have greater right-of-way impact and is less flexible in adjusting the design at strategic places to better fit existing development. Either 3-mile or 2-mile spacing of transfer roadways, or more likely a combination of the two, may be used in Scheme F depending upon specific conditions encountered.

CONCLUSIONS - LONG RANGE CONCEPTS

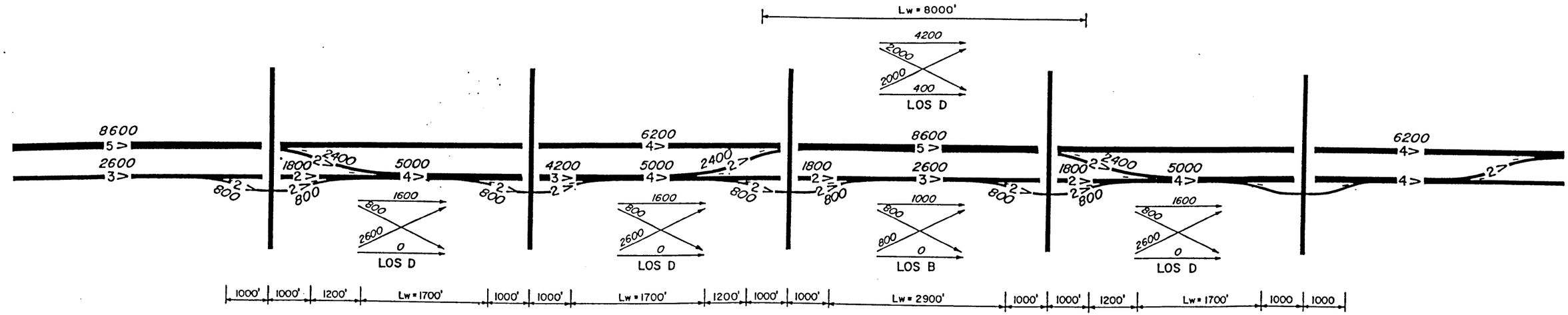
It was agreed by representatives of ADOT and the consultant that alternatives A, B, C and D should be eliminated from further consideration for the following reasons:

- Scheme A is a core freeway flanked by continuous C-D roads and one-way frontage roads has the maximum coss-section of all the schemes. Acquiring the necessary right-of-way would severely impact or eliminate major buildings along the coridor.

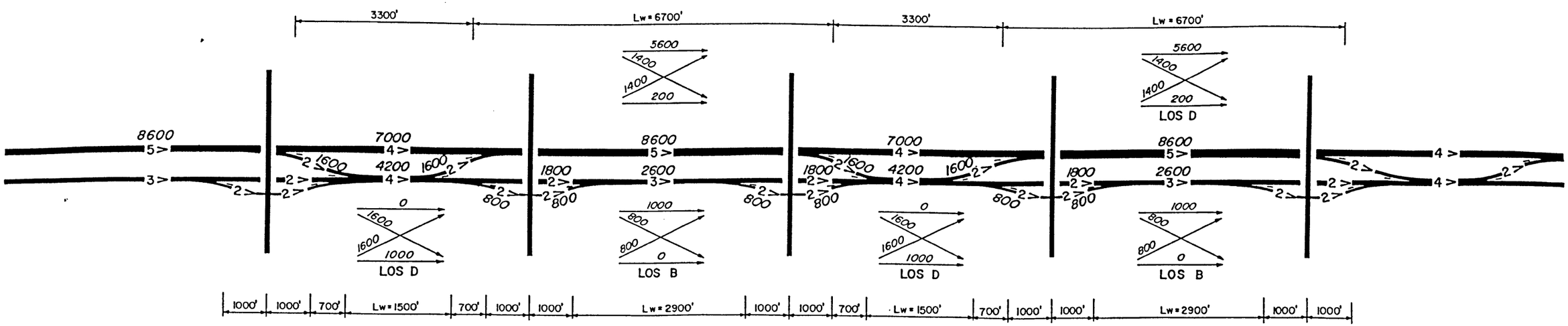
- Scheme B provides an elevated freeway flanked by continuous C-D roads and one-way frontage roads would require slightly less right-of-way than Scheme A. However, the construction cost would be several times greater than Scheme A and construction phasing and maintenance of traffic would be difficult, if not impractical.

- Scheme C is a double-deck facility with the C-D road on the upper level, and the mainline freeway on the lower level, flanked by frontage roads. Again, the excessive cost and traffic maintenance problems render that concept unacceptable.

- Scheme D provides an elevated express roadway in the median with the mainline freeway and frontage roads on either side. This scheme requires reconstructing all elements of the facility. The impracticability of maintaining traffic during construction required eliminating this alternative.



THREE-MILE TRANSFER ROAD SPACING



TWO-MILE TRANSFER ROAD SPACING

JACK E. LEISCH & ASSOCIATES	ARIZONA DEPARTMENT OF TRANSPORTATION INTERSTATE 17 CORRIDOR STUDY	ANALYSIS OF ALTERNATIVE RAMP SPACING COMBINATION C-D / FRONTAGE ROAD SCALE : NTS FEBRUARY 1989	EXHIBIT 45

INTERIM IMPROVEMENT CONCEPTS

The results of the evaluation of the existing facility indicate the immediate need for capacity enhancements within the corridor. In particular, the central section between the Papago Interchange and Thunderbird Road presently exhibits high traffic demands and poor operational characteristics. And while this section operates poorly today, traffic projections indicate a large increase in traffic volumes by the year 2010.

Near-term freeway widening concepts to provide additional capacity between Indian School Road and Thunderbird Road have been developed. The goal of these improvements is to provide an immediate capacity increase and improve safety and operations within the corridor. Objectives of the improvement are to provide additional through freeway capacity with minimal or no right-of-way acquisition, low implementation costs, and no cross street structure replacement. Ideally, these short range improvements would be compatible with the long range plan and could be initiated in a way to minimize "throw-away" construction. Further, interim improvements should be coordinated with the implementation of the Freeway Management System.

ALTERNATIVE WIDENING SCHEMES

Three methods of adding a lane to I-17 were developed and are presented in Exhibit 46. Alternatives range from simply adding an auxiliary lane between interchanges to providing a two-mile auxiliary lane and two-mile interchange spacing.

