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16. Abstract

The Montana Corridor from near the El Paso central business district east to Loop 375 is a major urban area transportation system element. Growth along the middle to eastern corridor end will likely create increased future demands. Improvements to transportation system elements within the corridor are clearly needed, but identification of the most desirable improvement scheme(s) is complicated by competing considerations.

Corridor improvement scenarios ranging from full frewway construction to strategic arterial development have been evaluated and compared. The TxDOT Large Network Demand Estimation System was used, with the complete El Paso highway network to evaluate network performance under each improvement scenario. Candidate improvement schemes were evaluated using two analysis levels which varied according to the quantity of detail and numbers of alternatives considered. Level One analysis examined a wide range of alternatives from a conceptual viewpoint. An active Technical Panel composed of TxDOT, City, and other officials chose among the Level One alternatives, narrowing the scope to those carried forward to the Level Two more detailed evaluation.

The most feasible alternative emerging from detailed analysis is a phased strategic arterial corridor development program. Elements and phasing recommendations are presented, and they include emphasis on minimal disturbance of adjoining property, use of public transportation, and demand reduction activities.

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Research Report Number 1942-1F

Research Project 7-1942
Montana Avenue Feasibility Study

conducted for the

Texas Department of Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research

THE UNIVERSITY OF TEXAS AT AUSTIN

August 1994
Revised May 1995

IMPLEMENTATION

This analysis of existing and future Montana Corridor traffic demands and operational concerns provides a well documented improvement program basis. The information contained within this study report outlines a variety of possible corridor improvements and documents associated consequences. This document will provide appropriate answers to many questions about a wide variety of potential Montana Corridor improvements. It should enable implementation of an appropriate, publicly acceptable improvement program.

Prepared in cooperation with the Texas Department of Transportation

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Research Supervisors

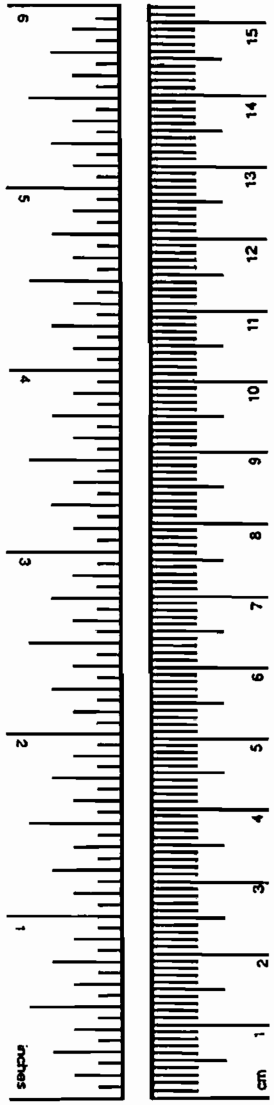
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.0765	meters cubed	m^3

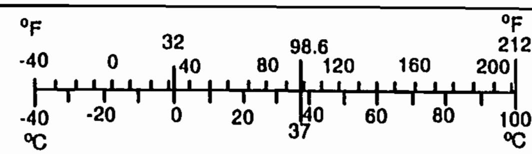
NOTE: Volumes greater than 1,000 L shall be shown in m^3.

Symbol	When You Know	Multiply by	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.20	square yards	yd^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1,000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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SUMMARY

The Montana Corridor from near the El Paso central business district east to Loop 375 is a major urban area transportation system element. Growth along the middle to eastern corridor end will likely create increased future traffic demands. Improvements to transportation system elements within the corridor are clearly needed, but identification of most desirable improvement scheme(s) is complicated by competing considerations.

Corridor improvement scenarios ranging from full freeway construction to strategic arterial development have been evaluated and compared. The TxDOT Large Network Demand Estimation System was used, with the complete El Paso highway network to evaluate network performance under each improvement scenario. Candidate improvement schemes were evaluated using two analysis levels which varied according to the quantity of detail and numbers of alternatives considered. Level One analysis examined a wide range of alternatives from a conceptual viewpoint. An active Technical Panel composed of TxDOT, City, and other officials chose among the Level One alternatives, narrowing the scope to those carried forward to the Level Two more detailed evaluation.

The most feasible alternative emerging from detailed analysis is a phased strategic arterial corridor development program. Elements and phasing recommendations are presented and they include emphasis on minimal disturbance of adjoining property, use of public transportation, and demand reduction activities.

CHAPTER 1 INTRODUCTION

This report presents analysis and recommendations encompassing the Montana Avenue Feasibility Study. A wide range of conceptual future alternative improvement measures were analyzed and recommendations based on the analyses are presented. These recommendations will be in the form of two or three improvement alternatives. The final alternatives recommended will be based on achieving desired levels of service, compatibility with land use characteristics, feasibility of successful implementation, community impact, improvement in quality of service and cost along with other cosiderations.

STUDY AREA

The study focuses on Montana Avenue, a major east-west arterial north of IH-10 in El Paso, Texas. The arterial originates right in the heart of the CBD area and continues east almost to the eastern El Paso corporate limits. There is high density development, both commercial and residential along the roadway specially in the western end and the mid portion. The arterial itself is being considered for improvement between Loop 375 and Paisano Drive. The western end is really a corridor along with Yandell and Wyoming, two other arterials in that region almost paralleling Montana. A map of the study area is presented in Figure 1.1.

SCOPE OF STUDY

The prime objective of this study is to recommend improvement alternatives for the Montana Avenue Corridor to provide additional capacity and improve the level of service while complementing land use characteristics. The improved facility would satisfactorily handle future traffic volumes while maintaining compatibility with existing and proposed land use characteristics. The alternatives analyzed are not limited to a particular facility type, rather an attempt has been made to explore a variety of options. The feasibility of the relatively new Strategic Arterial concept has been dicussed in detail as a possible Montana Avenue upgrade. Apart from this, freeway options are also analyzed. An attempt has been made to identify an appropriate solution to study area traffic needs. Recommendations presented are not elaborate but are conceptual in nature so that they can be readily adapted to suit changing needs, if any, during implementation.

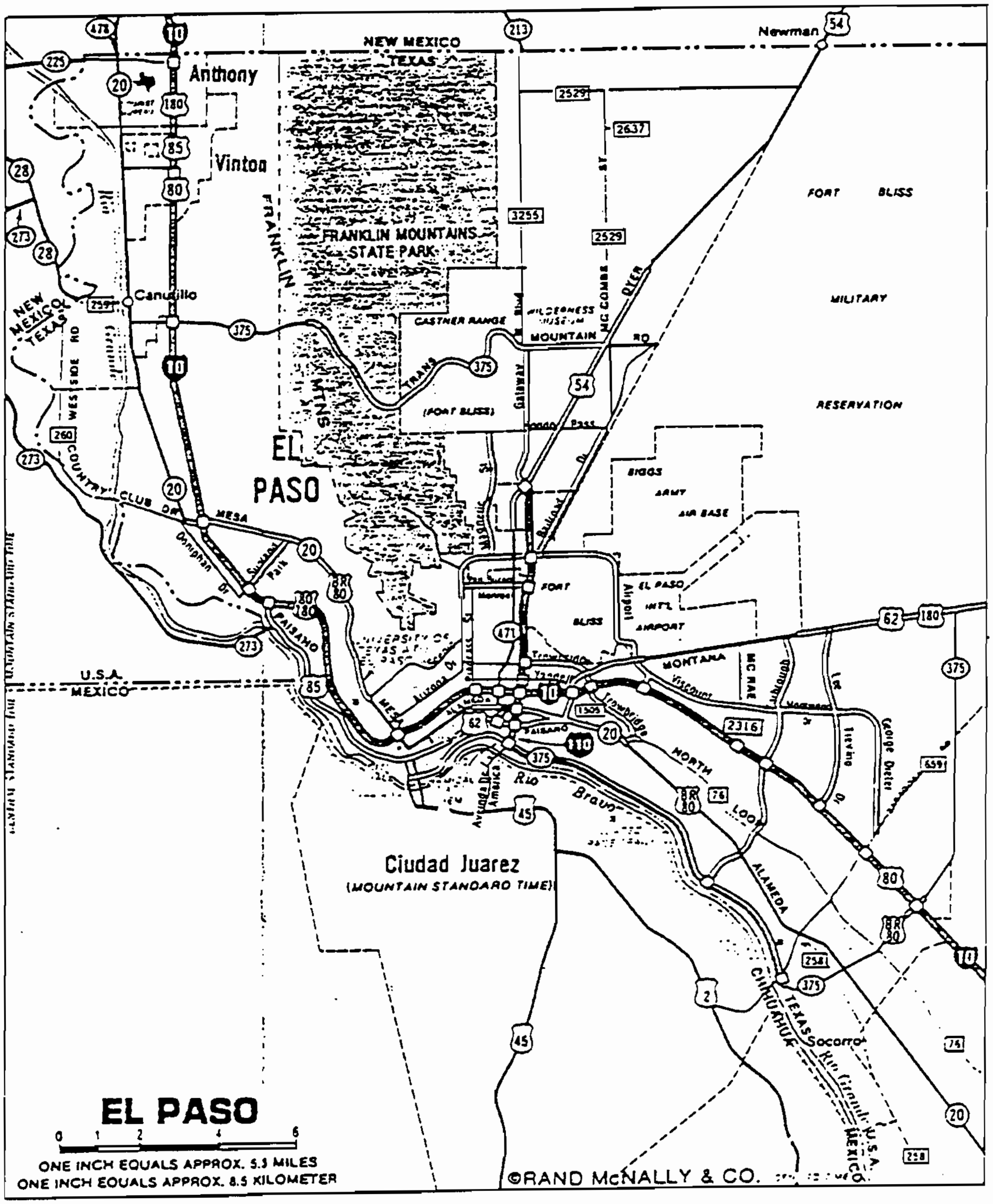


Figure 1.1 El Paso Area Map

STUDY OVERVIEW

The first step of this study is to outline existing and forecasted Montana Avenue corridor conditions. Existing conditions of the Montana corridor are based on current City of El Paso, Traffic and Transportation Department intersection volume counts, and aerial photographs provided by the Texas Department of Transportation. Also included are observations from several site visits. Forecasted conditions are based upon the current network with planned improvements. Forecasted traffic volumes are based upon the TxDOT Large Network Assignment Model. All forecasts within this study are for the year 2015. A complete description of the model and modeling alternatives are developed and analyzed. This stage of the study is termed level one. These alternatives are modeled on the TxDOT Large Network Assignment Model which was also used to determine base conditions. Benefits and disbenefits for each alternative are determined. These benefits and disbenefits are based upon modeling results, predicted network effects, evaluation of predicted traffic problems, and feasibility of successful implementation. The alternatives are paired down to four or five concepts to undergo more in-depth analysis in the next study phase. Included in this pairing down of alternatives are recommendations made by TxDOT officials, City of El Paso officials, and community representatives.

Included within the variety of level one alternatives is a do-nothing alternative, six freeway alternatives, and several strategic arterial alternatives. While general familiarity exists concerning freeways, along with specific freeway design standards, this is not the case with strategic arterials. Therefore this study dedicates a significant amount of effort in explaining the strategic arterial concept and describing its implementation. Included within this strategic arterial discussion is a general overview and specific recommendations for the Montana Avenue corridor including staged implementation recommendations.

The next phase of this study is termed level two. In this phase, the alternatives that are carried forward from level one undergo a more in-depth analysis. Along with level one analysis there are other computer analyses including the Highway Capacity Manual Software, PASSER II-90, and the TEXAS Model. In addition, comparisons between travel times, effect on parallel routes and local streets, and general right-of-way needs are made. An important aspect for comparing level two alternatives is the idea of costs to benefits. Benefits realized from each alternative will be compared along with costs associated with these benefits.

Finally several alternatives will be recommended as possible improvement alternatives. The strength and weaknesses of each alternative will be presented. The final alternative choice and a precise implementation time table are not made within this study. This decision is best made by TxDOT officials, City of El Paso officials, and the community. The purpose behind this study is that it be used as a decision guide, but not the only factor. Alternatives should not be limited by the recommendations within this study. If deemed necessary and/or beneficial, additions and changes to the recommended alternatives should be made. Items beyond the scope of this study must also be considered, such as attainability and cost of particular sections of required right-of-way and community responses. A final decision should only be made after consideration of all factors.

CHAPTER 2 EXISTING CONDITIONS

Arterial improvements may be planned for either a short term or over a long time period and the improvements may range from the application of simple traffic management techniques to controlled access facility construction. There are a number of tools available to evaluate alternative improvement strategies in terms of corridor performance. In the first part of the chapter a detailed description of Montana Avenue as it currently exists is provided. In the next part of this chapter the various tools and techniques available to evaluate arterial performence will be discussed in terms of their capabilities and limitations and the analysis and evaluation methodology. The final section of this chapter will identify existing traffic conditions along Montana Avenue using some of the described analysis and design models. Based on Highway Capacity Manual Software and PASSER II-90, existing levels of service and progression efficiency were analyzed to recognize critical corridor locations. These results form a basis of comparison for all forecasted traffic conditions.

EXISTING ARTERIAL CONDITIONS

Montana Avenue stretches from the eastern edge of El Paso to the central business district. The portion of the arterial being considered for improvement begins on the eastern end at Loop 375 and continues west to the Paisano Drive intersection. From this point, Montana Avenue is being considered for improvement along with Yandell Drive as a one-way pair to Mesa Street. Another option being considered is to convert the Montana, Yandell one-way pair to Yandell and Wyoming Avenue at the vicinity of Piedras. The total length of this corridor is approximately 13.5 miles, consisting of approximately 4.8 one-way pair miles and 8.7 two-way arterial miles.

Loop 375 to McRae Boulevard

As already mentioned, the first section discussed is the eastern end from Loop 375 to McRae. Included within this section is Saul Kleinfeld, George Dieter Road, Lee Trevino, Yarbrough, and Wedgewood. This section is flat and straight and approximately 6.25 miles long.

From the Loop 375 interchange to Lee Trevino the existing right-of-way is approximately 200 feet wide. The roadway consists of approximately 40 feet of paved surfaces and 3 lanes in each direction, and a median of at least 60 feet. Development along this stretch is sparse and relatively inexpensive. What little development there is, tends to be residential, consisting of mobile homes, trailer parks, and small commercial businesses. There are no large expensive developments or multi-story buildings near the roadway. It should be possible to obtain at least another 50 feet of right-of-way and possibly much more without being required to purchase any buildings.

From Lee Trevino to Wedgewood there is increasing development but it is still relatively sparse and residential. Between Wedgewood and McRae development is more extensive and predominately commercial but continues to be set well back from the arterial. From Lee Trevino west, intersection corners have increasing development. Development ranges from one developed corner at Lee Trevino to four developed corners at Wedgewood. Although the corners of intersecting roads are developed, buildings in general, are still set back and relatively inexpensive. Right-of-way along this stretch is still approximately 200 feet. West of Lee Trevino, the 60 foot median is reduced to approximately the width of one lane to McRae where the median widens again for a few thousand feet. Purchasing large amounts of additional right-of-way between these intersections may require acquisition of a few buildings but right-of-way should still be relatively inexpensive.

One aspect that is also important to this section of Montana Avenue is the development to the south. Development starts abruptly about two miles south of Montana. This development is dense, single family residential. From George Dieter to McRae this development comes closer to the arterial and west of McRae it is adjacent to the arterial. From aerial observations it is reasonable to assume that over time adjoining development will extend to the eastern end of Montana Ave.

McRae Boulevard to Airport Road

This section is the central part of the arterial and it ranges from McRae to Airport and includes Hawkins, Airway, Robert E. Lee, and Sioux. The total section distance is 2.29 miles and it is relatively flat and straight except for a curve at Airport.

West of McRae Boulevard to Airway Boulevard there is approximately 85 to 90 ft of paved roadway. This includes 3 lanes in each direction, narrow shoulders, and a turning lane in the median. Between Airway Blvd. and Airport Rd. there is approximately 90 ft of paved surface with three lanes in each direction, almost no shoulders, and a 20 to 25 ft median.

Compared to the eastern section, this roadway section is significantly more developed. From McRae to Airway there is dense residential development on the south side. The north side of the arterial is mainly commercial developments, however, both commercial and residential developments tend to be larger and more extensive than those found further east.

From Airway to Airport development is commercial on both sides. The corners of the intersections are, for the most part, highly developed. Airway, for example, has a very costly hotel on its north-east corner. At Robert E Lee, railroad tracks cross the arterial. This prevents development close to the western corners where the railroad tracks are, but both eastern corners have large commercial buildings.

Existing right-of-way on the central arterial section averaging 105 to 110 ft is approximately half that of the eastern section. Excluding the area between Airway and Hawkins, the ability to purchase additional right-of-way is limited by close development proximity. At the edge of the right-of-way along almost this entire section are either commercial buildings or commercial building parking. Many of the abutting parking lots provide the majority of the available parking and to purchase it in many cases could severely damage the parcel remainder. To purchase even an additional 50 ft of right-of-way along this section would be very expensive.

One exception to the right-of-way constrictions on this section exists between Airway Boulevard and Hawkins Boulevard. An access road on each side of the arterial provides an additional 30 to 40 ft of usable, low cost right-of-way per side. Unfortunately neither access road extends to either of the intersections right-of-way need is most critical.

Airport Road to Mesa Street

This section is the western end of the arterial. It ranges from Airport to Mesa and includes Magruder, Paisano, Huckleberry, Raynolds, US 54, Pershing Dr., Piedras and Cotton, along with various other local streets and represents a five mile total distance.