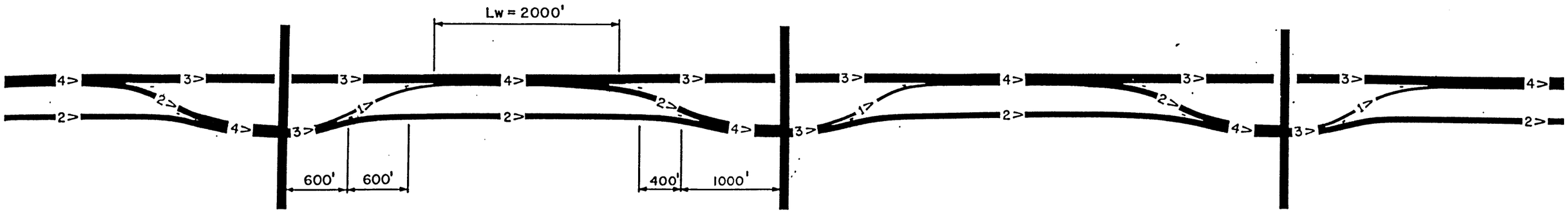
Widening Concepts

Concept A would add an auxiliary lane between the one mile cross streets. A lane is added as the single lane entrance ramp joins the freeway. The auxiliary lane is then dropped at the 2-lane exit ramp while three freeway lanes pass under the cross street structure. Adding the auxiliary lane would require reconstructing the existing entrance and exit ramps and modifying the present frontage road alignment.

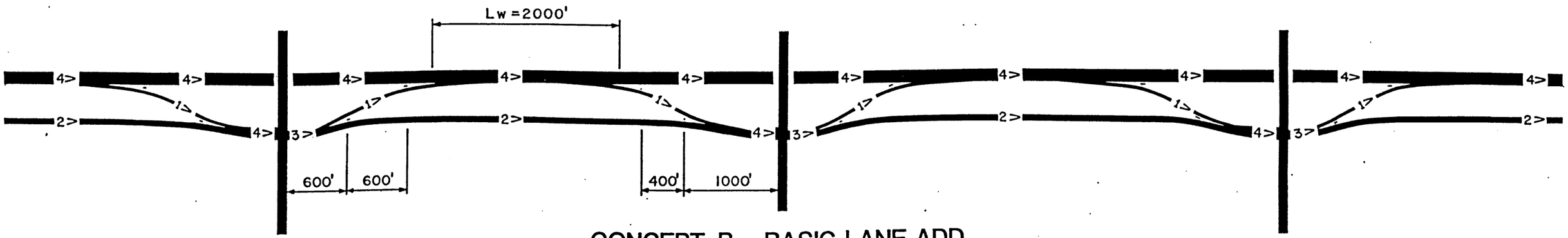
By adding the auxiliary lane between ramps, turbulence in the weaving section would be reduced and freeway operations would be improved. However, because only three freeway lanes are continuous, the through capacity of the facility remains unchanged.

Concept B would add one basic lane to the freeway in each direction. Existing ramps would be reconstructed and the frontage road would be realigned at the ramp junctions to facilitate a fourth continuous freeway lane. In order to attain four basic lanes under the existing cross street structures, a reduced cross section would be required. Freeway operations at the exit ramp terminals under scheme B would improve slightly over those in scheme A because of the increase in the number of basic lanes. However, a more significant improvement in Scheme B is that the through capacity is increased by adding a basic lane to the facility.

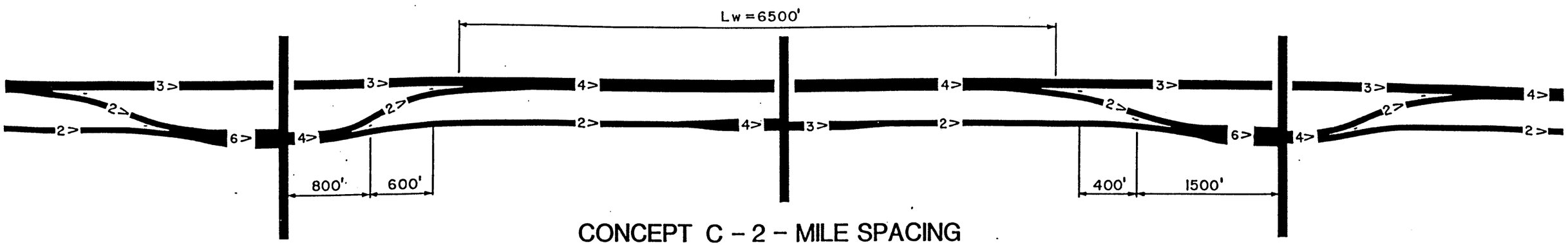
Concept C is a modification of the one-mile interchange spacing. Intermediate cross street interchange ramps are removed and an auxiliary freeway lane would be provided in each two-mile segment between entrance and exit ramps. Three freeway lanes would then pass under the interchange cross street structure. Frontage roads would be adjusted to accommodate two through lanes at the ramp junctions. Ramps would be reconstructed to provide an auxilliary lane and 2-lane exits. This configuration improves freeway operations by effectively directing local corridor traffic from the freeway to the frontage roads. The volume reduction on the freeway beyond the 2-lane exit ramps would improve the operation of the three mainline lanes through the interchange area. A mainline weaving length of



CONCEPT A – AUXILIARY LANE ADD



CONCEPT B – BASIC LANE ADD



CONCEPT C – 2 – MILE SPACING

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over 6,000 feet would facilitate the interaction between the higher entering and exiting volumes.

This concept would require additional intersectional and frontage road improvements and would not be compatible with a minimum cost/minimum right-of-way alternative. It is recommended, with this concept, that the frontage road be widened to two continuous lanes to accommodate frontage road traffic volumes.

Cross-Sectional Alternatives

Four alternative mainline widening schemes for providing an additional lane, including one that provides a high occupancy vehicle (HOV lane) were developed. These improvement plans are based on widening the freeway mainline pavement to the outside or a combination of widening to the outside and the inside. Each method has advantages and disadvantages based on safety, operations, ease of implementation, construction cost and right-of-way impacts. The alternative cross sectional widening schemes are shown for the minimum right-of-way section (200 feet) in Exhibit 47.

Scheme 1 would hold the outside curb line, reduce the lane width to 11 feet, widen the mainline pavement 8 feet to the outside reducing the outside shoulder to 2 feet. This alternative would minimize traffic disruption during construction because only the right shoulder would be rebuilt. Widening to the right would require relocating the frontage road to modify the entrance and exit ramps. These modifications may require the acquisition of right-of-way.