This section is different from the other two in that the majority of its length would consist of a one-way pair. From Airport Rd. to the Paisano/Montana split, a strategic arterial would be a two-way facility. At the Paisano/Montana split, Montana could continue as a one-way street west bound. The east bound direction would be on Yandell Dr. which intersects Paisano approximately 1500 ft south of the Montana/Paisano intersection. In some alternatives, the one-way pair remains Montana and Yandell to Mesa, while in others, the one-way pair transitions to Yandell and Wyoming in the Piedras vicinity.

Of the three sections, eastern, central, and western, the western is most densely developed. These developments vary consisting of both residential and commercial properties. Also spread throughout this section are buildings which have been designated historical landmarks or contributing properties. This characteristic alone can present many problems for arterial construction and changes.

As already mentioned, Montana cross secton is undivided from Airport Road to the Montana/Paisano split. Although this part is only a few tenths of a mile long, existing right-of-way is approximately 85 to 90 feet wide and development is dense, commercial, abutting the roadway. The acquisition of any significant amount of right-of-way will probably include a high percentage of properties on one side or the other, or possibly both sides. This area contains what will probably be some of the most costly right-of-way.

The small section of Paisano which connects to Yandell is roughly the same as described in the previous paragraph. The south side of the section is probably one of the most dense commercially developed areas along the entire corridor identified. The North side is a densely developed residential area. The angle at which Yandell intersects Paisano is skewed in such a manner that the turn onto Yandell is currently low-speed. Improving this condition would require significant right-of-way.

Montana from Paisano to Piedras is currently a two-way road with four lanes, two in each direction. The right-of-way varies but tends to be at least 60 to 65 ft. In some areas, such as the US 54 underpass the right-of-way is up to 20 ft wider. Development along this section is densely packed by a variety of residential and commercial buildings. Many building are close to the right-of-way and any appreciable taking could involve acquiring entire properties. Also many properties are dependent on the arterial edge for parking. Almost all commercial parking is on or close to the arterial edge and would be affected by any right-of-way expansion.

Yandell from Paisano to Piedras is predominately dense, individual, residential developments. The existing right-of-way is approximately 65 ft with some wider sections. From Paisano to US 54, Yandell consists of a series of curves and bends that would require straightening to achieve desired upgrade standards. Also along this part of the arterial is a cemetery which spans approximately four blocks.

From Piedras to Mesa, Yandell and Montana have similar development and design features. The right-of-way varies but is approximately 70 ft. On some sections there are two lanes in each direction, on others, only one lane in each direction. Development is dense with a mixture of commercial and residential properties. Many of the buildings are close to the existing right-of-way making expansion difficult without acquiring full parcels. Also along both streets parking is permitted in many areas. In many cases this is the only parking readily available to the property, in other cases it is the majority of parking.

At Piedras there is a jog in each road that must be straightened for almost any meaningful improvement. This will require the acquisition of at least several properties and possibly a significant amount depending on the desired improvement level. Wyoming from Piedras to Mesa has approximately the same description as Yandell and Montana.

ARTERIAL PERFORMANCE EVALUATION

The arterial street upgrading process involves arterial traffic condition evaluation for both the existing and the improved facility. If staged implementation of the improvements is being considered, arterial performance must be determined at each stage so upgrading effects can be evaluated.

Data Requirements

The basic data required for evaluating arterial street traffic conditions includes traffic volume data, details of arterial and intersection geometry, and traffic control and signalization data. Data pertaining to geometry can be obtained from maps, drawings, aerial photographs or field survey. Signalization data can be obtained from timing plans though field studies may be required in cases where semi-actuated control is provided. Traffic volume and turning movement counts are procured by field studies.

Geometric Data. The geometric configuration of intersections along the arterial are required. This includes the number of approaches, number of lanes per approach, and lane widths. The number of lanes and their widths significantly affect saturation flow rates for capacity analyses. Other relevant information such as the presence of left and right turn lanes and their lengths, approach grades, and parking conditions alongside the roadway should be noted. For arterial signal progression analysis, distances between intersections are required.

Traffic Data. Turning movement counts at each intersection approach are required. The usual process is to collect these data for the critical time periods of the day which usually are the A.M., P.M., and Noon peak periods. Care should be taken to see that the data collected represents typical weekday traffic. In case of future traffic, for included intersections, assignment models provide intersection turning movements. If the intersection is not represented in the network, an estimate of turning volumes can be made based on current volumes and a suitable growth factor based upon assigned volumes for the other intersections.

Signalization Details. At each intersection, the type of signal system (pretimed or actuated), the number of phases and type of phasing, cycle length(s), green splits, and clearance intervals are also required. Often intersections have different timing plans for different times of day. This should be taken into consideration and data should be obtained for all the relevant time periods.

Other Relevant Data. Besides the major data requirements detailed above, for a complete arterial street evaluation the following information should be collected :

1. Composition of traffic, including percentage of heavy vehicles.
2. Conflicting pedestrian movements.
3. Loading and unloading operations near intersections.
4. Saturation flows, lost time, and left-turn sneakers.
5. Speed data.

Evaluation Criteria for Arterial Performance

There are a number of measures of effectiveness (MOE) on the basis of which an arterial street performance can be judged. Not every MOE is provided by each analysis model so to get a complete picture more than one tool may have to be used. Some of the most commonly used arterial street evaluation criteria are discussed in this section.

Volume to Capacity Ratio. Capacity analysis forms a key factor in evaluation of signalized intersection performance. The analysis results are usually interpreted in terms of lane group volume to capacity (v/c) ratio or approach v/c ratio. A v/c ratio greater than 1.0 for an intersection approach indicates that one or more lane groups are oversaturated suggesting an actual or potential bottleneck and a condition requiring corrective measures. A v/c ratio less than 1.0 generally indicates that intersection geometrics can handle the given traffic demand.

Level of Service. Signalized intersection level-of-service (LOS) is defined in terms of delay which is a widely used measure of performance. The Highway Capacity Manual (HCM) [Ref. 8] defines signalized intersection levels of service in terms of average stopped delay per vehicle. This criteria are as follows:

LOS A	: ≤ 5 sec/veh
LOS B	: 5.1 to 15.0 sec/veh
LOS C	: 15.1 to 25.0 sec/veh
LOS D	: 25.1 to 40.0 sec/veh
LOS E	: 40.1 to 60.0 sec/veh
LOS F	: > 60.0 sec/veh

The LOS and capacity together form the basis of signalized intersection performance evaluation. Generally levels of service C and D are considered acceptable. A LOS F reflects breakdown conditions with unacceptable delays. High delay may be due to poor progression, unsuitable signal timing or inadequate capacity.

Queue Delay. Queue delay can be defined as the time during which a vehicle has to travel at a speed much less than the desired speed due to the presence of other vehicles at an intersection approach. While in a queue the vehicle may not stop but might spend a significant amount of time traveling slowly and thus influence the driver's perception of quality of service provided. Long queue lengths and large queue delays are an indication of poor arterial performance and the presence of a bottleneck situation.

Progression. Good progression in terms of both speed and bandwidth indicates a properly functioning arterial street provided delay levels are not unacceptable. In some cases good progression can exist along with excessive delays. In such circumstances, geometric or signalization changes at intersections with high delay values should be studied .

Number of Stops. Determination of number of stops per unit distance on a roadway section and the percentage of vehicles stopping may also serve as a measure of effectiveness. Although less commonly used, it does reflect the quality of service and may indicate poor progression and signal timing plan.

Travel Time and Speed. Many models provide estimated travel times and average speed of vehicles traversing the arterial. Longer travel times and speeds much below the desired speed of the driver indicate poor service quality.

Fuel Consumption and Emissions. With increased focus on air quality, vehicular emissions and fuel consumption have become important arterial street evaluation factors. Many computer models provide a measure of these factors. Fuel consumption and emissions reflect corridor performance.

Arterial Evaluation and Design Tools

A number of software packages are available to evaluate signalized intersection traffic operations and arterial streets as a whole. These computer models can be simulation models or they may be deterministic non-simulation models. Among the commonly used simulation models are TEXAS Model, TRAF-NETSIM, and TRANSYT-7F. Other commonly used models are HCS and PASSER II-90. A brief description of these models, their capabilities, limitations and applications are discussed in this section.

Highway Capacity Manual Software (Ref.10). The Highway Capacity Software (HCS) is a software package for design and analysis of various transportation components including freeways, signalized intersections, and arterial streets among others. The HCS is based on the 1985 Highway Capacity Manual. The signalized intersection analysis for capacity and level of service is based on Chapter 9. The analysis procedure involves five separate modules which are (1) Input, (2) Volume adjustment, (3) Saturation flow, (4) Capacity analysis, and (5) Level of service modules. The user must provide data for the input module only, the calculations are performed by the software. However if the user wishes to change certain values in the other modules it can be done.

Data requirements for the input module comprise geometrics, traffic, and signalization information. Geometric characteristics include area type (CBD or not), number of lanes, lane width, approach grades and storage length of left and right turn lanes if any. Traffic data includes turning movement counts, peak hour factor, percentage of heavy vehicles, conflicting pedestrian flow rate, parking activity and vehicle arrival type. Details about signalization cover cycle length, green times, phasing plan and actuated vs. pretimed operation.

Output information comprises stopped delay and level of service for lane groups and by approach. An average value of intersection delay and LOS is also provided. The results can be used to evaluate current or future conditions and intersection improvements.

For performing a quick capacity, delay or level of service analysis at signalized intersections, HCS is a very convenient tool. Also because of the ease with which data can be changed or reentered, improvement alternatives can be evaluated with little effort. Output in terms of delay and level of service can readily be interpreted. However there are some model limitations. For instance, complex intersection geometry (say a five-legged intersection) cannot be properly modeled and analyzed. Another limitation is that an actuated signal is basically represented as a pretimed signal and cannot take into account 'max outs' and 'gap outs'. The model also does not give delay values in oversaturated conditions (v/c ratio is above 1.2).

TEXAS Model for Intersection Traffic (Ref.12). The TEXAS Model which is an acronym for Traffic EXperimental and Analytical Simulation Model is, as the name suggests, a microscopic simulation package for intersection analysis. It can also perform analysis of a diamond interchange. The TEXAS model is highly versatile and can be used to analyze virtually any intersection traffic control option. It can be utilized to evaluate current or proposed intersection design, roadway geometry modifications, changes in driver vehicle characteristics, different types of intersection controls and, for signalized intersections, different timing plans.

The model examines each driver-vehicle unit microscopically for every 0.5 to 1.0 second time unit as it traverses the intersection. Driver and vehicle characteristics, desired outbound approach and lane choice on inbound lanes are randomly assigned based on user input. Each unit is also provided with information about desired speed, current velocity and acceleration, sight distances and traffic control devices.

The TEXAS Model uses four data processors which are (1) Geometry processor, (2) Driver-vehicle processor, (3) Simulation processor, and (4) Emissions processor. Input data for the geometry processor includes intersection shape (defined by azimuth on each leg), number of legs and associated lanes, lane widths and curb return radii. Data required for the driver-vehicle processor comprises driver and vehicle class, desired speed and destination, headway distribution and directional traffic volume percentages. The simulation processor requires information about type of traffic control and, in the case of signalized intersections, signal information including phasing, timing plan, and detectors. Besides these, various other decision factors such as simulation and car following parameters are involved. Data can be easily input through the use of two interactive user friendly input processors. Also there is a permanent library with twenty commonly used geometry and traffic combinations which the user can modify to suit his/her needs.

Model output information includes overall delay, stopped delay, queue delay and travel times. These measures of effectiveness can be used directly to evaluate intersection performance. To get fairly accurate results, a start up time of at least 5 minutes and a simulation time no less than 15 minutes should be used. Also it is a good practice to use the mean of several replicate runs.

The TEXAS Model is probably the best simulation model to analyze a signalized intersection (or any type of intersection control for that matter) and evaluate a wide variety of geometry and traffic control designs. Because of the detailed simulation capabilities TEXAS model can provide fairly accurate results. Also because of the graphic capabilities, alternative improvement/design strategies can be viewed for their traffic operations effect. Just by observing the simulation graphically, the use of a particular design can be justified and explained even to a layman. However, because of the thorough nature of analysis this model is data intensive and requires careful data entry. Also the user should be familiar with the variables being used and their analysis effect.

PASSER II-90 (Ref. 11). PASSER II-90 (Progression Analysis and Signal System Evaluation Routine) is an optimization tool developed mainly for multiphase signal systems. It can be used for evaluation and optimization of signal timing along an arterial street with up to 20 intersections to provide progression. It can also be used to analyze isolated intersections for signal timing, delay and capacity evaluations.

PASSER II-90 combines Brook's interference algorithm with Little's optimized bandwidth equation to determine the combination of cycle length, phasing sequence and offsets which maximizes the bandwidth to cycle length ratio. Green splits for various phases at each intersection are calculated based on movement magnitudes and to minimize delay. Delay values are determined using a modified Webster delay equation.

Input data required for PASSER II-90 includes traffic volumes, permissible phasing sequence, range of cycle lengths, saturation flow rates, intersection spacing and queue clearance times. Additionally the user must specify the type of progression desired (one-way or two-way) and progression speed.

There are several MOE's provided by PASSER II-90. For individual traffic movements LOS based both on v/c ratio and delay is calculated. Intersection performance can be judged by average intersection delay and average fuel consumption. For arterial street progression the main measure of effectiveness is efficiency, which is a measure of the proportion of the cycle length that can be used for through movement progression. Another measure of arterial progression is attainability which provides a comparison between the maximum possible progression and the current progression solution.

PASSER II-90 is a user friendly program and allows the user to evaluate a variety of phasing patterns and geometry changes to get the best possible progression with minimum delay. A limitation of the model is the use of Webster's equation for delay calculation which may give unreasonable delays near saturated flow conditions. Also intersections with complex geometry cannot be properly modeled.

EXISTING TRAFFIC CONDITIONS

Arterial performance under existing traffic conditions must be studied in order to identify bottlenecks and provide a reference level for improvements. Geometric data required for evaluating existing traffic conditions along Montana Avenue was obtained from maps and aerial photographs of the corridor and intersections. These materials were provided by the Texas Department of Transportation, El Paso. Intersection signalization details and traffic counts were provided by the City of El Paso, Traffic and Transportation Department. These data are presented in Appendix A.

The performance of each signalized intersection along Montana Avenue, as well as corridor performance was evaluated using the computer packages described earlier. The two measures of effectiveness used were intersection LOS and average intersection delay. The Highway Capacity Software was used to determine existing signalized intersection LOS. Results of the HCS analysis are shown in Tables 2.1 through 2.3. Delay values are also provided by HCS but if the v/c ratio for any movement is greater than 1.2 the software does not calculate the delay value and LOS for the intersection. PASSER II was therefore used to obtain delay values as well as evaluate corridor signal coordination (See Table 2.4). However, as the delay values for oversaturated conditions simply increase with observation time they should be examined critically.

Three time periods, AM peak, PM peak and Noon peak were analyzed. Each signalized intersection LOS was determined using HCS. Since for progression analysis intersections along the corridor must have the same cycle length, Montana Avenue was divided into three sections. At present all intersections in these three sections have the same cycle length. The western section includes six intersections from Cotton to Gateway North. The middle part consists of ten intersections from Raynolds to Robert E. Lee. Finally, the eastern corridor section comprises six intersections including Hawkins and Lee Trevino. Airway was analyzed separately as its cycle length is different from the other intersections.

As mentioned earlier, results of LOS, delay, and coordination analysis are presented in Tables 2.1 through 2.4. From the results it can be observed that the problem intersections with high delays and poor LOS are Airway, Hawkins, and McRae. During peak periods, significant delay values exist especially on cross-streets. This is mainly due to high left-turning traffic volumes at these intersections. Other intersections with fairly high delays are Magruder, Mescalero and Sioux. Intersections in the western portion are currently performing at acceptable levels of service. The progression analysis results show that presently there is very little signal coordination along the arterial. Some reduction in delay can be achieved by improving current signalization conditions. However, in the long term the critical intersections would require major changes such as grade separations.

SUMMARY

Arterial improvement is being increasingly considered in urban areas as a means of providing mobility. In this chapter an arterial candidate for potential upgrade has been identified and described. Also in this chapter the methodology and available tools for analyzing and evaluating arterial performance were discussed. These tools were used to identify existing traffic conditions on Moatana Avenue and to locate critical intersections.

TABLE 2.1 LEVEL OF SERVICE FOR EXISTING AM PEAK CONDITIONS (1985 Highway Capacity Manual Procedures)

Intersection	LOS Eastbound	LOS Westbound	LOS Northbound	LOS Southbound
Cotton	C	B	B	B
Piedras	B	B	B	C
Raynor	A	A	C	-
Copia	B	B	B	B
Gateway South	B	B	-	B
Gateway North	B	B	B	-
Raynolds	B	B	B	B
Huckleberry	B	B	C	C
Chelsea	B	B	C	C
Trowbridge	B	B	D	D
Paisano	B	-	-	C
Magruder	B	C	C	C
Geronimo	B	B	C	C
Mescalero	*	B	C	D
Sioux	C	C	D	C
Robert E. Lee	B	B	C	C
Airway	E	*	E	E
Hawkins	D	*	D	D
Rutherglen	A	D	D	D
McRae	C	*	*	D
Wedgewood	B	D	D	D
Yarbrough	A	B	*	-
Lee Trevino	B	B	*	-
George Dieter	C	B	*	E

* Denotes v/c ratio greater than 1.2

- Indicates movement does not exist

TABLE 2.2 LEVEL OF SERVICE FOR EXISTING NOON PEAK CONDITIONS (1985 Highway Capacity Manual Procedures)