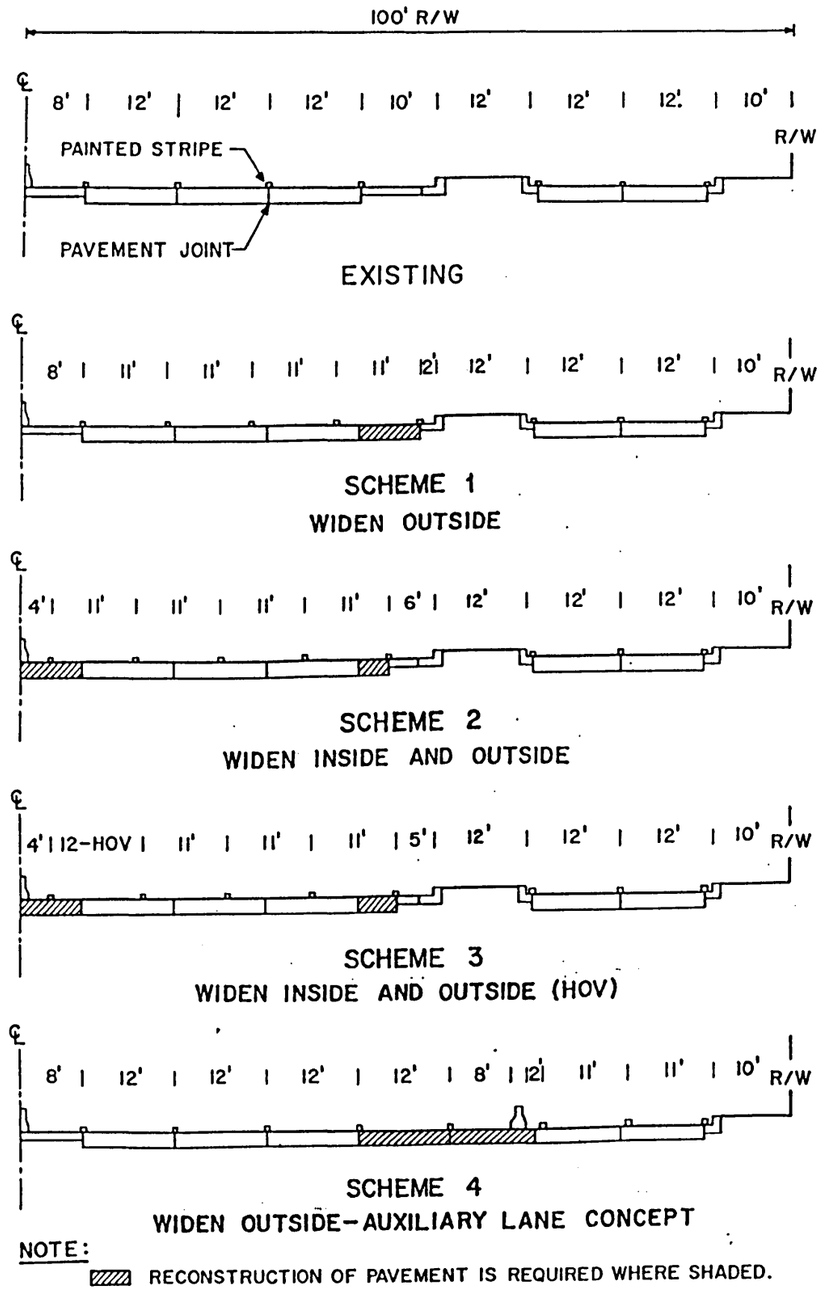
While reducing the lane width to 11 feet may have little operational impact, the virtual elimination of the right shoulder would most likely adversely affect operations and safety. The close proximity to roadside obstructions, such as guardrail and light standards, and the lack of an emergency breakdown area makes this alternative less desirable than the other widening schemes. It is recommended that this scheme be considered only with the Concept A widening method.

Scheme 2 would hold the outside curb and widen the freeway both to the inside and outside to provide four 11-foot lanes plus a 4-foot inside shoulder. Reducing the inside shoulder would allow enough width for a 6-foot breakdown area on the right. This alternative would also minimize the amount of frontage road relocation and therefore reduce the potential for acquiring right-of-way.

The 6-foot breakdown on the right area would increase the distance from roadside obstructions and provide the minimum space for emergency parking, traffic enforcement, and highway maintenance activities. From a safety and operation viewpoint, this scheme is preferable to Scheme 1. Because both left and right shoulder would be reconstructed, additional shifting of traffic during construction would be required to implement this scheme resulting in a higher construction cost.

Scheme 3 is essentially the same configuration as that in Scheme 2 with the exception of a 12-foot inside HOV lane. The right shoulder would be reduced to 5 feet in order to attain the 12-foot HOV lane. The advantages and disadvantages associated with this alternative and Scheme C are virtually identical. With no buffer between the HOV lane and the general use lanes, the vehicle speed differential may create an unsafe condition and have a negative impact on the speed of vehicles in the HOV lane.

Scheme 4 indicates widening to the right into the separation between the mainline of I-17 and the frontage road to provide four 12-foot



NOTE:
▨ RECONSTRUCTION OF PAVEMENT IS REQUIRED WHERE SHADED.

ADVANTAGES	DISADVANTAGES
	• PRESENT NUMBER OF LANES UNABLE TO PROVIDE FOR TRAVEL DEMAND • DURING PEAK DEMAND FACILITY OPERATES AT LOW LEVEL OF SERVICE
• RECONSTRUCTS RIGHT SHOULDER ONLY • MINIMIZES TRAFFIC DISRUPTION DURING CONSTRUCTION	• REQUIRES FRONTAGE ROAD RELOCATION AT MERGE/DIVERGE LOCATIONS • DOES NOT PROVIDE BREAKDOWN AREA ON RIGHT • REDUCES LANE WIDTH
• PROVIDES PARTIAL BREAKDOWN AREA ON RIGHT • MINIMIZES FRONTAGE ROAD RELOCATION AT MERGE/DIVERGE LOCATIONS	• REQUIRES RECONSTRUCTION OF LEFT AND RIGHT SHOULDERS • REQUIRES ADDITIONAL SHIFTS OF TRAFFIC DURING CONSTRUCTION • REDUCES LEFT SHOULDER WIDTH • REDUCES LANE WIDTHS
• PROVIDES HOV LANE • MINIMIZES FRONTAGE ROAD RELOCATION AT MERGE/DIVERGE LOCATIONS • PROVIDES PARTIAL BREAKDOWN AREA ON RIGHT	• REQUIRES RECONSTRUCTION OF LEFT AND RIGHT SHOULDERS • REQUIRES ADDITIONAL SHIFTS OF TRAFFIC DURING CONSTRUCTION • REDUCES LEFT SHOULDER WIDTH • REDUCES LANE WIDTHS
• PROVIDES 12' LANE WIDTHS • PROVIDES BREAKDOWN AREAS BOTH LEFT AND RIGHT • LEFT LANE COULD BE CONVERTED TO AN HOV LANE	• COMPATIBLE WITH CONCEPT "A" ONLY • REQUIRES RECONSTRUCTION OF THE SEPARATION BETWEEN THE MAINLINE AND FRONTAGE ROAD • REQUIRES ADDITIONAL FRONTAGE ROAD RELOCATION AT MERGE/DIVERGE LOCATIONS

JACK E. LEISCH & ASSOCIATES

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERSTATE 17 CORRIDOR STUDY

INTERIM IMPROVEMENTS
CROSS-SECTIONAL ALTERNATIVES

SCALE : NTS

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freeway lanes and an 8-foot right shoulder. The frontage road lanes would be reduced to 11 feet and a double-faced concete barrier would separate the freeway and frontage road traffic.

This scheme is compatible with widening Concept A only. From an operations and safety standpoint, this alternative would be more desirable than the previous schemes because it would have 12-foot freeway lanes and greater right and left shoulder widths. In addition the left lane could be used as an exclusive HOV lane. However, this alternative does require more extensive construction than the preceding schemes because of the freeway/frontage road separation reconstruction and the drainage relocation. This alternative would require more right-of-way acquisition than the other alternatives.

CONCLUSIONS - INTERIM IMPROVEMENTS

The investigation of Interim improvement concepts has only just begun. Consequently no definitive recommendations or conclusions can be reached at this time in the design study. It is, however, anticipated that three alternatives will be developed and studied in greater depth. One of these alternatives would require no right-of-way acquisition. As can be imagined, this scheme will be limiting in both capacity improvement and compatibility with traffic management objectives. The other two alternatives would require right-of-way acquisition. These alternatives would reflect the differing cross-section alternatives, widening concepts, traffic management requirements and as much as possible, compatibility with longer range improvements.

INCREMENTAL PLAN IMPLEMENTATION

Construction phasing has been considered to incrementally implement the interim and long range improvement plans. This serves three basic purposes: 1) improvement plans are implemented on an as needed basis when they are warranted by increasing demand, 2) incremental phasing provides flexibility to modify the incremental improvements because of unforeseen changes in traffic patterns or demands, and 3) incremental improvements lower initial construction cost.

Three phases were developed to upgrade to corridor on an as needed basis. Each phase would provide improvements to the corridor while maintaining compatibility with successive construction projects. Compatibility between phases reduces the need for "throw-away" construction while upgrading the facility. The three implementation phases are shown summarized in Exhibit 48 and are described below.

PHASE I

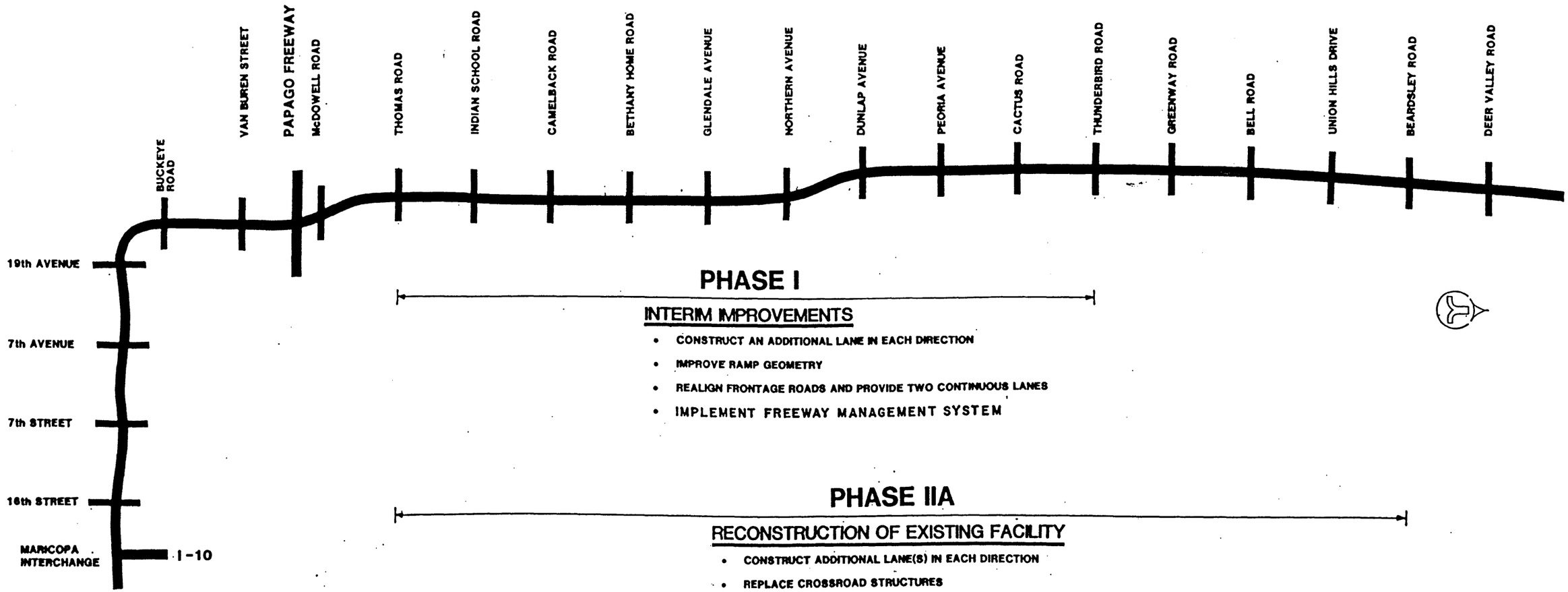
Phase I consists of interim improvements that would increase facility capacity while minimizing construction costs, traffic disruption, and right-of-way impacts. These improvements add a fourth lane in each direction, improve ramp geometry, and implement the Freeway Management System, including ramp metering. These improvements are expected to extend the life of the existing facility until more extensive improvements can be developed, financed and implemented.

PHASE II

Phase II improvements would be more extensive than Phase I. These construction efforts would significantly upgrade the facility by adding freeway lanes, rebuilding crossroad bridges, modifying interchanges, and widening and realigning the frontage roads to their ultimate configuration. Phase II has been separated into two sub phases -- one improving the central and north sections of I-17 and the other improving the south section. Because projected increases in traffic demand in this area are lower than other sections of the corridor, the south section can most likely be improved over time by replacing and reconstructing the freeway elements as they exceed their designed service life. It is possible that Phase II improvements would provide adequate operation beyond the year 2010.

PHASE III

Should changes in traffic patterns or demand exceed the capacity of the corridor, Phase III improvements could then be implemented to expand the facility to its ultimate configuration. Phase III improvements could include constructing elevated roadways and/or implementing a partial C-D road scheme in some locations.