Intersection	LOS Eastbound	LOS Westbound	LOS Northbound	LOS Southbound
Cotton	D	B	B	B
Piedras	B	B	B	C
Raynor	A	A	C	-
Copia	B	B	B	B
Gateway South	B	B	-	B
Gateway North	B	B	B	-
Raynolds	B	B	B	B
Huckleberry	B	B	C	C
Chelsea	B	B	C	C
Trowbridge	C	C	D	C
Paisano	B	-	-	C
Magruder	C	C	C	C
Geronimo	B	B	C	C
Mescalero	*	B	C	C
Sioux	C	C	D	C
Robert E. Lee	B	B	C	C
Airway	E	E	E	E
Hawkins	D	C	E	E
Rutherglen	B	B	C	C
McRae	D	B	D	C
Wedgewood	B	B	B	C
Yarbrough	A	A	D	-
Lee Trevino	B	B	E	-
George Dieter	C	B	E	E

* Denotes v/c ratio greater than 1.2

TABLE 2.3 LEVEL OF SERVICE FOR EXISTING PM PEAK CONDITIONS (1985 Highway Capacity Manual Procedures)

Intersection	LOS Eastbound	LOS Westbound	LOS Northbound	LOS Southbound
Cotton	C	B	B	B
Piedras	C	C	B	C
Raynor	A	A	C	-
Copia	B	B	B	B
Gateway South	B	B	-	C
Gateway North	B	B	B	-
Raynolds	B	B	C	C
Huckleberry	B	B	C	C
Chelsea	B	B	C	C
Trowbridge	C	C	D	C
Paisano	B	-	-	C
Magruder	C	C	C	C
Geronimo	C	B	D	D
Mescalero	*	B	C	F
Sioux	C	C	D	D
Robert E. Lee	C	B	D	C
Airway	F	E	E	*
Hawkins	F	C	E	*
Rutherglen	*	B	E	E
McRae	C	B	F	E
Wedgewood	C	B	D	F
Yarbrough	A	*	F	-
Lee Trevino	B	B	E	-
George Dieter	C	B	E	E

* Denotes v/c ratio greater than 1.2

\- Indicates movement does not exist

TABLE 2.4 PASSER II ESTIMATED DELAYS FOR EXISTING CONDITIONS

	AM Peak		Noon Peak		PM Peak	
Intersection	Average Delay	Cycle Length	Average Delay	Cycle Length	Average Delay	Cycle Length
Cotton	14.7	70	18.3	75	16.7	80
Piedras	20.4	70	19.4	75	22.5	80
Raynor	8.0	70	7.8	75	11.4	80
Copia	11.0	70	14.1	75	15.8	80
Gateway South	14.9	70	12.7	75	7.3	80
Gateway North	13.5	70	10.7	75	10.3	80
Raynolds	11.7	90	12.0	90	16.5	100
Huckleberry	8.2	90	9.0	90	7.0	100
Chelsea	13.3	90	14.5	90	20.9	100
Trowbridge	17.1	90	17.7	90	23.0	100
Paisano	19.5	90	14.1	90	15.7	100
Magruder	40.1	90	22.4	90	22.6	100
Geronimo	17.0	90	15.8	90	23.1	100
Mescalero	29.7	90	25.9	90	34.9	100
Sioux	23.3	90	26.4	90	29.0	100
Robert E. Lee	9.2	90	15.6	90	17.1	100
Airway	245.9	210	40.9	210	44.9	210
Hawkins	164.3	115	23.1	85	98.0	150
Rutherglen	20.2	115	7.5	85	8.2	150
McRae	209.4	115	22.4	85	44.3	150
Wedgewood	30.7	115	15.6	85	25.6	150
Yarbrough	16.5	115	6.2	85	9.7	150
Lee Trevino	28.1	115	15.1	85	16.7	150

In the next chapter, basic strategic arterial street elements are introduced to develop an understanding of improvement considerations. The remainder of this report is dedicated to an evaluation of alternative Montana Avenue improvements.

CHAPTER 3 STRATEGIC ARTERIAL CHARACTERISTICS

Many operations around the country have implemented different techniques for improving the corridor quality of service. Few organizations have designed strategic arterial streets but many have integrated these elements for other purposes. Strategic arterial elements and implementation methods used in this chapter are new only in the sense that they are labeled as "strategic arterial" improvements. The term strategic arterial can be defined as:

> ...an urban street designed, controlled, and managed to function as an urban principal arterial with design characteristics tending toward the higher end of ... nonfreeway urban principal arterials. (Ref. 3)

In metropolitan areas, urban arterial development has lagged behind freeway construction. In addition, public mass transit has not alleviated traffic congestion. Freeway demand will double in the next 20 years but constructing significant additional freeway lane miles is unlikely. Strategic arterial streets could deliver service quality slightly less than expected freeway service levels and must be considered for network improvements. Arterial improvements will benefit a community by:

- improving service at a lower construction cost,
- staging implementation,
- retrofitting to adapt to land use, and
- accommodating bus transit routes.

DESIGN GUIDELINES

Functionally a strategic arterial belongs to the third category of principal arterials discussed in chapter one namely, (3) other principal arterial (with partial or no control of access) (Ref. 1). Although strategic arterials are placed in category three, many of the design elements previously limited exclusively to freeways and expressways are incorporated (Ref. 7). Design guidelines recommended for strategic arterials in The Center for Transportation Research Report 1107-4 Design Guidelines and Other Considerations for Strategic Arterial Streets (Ref. 3) are as follows:

- providing safe operations at selected design speed of 45 to 50 mph
- accommodating moderate to high traffic volumes (on the order of 800 to 1000 vehicles/hour/lane, with total volumes of 2,000 to 3,000 vehicles per hour per direction); and

- serving a major portion of the medium length trips in an urban area or corridor (typical trip lengths of 5 to 10 miles), on facilities continuous for 3 to 8 or more miles at moderate travel speeds (30 to 45 mph).

A strategic arterial should provide both mobility and land access. Strategic arterials are expected to provide a high level of mobility with limited access. Compared to a traditional arterial street a strategic arterial places greater emphasis on the mobility function than property access (Refs. 3, 4).

The quality of service on strategic arterials is higher than other traditional principal arterials but lower than freeways. According to CTR research Report 428-1F, Conceptual Strategic Arterial Streets System for Harris County the quality of service is based on (1) range of service, (2) travel time, (3) reliability of operations, and (4) safety (Ref. 7). The following discussion on the design of strategic arterials focuses on how a strategic arterial is different from other principal arterials.

Strategic arterials should be designed to attract longer trip lengths than traditional arterials. While a traditional principal arterial tends to attract short trips, a strategic arterial should attract somewhat longer trips (Ref.7). Attraction of short to medium length trips from freeways would relieve freeways allowing improved longer trip service. For a strategic arterial to attract trips of 5 to 10 miles, the strategic arterial must be at least as long as the attracted trips. This is the reason why improvement of a short length of an arterial will not provide many strategic arterial benefits. Arterial lengths upgraded to a strategic arterial should be 8 to 10 miles. This is required to provide increased trip attractions and noticeable improvements to users.

The 1985 Highway Capacity Manual suggests three factors influencing arterial traffic operations: arterial environment (geometry and adjacent land uses), vehicle interaction (traffic density, vehicle characteristics, turning maneuvers, and speed differentials), and traffic signal control (stopping and intersection delay). Implementing strategic arterial design techniques with signal progression, access control, and grade separations will address these characteristics increasing roadway capacity and reducing traffic friction. Proper design will promote positive guidance and a safer driving environment. The following sections are dedicated to design, management, and geometric improvements that effect quality of service.

Design Speed

The design speed for a strategic arterial is 50 mph or higher with a minimum of 40 mph (Ref. 3). The design speed on a strategic arterial is governed by the frequency of at-grade intersections, access control, and safety considerations including sight distance and stopping sight distance (Refs. 4, 5). Unlike freeways, the most dominant factor effecting average speed on a strategic arterial is signal frequency and placement (Ref. 3).

Cross Section

Figure 3.1 shows the typical cross section for a six lane strategic arterial including minimum and desirable values (Ref. 7). The main two differences between this cross section and a traditional arterial are inclusion of a concrete median barrier and auxiliary lanes or shoulders. The auxiliary lane is crucial to providing operational reliability. This lane is used to prevent stopping vehicles from obstructing through flow (Ref. 9). By providing a lane for turning and disabled vehicles the strategic arterial avoids degrading the though traffic quality of service.

STRATEGIC ARTERIAL SELECTION (Ref. 3)

Strategic arterial identification encompasses adjacent land use type and intensity, patterns and intensities of arterial and cross street flow, and physical street characteristics. Right of way limitations are critical since significant improvements may demand additional lanes or special ramp designs. A strategic arterial can be implemented most easily where low density development does not prohibit right-of-way acquisition. One-way pair strategic arterial termination will allow arterial capacity to be maintained and evenly distribute traffic. Areas of high pedestrian traffic may be unattractive because desirable arterial speeds are high and may create unsafe pedestrian crossings.