PHASE I

INTERIM IMPROVEMENTS

- CONSTRUCT AN ADDITIONAL LANE IN EACH DIRECTION
- IMPROVE RAMP GEOMETRY
- REALIGN FRONTAGE ROADS AND PROVIDE TWO CONTINUOUS LANES
- IMPLEMENT FREEWAY MANAGEMENT SYSTEM

PHASE IIA

RECONSTRUCTION OF EXISTING FACILITY

- CONSTRUCT ADDITIONAL LANE(S) IN EACH DIRECTION
- REPLACE CROSSROAD STRUCTURES
- RECONSTRUCT INTERCHANGES
- REALIGN/WIDEN FRONTAGE ROADS

PHASE IIB

RECONSTRUCTION OF EXISTING FACILITY

- CONSTRUCT ADDITIONAL LANE(S) IN EACH DIRECTION
- REPLACE/WIDEN STRUCTURES
- IMPROVE RAMP GEOMETRY
- REALIGN FRONTAGE ROADS AND IMPROVE
- INTERSECTION CHANNELIZATION

PHASE III

CONSTRUCT C-D/EXPRESS ROADWAYS

- CONSTRUCT C-D/EXPRESS ROADWAYS
- MODIFY EXISTING FACILITY AND FRONTAGE ROADS AS NEEDED

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APPENDICES

APPENDIX A - DATA COLLECTION

APPENDIX B - EVALUATION AND RATING CRITERIA

APPENDIX-A

PHASE I DATA COLLECTION

DATA ITEM	SOURCE
TRAFFIC VOLUMES	
1985 24-Hour Mainline, Ramp, and Frontage Road Counts	ADOT Travel and Facilities Branch
1986 24-Hour Mainline, Ramp, and Frontage Road Counts	ADOT Travel and Facilities Branch
1986 24-Hour Ramp Counts	ADOT Travel and Facilities Branch
1986 Interchange Intersection Turning Movement Counts	ADOT Traffic Studies Branch
1987 Arizona State Highway Traffic	ADOT Traffic Planning Division
1988 24-Hour Mainline, Ramp, and Frontage Road Counts	ADOT Travel and Facilities Branch
1988 Interchange Intersection Signal Phasing Diagram	ADOT Traffic Operations
TRAFFIC ACCIDENT DATA	
1985-1987 Traffic Accident Collision Diagrams	ADOT Traffic Studies Branch
1985-1987 Traffic Accident Report Summaries	ADOT Traffic Studies Branch
1985-1987 Statewide Accident Rates	ADOT Traffic Studies Branch
1985-1986 Arizona Statewide Traffic Accident Summaries	ADOT Traffic Studies Branch
Accident Report Coding Sheet	ADOT Traffic Studies Branch
TRAFFIC FORECASTS	
2010-34 Traffic Forecast Model:	
2010 Average Weekday Travel Forecast Map	ADOT Systems Analysis Branch (MAGTPO)
2010 Selected Link Assignment	ADOT Systems Analysis Branch (MAGTPO)
RECORD DRAWINGS	
Available Half-Size "As Built" Plans	ADOT Engineering Records
Corridor Right-of-Way Plans	ADOT Right-of-Way Plans and Servics

APPENDIX-A

PHASE I DATA COLLECTION

DATA ITEM	SOURCE
CURRENT CONSTRUCTION PLANS	
I-10 Traffic Management System Plans	HNTB
I-10/I-17 Papago Interchange Plans	HNTB
I-17 Median Closure Plans	ADOT-Engineering Records
FUTURE CONSTRUCTION AND CONCEPT PLANS	
Indian School Road Traffic Interchange	Lichliter-Jameson & Associates
Bell Road Traffic Interchange	ADOT-Highway Plans
Paradise Freeway/I-17 Traffic Interchange	ADOT-Urban Highways
Outer Loop Change of Access Report	DeLeuw-Cather
Outer Loop/I-17 Traffic Interchange 85 % Plans	CRS Sirrine
1988 Six-Year Major Street Program	City of Phoenix
Arizona Five-Year Transportation Facilities Construction Program 1989-93	ADOT
PHOTOGRAPHY	
10-4-85 1"=400' Aerial Photographs	ADOT Photogrammetry & Mapping Services
9-6-88 1"=400' Aerial Photographs	ADOT Photogrammetry & Mapping Services
1-24-89 1"=200' Aerial Photographs	ADOT Photogrammetry & Mapping Services
1-24-89 1"=100' Aerial Photographs	ADOT Photogrammetry & Mapping Services
35 MM Color Photos of Directional Signing	CONSULTANT
Videotapes of Mainline, Frontage Road and Crossroads	CONSULTANT

APPENDIX-A

PHASE I DATA COLLECTION

DATA ITEM	SOURCE
UTILITIES-MAJOR FACILITES	
Storm Drainage	City of Phoenix
Sanitary Sewer	City of Phoenix
Water	City of Phoenix
High Voltage Power Lines	APS, SRP
Irrigation Lines	SRP
Natural Gas Lines	SW Gas, El Paso Gas
Telecommunications	AT&T, U.S. West
Other Pipe Lines	Lockheed Air, Southern Pacific Pipe Line
PUBLIC TRASPORTATION	
Existing and Future Ramp Meter Bypasses	Regional Public Transportation Authority
Black Canyon Rapid Transit Corridor Report	Regional Public Transportation Authority
Valtrans Proposed Corridors	Regional Public Transportation Authority
PREVIOUS REPORTS	
I-17/I-10 Corridor Study Report	JHK & Associates
I-17/I-10 Working Papers	JHK & Associates
Systemwide Capacity Technical Memoranda	HNTB
LAND USE	
Field Identification of Corridor Land Uses and Frontage Road Access	CONSULTANT

APPENDIX B

EVALUATION AND RATING CRITERIA

GEOMETRIC FEATURES

HORIZONTAL ALIGNMENT CRITERIA

Rating	Degree of Curve
GOOD	Tangent to 5°15'
FAIR	5°15' to 8°15'
POOR	Greater than 8°15'

Reference: Table III-11, AASHTO A Policy on Geometric Design of Highways and Streets p. 191 (1984)

Because many portions of the study area were designed according to the 1954 AASHTO Design Policy, it should be noted that AASHTO design policy for higher speed curves has changed slightly since 1954. Design revisions of side friction factors have meant a reduction in maximum curvature for 60 mph highways from 5°30' to 5°15' for e_{max}=0.10 ft/ft.

Vertical Alignment

The first analysis compared mainline profile grades with maximum recommended values. For evaluation purposes, the entire study area has been considered to be in level terrain. With this assumption and the previously established design speed of 60 mph, the following criteria were used:

VERTICAL ALIGNMENT CRITERIA

Rating	Grades (Percent)
GOOD	Less than 3%
FAIR	3% to 4%
POOR	Greater than 4%

Reference: Table VIII-1, AASHTO A Policy on Geometric Design of Highways and Streets p. 633,(1984)

In addition, the operational effects of long and/or steep grades were investigated. Accident research has established the necessity of avoiding designs that produce significant speed reductions by large trucks.

VERTICAL ALIGNMENT CRITERIA

Combined Grade and Length of Grade

Rating	Truck Speed Reduction
GOOD	Less than 10 mph
FAIR	10 to 15 mph
POOR	Greater than 15 mph

Reference: Figure III-30, AASHTO A Policy on Geometric Design of Highways and Streets P. 262, (1984)

Vertical alignment also includes sag and crest vertical curvature. Design for these geometric features is based on adequate stopping sight distance requirements. Vertical curve design ratings are included in the stopping sight distance evaluation section of this report.

Stopping Sight Distance

Both vertical and horizontal stopping sight distance were investigated by reviewing as-built plans and profiles, and videotapes of the facility. The following criteria were established for evaluating stopping sight distance:

STOPPING SIGHT DISTANCE CRITERIA
Crest Vertical Curves

Rating	SSD	K
GOOD	Greater than 525 ft.	Greater than 190
FAIR	450 to 525 ft.	150 to 190
POOR	Less than 450 ft.	Less than 150

Note: K = Length of Vertical Curve/Algebraic Difference in Grades.

Reference: AASHTO A Policy on Geometric Design of Highways and Streets. Table III-32, P. 307 and Figure III-39, p. 308, (1984)

STOPPING SIGHT DISTANCE CRITERIA
Horizontal Curves

Rating	SSD	M
GOOD	Greater than 525 ft.	Note 1
FAIR	450 to 525 ft.	Note 2
POOR	Less than 450 ft.	Note 3

Reference: AASHTO A Policy on Geometric Design of Highways and Streets. Figure III-25A and III-25B, p. 244 and 245, (1984)

Note: M is the minimum offset between a sight obstruction and the center of the inside lane.

Note 1: M equals or exceeds value given by Figure III-25A for speed of 60 mph.

Note 2: M at least equals value given by Figure III-25A for design speed of 50 mph.

Note 3: M is less than value given by Figure III-25A for design speed of 50 mph.

It should be noted that vertical alignment ratings were based on an adequate stopping sight distance in relation to the desirable design speed. The Arizona Department of Transportation policies recommend a 1000 foot minimum vertical curve length. This minimum length is desirable for developing smooth and flowing alignments to increase driver comfort. However, vertical curves of less than 1000 feet were not rated downward if they met the criteria for stopping sight distance.

Stopping sight distance design has changed significantly in the new AASHTO Policy. Driver eye height and braking friction parameters have been revised. Also, the latest design policy emphasizes the need to consider full design speed (rather than a lower wet pavement speed) in stopping sight distance design. These revisions significantly decrease the "effective" design speed of any existing (i.e., older) vertical curves. Stated simply, alignments previously meeting minimum AASHTO criteria no longer do so.

Cross Section

Evaluation criteria were based on the combination of the following elements:

- Lane Widths;
- Shoulder Widths (both left and right);
- Median Width;
- Roadside Design (slope steepness and fill height); and
- Roadside Barrier Design

The following criteria were established for rating cross-sectional design features:

CROSS SECTION CRITERIA

Rating	Design Values
GOOD (Each of the features must meet criterion)	o Lane Width of 12 feet. o Right Shoulder Width of at least 10 feet. o Left Shoulder Width at least 4 feet paved (4-lane sections) or at least 10 feet (for 6-lane) and 8-lane sections). o Fore-slope designed to 6:1 for 0 to 5 ft. of fill; and 4:1 for greater than 5 ft. o Roadside barrier designed and placed according to current AASHTO standards. o Median barrier provided for width and traffic volumes as described by current AASHTO standards.
FAIR (Each of the features must at least meet criterion)	o Lane Width of 12 feet. o Right Shoulder Widths at least 10 feet. o Left Shoulder Width of 1 to 4 feet (for all freeway sections). o Fore-slope designed to 4:1 for 0 to 15 feet of fill; and 3:1 for greater than 15 feet of fill. o Roadside Barrier (concrete or guardrail) with ony minor deficiencies relative to AASHTO standards.
POOR (Rating warranted if any of the features has noted deficiency)	o Lane Width less than 12 feet. o Right Shoulder Width less than 10 feet. o No left shoulder. o Unprotected fore-slope 3:1 or steeper. o Roadside barrier designed or placed conflicting with current AASHTO standards.

Reference: AASHTO A Policy on Geometric Design of Highways and Streets Chapter IV, pp. 353-412; Chapter VIII, pp 629-719, (1984)

Decision Sight Distance

The purpose of decision sight distance is to provide time for driver decision-making. Decision sight distance is an increment of sight distance, greater than stopping sight distance, that should be provided in advance of exits, major forks and lane drops. At these locations, drivers must perceive, decide a course of action, and navigate.

DECISION SIGHT DISTANCE CRITERIA

Rating	Decision Sight Distance (ft)
GOOD	Greater than 1275 ft.
FAIR	1025 to 1275 ft.
POOR	Less than 1025 ft.

Reference: AASHTO A Policy on Geometric Design of Highways and Streets Table III-3, p. 147, (1984)

Note the decision sight distance concept is new to the 1984 AASHTO Policy. It evolved from human factors research and operational experience in the 1960's and 1970's. Therefore, the design of most of the existing system does not necessarily provide adequate decision sight distance.

Ramp Terminal Design

The quality of each ramp design was determined by evaluating three separate design elements, the first element evaluated was the ramp terminal design. Ramp terminal design affects the driver's ability to merge and diverge with the mainline traffic flow. The second element reviewed, was the acceleration or deceleration length provided on each ramp. This is a critical element because it determines the driver's ability to transition between the frontage road and the mainline. The last element evaluated was the ramp curvature at the physical merge or diverge.

RAMP TAPER RATES

Rating	Entrance Ramp Taper	Exit Ramp Diverge
GOOD	Greater than 50:1	Tangent to 4°
FAIR	40:1 to 50:1	4° to 5°
POOR	Less than 40:1	Greater than 5°

Reference: AASHTO A Policy on Geometric Design of Highways and Streets, pp. 1037 to 1045 (1984)

RAMP ACCELERATION/DECELERATION LENGTHS

Rating	Entrance Ramp	Exit Diverge
GOOD	Greater than 910 Ft.	Greater than 430 Ft.
FAIR	500 to 910 Ft.	315 Ft. to 430 Ft.
POOR	Less than 500 Ft.	Less than 315 Ft.