It has been suggested that a strategic arterial policy be established so applications are consistent and standards are accepted. Basic strategic arterial characteristics include:

- Preferential green time treatment
- Grade separations at congested intersections
- Prohibit new driveways if alternate access exists (or require special permits)
- Establish new development process with stringent permitting criteria
- Create policy for existing driveway reconstruction
- Require land transfer by property owners for arterial right-of-way
- Develop quick response removal policy for accident vehicles

It is critical to gain community acceptance during the development process to ease implementation transition. Common objections include aesthetics, pedestrian treatment, parking removal, and property access. The best strategy is to mail information to affected property owners and conduct public hearings during early implementation stages. Keeping the public informed and emphasizing safety improvements may increase community acceptance.

TRAFFIC MANAGEMENT IMPROVEMENT TECHNIQUES

There are three main techniques for managing traffic using existing geometry. Each method has both advantages and disadvantages regarding the type of relief and efficiency it

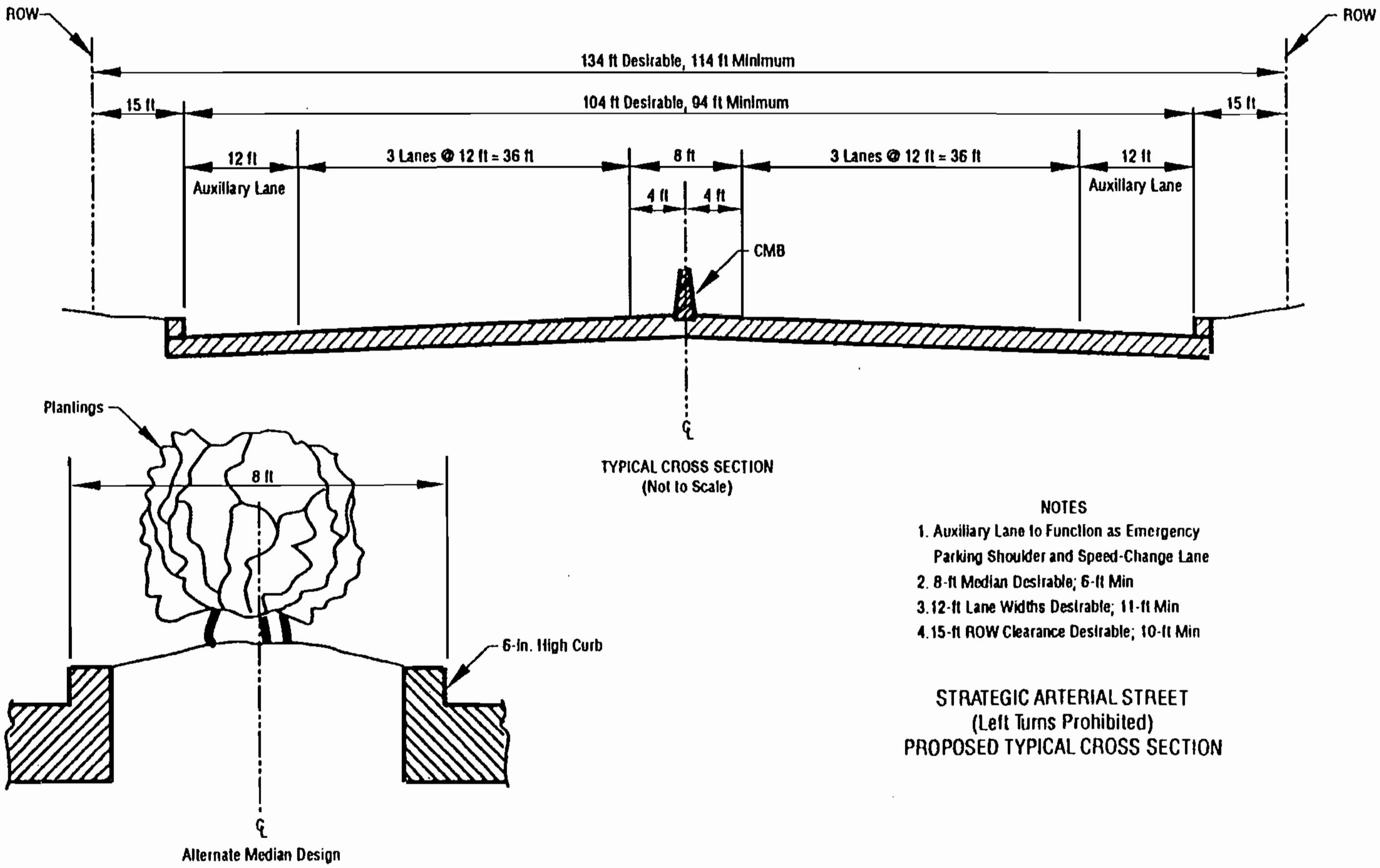


Figure 3.1 Typical Strategic Arterial Cross Section

provides. Primary focus is intersections because most traffic delay along a corridor results from signals and turning movements. The following sections discuss improvement options including signal coordination, intersection improvements (emphasizing intersection flaring, restriping for improved channelization, and free right-turn applications), and one-way pairs. Each section will identify possible implementation limitations and social and economic impacts.

Signal Coordination

The first, and probably easiest, management technique for an engineer to implement is signal coordination. Proper signal timing along a corridor can group cars together in large platoons making it possible to travel through the corridor experiencing very little traffic signal delay. Coordination implies signals along the corridor operate in concert guiding platoons through intersections without stopping. The cycle length of all signals must be equal but can consist of different phasing patterns. The start of green signal phases of successive intersections is delayed or "offset" so that platoons approaching each intersection will arrive during or near the beginning of the green phase.

Arterial progression will be most effective if the solution includes a large green bandwidth, indicating long platoons can progress without interruptions. This can be accomplished by allotting a high green time percentage to the progression direction(s). There are two types of progression that can be designed: one-way or two-way.

One-Way Progression. One-way progression is the easiest progression type to design. This simply means coordination is timed to accommodate only one travel direction. This is best applied during the morning or evening peak periods. A different signal timing plan can be used for each peak favoring the highest demand direction. For example, coordination would be inbound to the CBD in the morning and outbound in the evening. By using one-way progression, it is easier to develop a larger bandwidth because more green time can be allocated to the peak direction. One side note to this point is that bandwidth is expressed in units of time (seconds) so the associated platoon size can be estimated using inter-vehicle platoon time headways.

Two-Way Progression. Two-way progression develops progression in both directions at the same time. Development of large green bandwidths is a difficult process because one direction usually limits the other. This type of progression is best when the directional split is roughly 50/50. If one direction has considerably less volume, two-way progression will be undesirable because two-way throughbands will usually be smaller than comparable one-way progression schemes. Two-way progression is useful during off-peak periods because flow has a tendency to be balanced and neither direction will be restricted. Arterial progression is easier to implement if cross street volumes are small because more green time can be given to arterial flows. Offsets for two-way progression are limited to half cycle increments whereas one-way progression is completely flexible.

Signal coordination is usually a short term solution because demand tends to change irregularly over time. Unexpected delays may also result for turning movements if area development increases differently than predicted. Providing preference to arterial through traffic often causes cross street traffic to suffer due to reduced green time and no progression.

Intersection Improvements

Beyond optimizing the signal timing, there are other intersection elements that can also be improved. Minor changes can create a better managed intersection and increase capacity with little effort. Below are examples of intersection modifications that could improve traffic flow. Figures 3.2a-d illustrate how each improvement would change intersection layout.

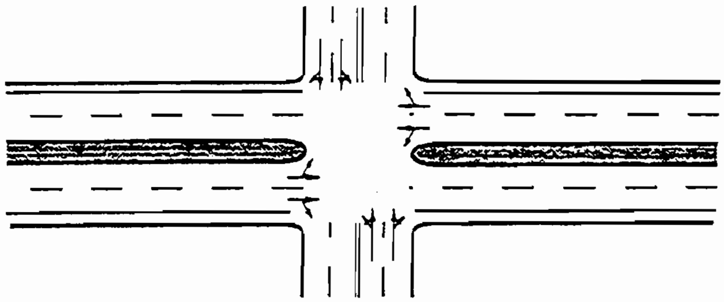
Creating exclusive turn lanes. Immediate additional capacity can be available to both turning and through movements. Exclusive turn lanes provide additional storage for turning vehicles and the opportunity to implement protected turning phases. Increased through capacity comes from the fact that turning movements (both left and right) require a longer time to get through the intersection and slower vehicles would no longer share through lanes.

1) Restriping. Additional lanes can sometimes be created without expanding right-of-way. With adequate pavement width, it may be possible to restripe an intersection with 10 or 11 foot lanes to create an exclusive turn lane or convert the shoulder area to another through or right lane. This will separate movements and distinguish lane designations to increase through traffic flow potential. However, as illustrated later in this chapter, narrower lane widths reduce lane capacity.