Reference: AASHTO A Policy on Geometric Design of Highways and Streets, pp. 1037 to 1045 (1984)

RAMP CURVATURE AT THE PHYSICAL MERGE/DIVERGE

Rating	Entrance Ramp	Exit Diverge
GOOD	Tangent to 5°15	Tangent to 5°15'
FAIR	5°15' to 8°15'	5°15' to 8°15'
POOR	Greater than 8°15'	Greater than 8°15'

Reference: AASHTO A Policy on Geometric Design of Highways and Streets, pp. 191 (1984)

OPERATIONAL CHARACTERISTICS

Lane and Route Continuity

Lane and route continuity provides a minimum number of continuous through lanes along a marked interstate route. In all cases, at least two through lanes should be provided. On higher volume freeways, three or four continuous lanes may be necessary. Continuity implies that drivers following the route and using those lanes need not change lanes or exit to remain on the route. This is generally accomplished by adding and dropping lanes only on the right, and through special system interchange designs.

LANE AND ROUTE CONTINUITY CRITERIA

Rating	Criteria
GOOD	Section has lane/route continuity
FAIR	Not applicable
POOR	Section lacks lane/route continuity

Reference: (AASHTO) A Policy on Geometric Design of Highways and Streets pp.986-989 (1984)

Lane Balance at Entrances and Exits

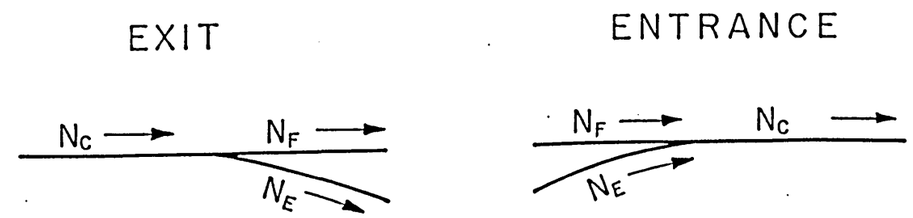
Providing lane balance facilitates access to and from to the freeway while minimizing disruption to through traffic caused by unnecessary lane changing. Figure B-1 illustrates the principal of lane balance. Evaluation criteria are summarized below:

LANE BALANCE CRITERIA
AT ENTRANCE AND EXIT RAMPS

Rating	Criteria
GOOD	Ramp terminal is designed according to lane balance criteria shown in Figure B-1.
FAIR	Not Applicable
POOR	Lane balance criteria are not met by existing ramp terminal design.

Figure B-1

LANE BALANCE CONTROLS



GENERAL FORMULA

$N_C = N_F + N_E - 1$

MAXIMUM: $N_C = N_F + N_E$

MINIMUM: $N_C = N_F + N_E - 1$

N_C, N_F, N_E, – No. of lanes, respectively, on: freeway carrying Combined traffic; freeway, exclusive of ramp traffic; exit or entrance ramp.

ONE MORE LANE GOING AWAY AND NOT MORE THAN ONE LANE DROP AT A TIME *

* Normally Lane Dropped Is Auxiliary Lane.

NUMBER OF LANES AFTER MERGE:

- EQUAL TO SUM OF ALL JOINING LANES

OR

- EQUAL TO SUM OF ALL JOINING LANES, LESS ONE

Reference: Figure 11.12, pg. 384, FHWA, Dynamic Design For Safety, 1975

Ramp Sequencing

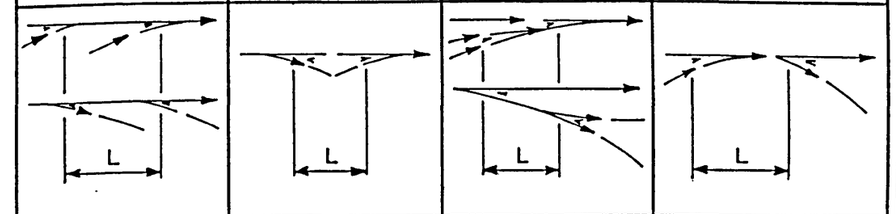
The close proximity of successive entrance and exit ramps can have significant safety and capacity effects. Entrance and exit ramp spacing criteria are summarized in Figure B-2.

RAMP SPACING AND SEQUENCING CRITERIA

Rating	Criteria
GOOD	Spacing is "desirable" or better according to criteria in Figure B-2.
FAIR	Spacing is greater than "absolute minimum" but less "desirable".
POOR	Spacing is less than "absolute minimum".

Figure B-2

RECOMMENDED MINIMUM RAMP TERMINAL SPACING *



	EN-EN OR EX-EX		EX-EN		TURNING ROADWAYS		EN-EX (WEAVING)			
	FULL FREEWAY	C-D ROAD OR FWY. DIST.	FULL FREEWAY	C-D ROAD OR FWY. DIST.	SYSTEM INTERCHANGE	SERVICE INTERCHANGE	SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
							FULL FWY	C-D ROAD OR FWY DIST	FULL FWY	C-D ROAD OR FWY DIST
DESIRABLE	1500	1200	750	600	1200	1000	3000	2000	2000	1500
ADEQUATE	1200	1000	600	500	1000	800	2500	1800	1800	1200
ABSOLUTE	1000	800	500	400	800	600	2000	1600	1600	1000

* BASE UPON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY

Reference: Figure X-67, Pg. 1035, 1984 AASHTO Policy on Geometric Design of Highways Jack E. Leisch, Transportation Research Record 631, 1977, Pg. 19

Freeway Guide Signing

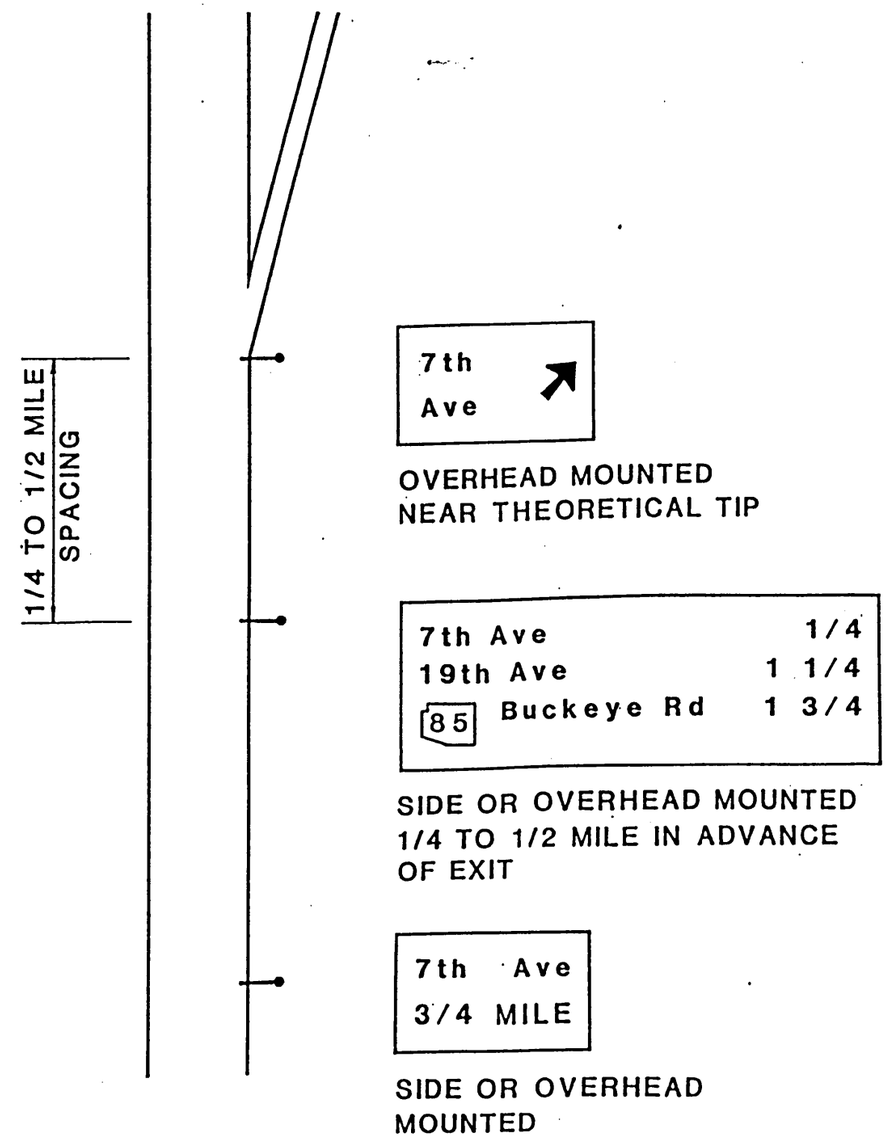
Signing is an often overlooked feature of urban freeways, even though a good signing system can improve freeway operations. There are two important elements of signing. The first is the system configuration, i.e., the location, sign message, and sequence design of advance and exit signs. The Manual on Uniform Traffic Control Devices (MUTCD) provides guidelines for such design. The second consideration, particularly important on urban freeways, is the number of signs and messages at any one location. This should be kept to a minimum to avoid exceeding the driver's decision making capabilities.

Two separate freeway system signing analyses were conducted. The first analysis studied freeway exit sign sequencing. Photographs of each sign on the system were used in combination with videotapes to evaluate the location and message display of each exit sign with respect to the MUTCD guidelines outlined in Figure B-3.

The second analysis focused on the guidelines shown in Figure B-4. These guidelines limit the number of signs and message units on each sign in effort to maximize driver perception and understanding. Rating criteria for both analyses are summarized below:

Figure B-3

RECOMMENDED SIGNING GUIDELINES



Reference ; Manual of Uniform Traffic Control Devices , Chapter 2 F

SIGNING CRITERIA

Rating	Sign Sequence and Location
GOOD	o 2 advance and 1 gore sign, with location per Figure B-3. o Gore sign overhead mounted at tip. o Special "exit only" panels used at lane drops. o No more than 5 message units per sign.
FAIR	o 1 advance and 1 gore sign. o Gore sign overhead mounted at tip. o Minor message inconsistency between signs for same exit. o Minor location problem.
POOR	o Gore sign not located overhead. o Improper lane drop signing. o No advance signs. o More than 6 message units per sign.

SIGNING CRITERIA
Sign Panel Design and Truss Arrangement

Rating	Sign and Truss Configuration
GOOD	Message units per sign and maximum total per assembly conform with the "Desirable" guidelines in Figure B-4.
FAIR	Message units per sign and maximum total per assembly conform with the "Absolute" guidelines in Figure B-4.
POOR	Message units per sign or total maximum message units per assembly exceed the "Absolute" guidelines in Figure B-4.

Figure B – 4

RELATIONSHIP OF NUMBER OF SIGN PANELS TO NUMBER OF MESSAGE UNITS
(DIRECTIONAL SIGNS)

NUMBER OF SIGN PANELS IN SERIES AT ONE LOCATION		NUMBER OF MESSAGE UNITS*			
		MAX. PER SIGN		MAX. TOTAL ASSEMBLY	
NUMBER	APPLICATION	DESIRABLE	ABSOLUTE	DESIRABLE	ABSOLUTE
▭	FREQUENTLY	5	6	5	6
▭ ▭	OCCASIONALLY	4	5	8	10
▭ ▭ ▭	SPECIAL CASE	3	4	9	11
▭ ▭ ▭ ▭	NEVER	—	—	—	—

* Examples of message units (Each represents one unit):
- Arrow
- Shield and route number
- Cardinal direction, as "South", "West", etc.
- Single destination or name of facility, as "Broad St."
- Informational message as "Keep Right", "Exit 1/2 Mi.", etc.

Reference: Jack E. Leisch Transportation Research Record 631, 1977, Pg. 56

PERFORMANCE MEASURES

Evaluating the geometric, operational and physical characteristics of a facility is most useful when relating them to traditional highway performance measures--level of service and accident experience. To assist in this comparison, rating criteria were established for both level of service and accident rates.

Level of Service

On a daily basis, urban freeways typically experience lower levels of service than rural freeways. It is generally not cost-effective to expect an urban freeway system to operate during peak periods at level of service C or better. The following rating criteria for level of service were therefore established:

PEAK HOUR FREEWAY
LEVEL OF SERVICE CRITERIA

Rating	Level of Service
GOOD	A-C
FAIR	D
POOR	E-F

Accident Experience

When evaluating accident experience, it is useful to compare the facility under study with state- and nation-wide averages. The following table summarizes accident rates for urban freeways for the state of Arizona and the national average.

TABLE B-1
URBAN INTERSTATE ACCIDENT EXPERIENCE

Urban Interstate	Rate [1]
I-17 (1985-1987)	2.06
Arizona Statewide Average (1985-1987) [2]	1.59
U.S. Average [3]	1.43

[1] Accidents/Million Vehicle Miles (MVM).

[2] Source: Arizona Department of Transportation

[3] Source: AASHTO Manual on User Benefit Analysis for Highway and Bus Transit Improvements (1975)

For evaluation purposes, Arizona statewide averages formed the basis of rating criteria. A "good" rating was assigned to any section with a rate 0.67 times that of the applicable Arizona average rate. Poor ratings were assigned when the rate was at least 1.33 times the applicable Arizona average. For example, a segment was considered poor if its total accident rate was greater than 1.33 X 1.59, or 2.11 accidents per MVM.

SAFETY PERFORMANCE CRITERIA

Rating	Total Accident Rate MVM
GOOD	Less than 1.07
FAIR	1.07 to 2.11
POOR	Greater than 2.11

Reference: Table B-1