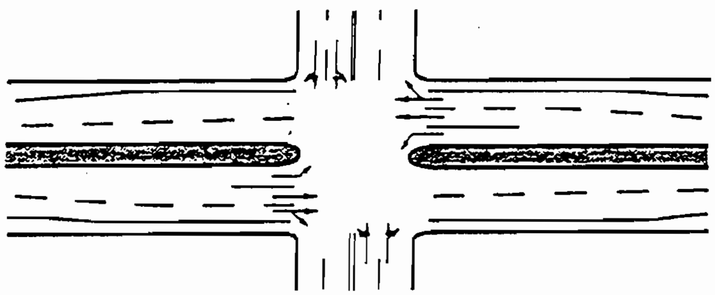
2) Intersection flaring. This is a process where the intersection approaches are enlarged to provide more capacity. This often requires additional right-of-way because lanes are added to current intersection geometrics. The positive aspect is that the only right-of-way required is in the vicinity of the intersection and the amount needed for one lane is approximately 12 feet wide and 100-200 feet long. With regard to a left-turn lane, it is often possible to use the median for the required area and no additional land is needed.

Constructing a free right-turn movement. This would involve minimal construction (possibly a bit of right-of-way) and it essentially removes intersection right-turns. This would eliminate right-turn intersection delay that vehicles incur while waiting for adequate gaps, provided there is an acceleration lane allowing right-turns to continue without stopping.

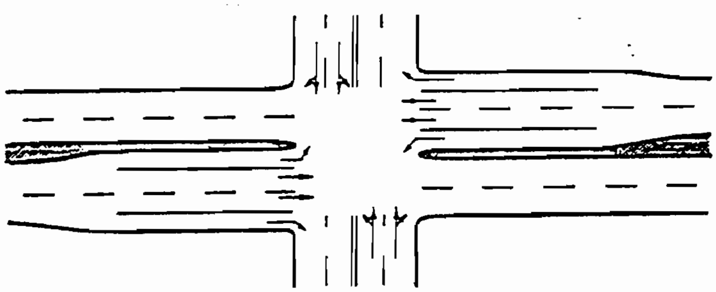
Many of these intersection improvements have drawbacks that should not be overlooked. For instance, an exclusive left-turn could actually attract additional demand over and above what has been forecasted. The increased volume may eventually require the phasing pattern to include a protected left-turn phase, introducing additional delay to all other movements. Free right-turns, on the other hand, may prove to be completely nonbeneficial. If an acceleration lane is provided after the turn, drivers not realizing that they do not have to stop may cause a dangerous rear-end



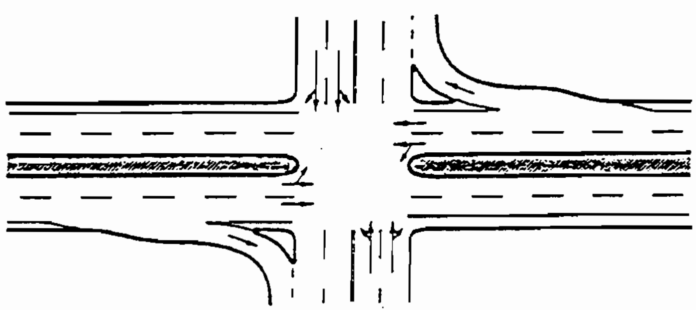
a. General Intersection



b. Intersection Restriping



c. Intersection Flaring



d. Free Right Turn

Figure 3.2 Improvements Using Intersection Modifications

collision situation. In the case where an acceleration lane is not possible, the free right-turn will be ineffective because drivers must stop for oncoming vehicles.

One-Way Pairs

One-way pairs are the third example of how traffic management could be implemented. They have a great network impact because they could change the current major flow through the area. The main reason for developing a one-way pair is that conflicts due to opposing traffic are removed. Vehicles turning left across opposing traffic must stop or reduce speed effectively blocking through traffic flow. It might also be possible to simplify the signal timing and increase the through traffic green time because left-turn phasese are not needed.

There are two one-way pair operational concepts. The most common layout is referred to as the conventional method where opposing traffic on the adjacent one-way street is to the left of the driver, although separated by a city block. It is the preferred design because it gives drivers a natural sense of how streets are arranged. The unconventional layout is not often used, however, it can be used in a case where connections at each terminus are more conveniently accessible if operations are reversed. This may be a more inexpensive option and it may be the easiest design.

GEOMETRIC CONSTRUCTION IMPROVEMENT TECHNIQUES

Beyond traffic management efforts, construction options may be necessary. Geometric improvements to a corridor can provide greater flow and significantly reduce travel delay. The two techniques described in this chapter have positive and negative impacts on the system and could carry substantial construction costs as well. A center concrete median barrier controls access to and from an arterial by restricting all left-turn movements and eliminating midblock traffic stream friction. A grade separated intersection replaces a signal and gives 100 percent green time to through arterial traffic. This removes all main line intersection delay and provides greater corridor continuity. The following sections discuss these two methods of improvement, pointing out benefits and disbenefits as well as social and economic limitations.

Concrete Median Barrier

The first type of geometric improvement is a concrete median barrier controlling access to and from driveways and cross streets. Travel time along a corridor can significantly increase due to frequent left-turning across opposing traffic. If an arterial has uncontrolled access to many driveways, the concrete median barrier will prohibit left-turning across opposing traffic. Access to businesses on the opposite side can be provided by an indirect path using a series of right-turns.

Unlike typical arterial streets, the strategic arterial incorporates at least a minimum access control level. Control of access is an integral strategic arterial characteristic since through access control, traffic friction is reduced and operational reliability is increased (Refs. 3, 7). Access is controlled on strategic arterials by combining driveways, preventing left-turns onto the arterial, limiting property access to other streets where possible, and controlling driveway geometrics and streets abutting the arterial (Refs. 3, 4). Where possible, continuous auxiliary lanes along the entire arterial or partial sections may provide property access. Paint striping and signage may be all that is needed to distinguish the auxiliary lane from main lanes (Ref. 3). Actual design features used to control access are discussed further in the design features section and strategic arterial configurations are shown in Figures 3.3 and 3.4. Also in some situations it is possible and desirable to limit or purchase access rights without acquiring property (Ref. 3).

An advantage of a concrete median barrier is enhanced arterial continuity. The continuous barrier gives the effect of a high-speed thoroughfare and improves overall travel speed. When all left-turn traffic is eliminated and signals are simplified, delay may be reduced and through traffic flow increased. Greater flow attracts longer arterial trips and provides connectivity between outlying areas and central attractions.

Removal of left-turns using a barrier will also improve corridor safety. First, it will separate opposing traffic streams and eliminate head-on collision possibilities. Second, vehicles will no longer wait in the median for an acceptable gap in the opposing traffic stream and are directed to safer crossing maneuvers. As a result, movements occurring midblock and at intersections are reduced to major street through traffic and right-turns.

It is necessary to note concrete median barrier disadvantages. By restricting access to vehicles traveling in only one direction, businesses may experience an initial decrease in customers. Where competition is high, convincing businesses to accept barrier impacts may be difficult. Barrier placement presents additional construction costs as indirect turns are needed. It is imperative to accommodate desired left-turns using indirect routes. Design and impact are two major median barrier installation concerns.

Barrier Design Considerations. Design considerations should include barrier dimensions and continuity. Standard dimensions of a New Jersey concrete median barrier suggest a height of 33 inches with a six inch top width and a 28 inch base width. These dimensions are based on maintaining a vehicle on the roadway to avoid serious accidents. When visual impact is a concern, a guardrail or curbed median can be used.

The objective of a concrete median barrier is to restrict and control arterial access so it is important to consider strategic median opening locations. Many cross streets may have traffic volumes that require full arterial access but midblock access must be reduced or eliminated. Drivers may experience some initial inconvenience but the benefit is improved flow and enhanced safety.

Indirect Left-Turns. Design considerations should reflect left-turn impact, access management, and developmental constraints. The impact of eliminating left-turns can be evaluated

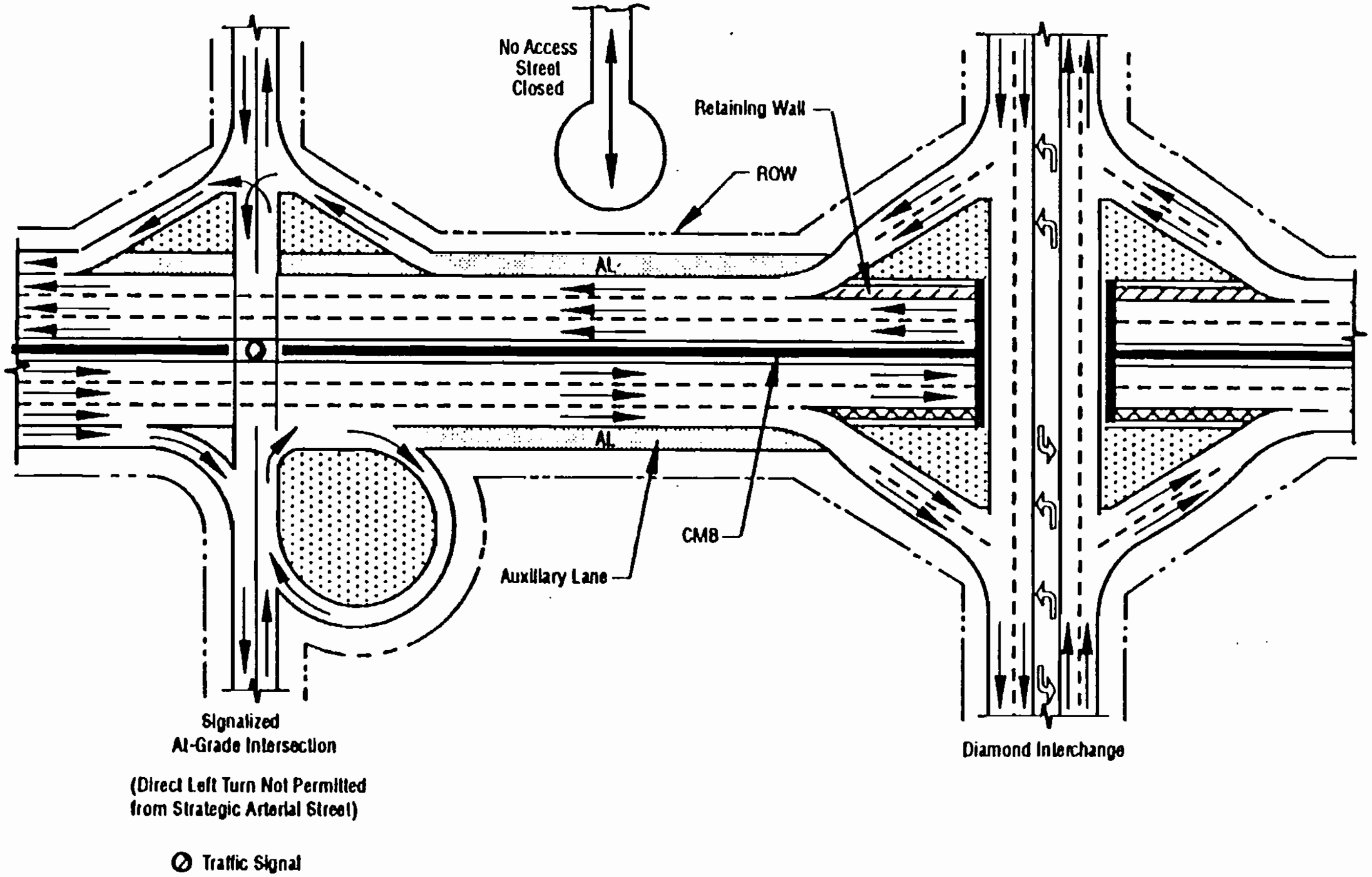


Figure 3.3 Strategic Arterial Special Features, Schematic Layout

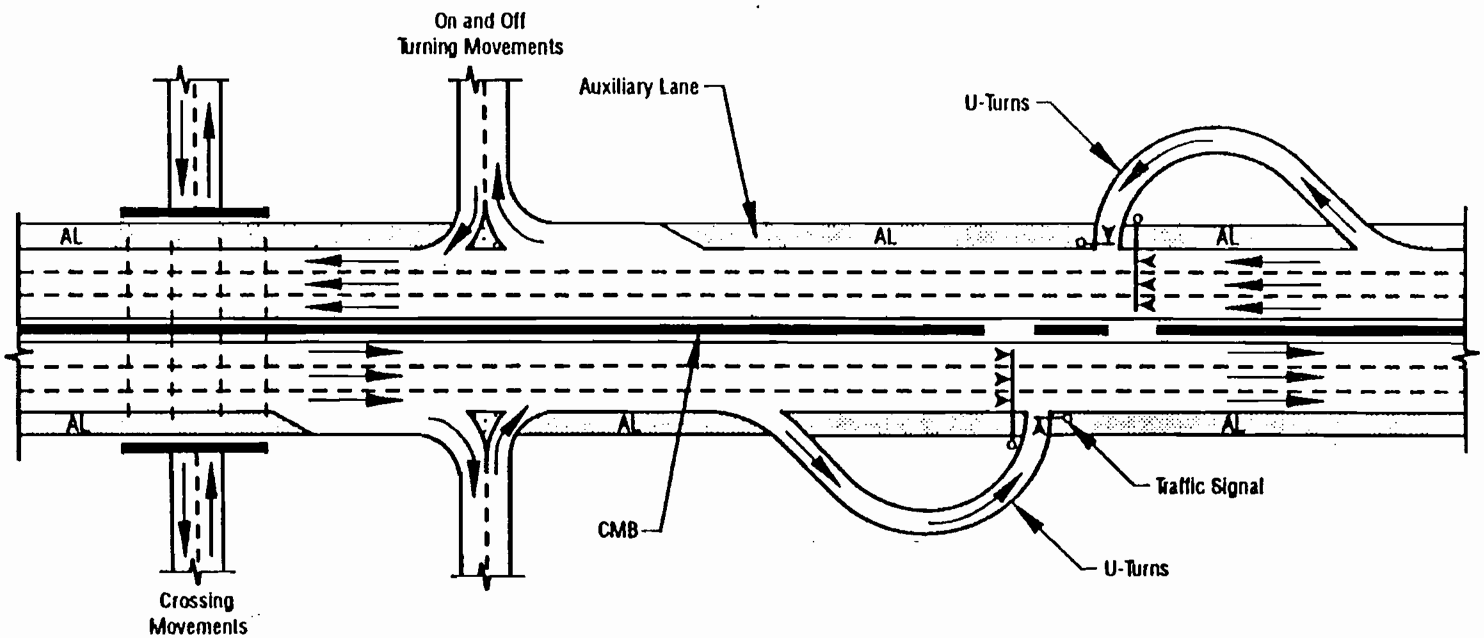


Figure 3.4 Strategic Arterial Special Features, Schematic Layout

considering left-turns occurring at driveways and intersections. New routes will be formed and travel patterns will change, so careful design must provide convenient alternative turn paths.

Strategic arterial access management is important to promote better traffic flow and improved safety. If access is uncontrolled, through traffic speed changes caused by many ingress and egress points along the corridor could dramatically increase overall travel time. Restricting access with a barrier eliminates the two-way left-turn lane resulting in improved safety and reduced vehicle friction. Access management must be regarded as a crucial design aspect.

Identifying the most feasible type of indirect turn is dependent on land development density. Urban intersections are typically surrounded by dense commercial development, making adjacent right-of-way acquisition most expensive. The magnitude of density will likely influence the decision to restrict turns and limit possible designs. Therefore, multiple indirect turn solutions should be formulated as development may limit feasible alternatives.

An indirect left-turn is a relatively new geometric concept because drivers, as well as planners, do not desire extended travel routes. To accomplish a left-turn, a driver is required to make a series of right-turns and/or U-turn and a right-turn. This can be very awkward and confusing for drivers since unfavorable longer travel times and indirect routes can be created. The following sections describe various indirect left-turn options.

1) Jug handles. Jug handles can be accomplished either at an intersection or midblock location. An intersection jug handle is simply an at-grade right exit ramp which intersects the cross street. Ramp alignment directs traffic back far enough to provide sufficient queue storage for cross street traffic, or the ramp can be used as additional exiting vehicles storage. Midblock jug handles also have a right exit but curve to intersect the major street. This maneuver is used for U-turns or T-intersections. A disadvantage to midblock jug handles is additional signalization, which could influence signal progression quality.

2) U-turns. A U-turn can be accommodated in a wide major street median. A driver can accomplish a left-turn equivalent by driving through the intersection, making a U-turn, and then a right-turn. AASHTO standards suggest a minimum median width of 71 feet to accommodate a WB-50 design vehicle, or 50 feet for a passenger vehicle. A desirable U-turn design provides acceleration and deceleration length for vehicles, thereby minimizing weaving conflicts. Candidates for U-turns will be intersections having wide medians and dense commercial development. Advanced land development may make it difficult to construct jug handles or reverse loops.

3) Reverse loops. The final example of an indirect left-turn is a reverse loop, best described as an at-grade cloverleaf. In a reverse loop, drivers travel through the intersection and around the loop to merge with cross street traffic. The major disadvantage is that the intersection is traversed twice, and a driver could become disoriented and frustrated. Similar to the U-turn, a reverse loop is also dependent on land development magnitude and sensitivity. Since design standards recommend a large radius loop, ample right-of-way must be reserved.

Grade Separated Interchanges

For intersections with high traffic volumes on all approaches, grade separated interchanges should be considered. If intersection traffic demands require more signal green time than can be provided, then the level of service is very poor. A grade separation essentially provides uninterrupted movement to major street through traffic and thereby reduces traffic volumes using the at-grade intersection. Major street through traffic will benefit with greatly increased travel speed and the cross street will experience less intersection delay.

Upon identifying a grade separation candidate, three major design elements must be examined. First the arterial street cross section must be designed including through lanes and exit ramps. A strategic arterial grade separation has a desirable cross section of three through lanes in each direction. Two through lanes in each direction may be acceptable depending on projected volumes. Minimum median widths are six feet for the center and ten feet between through lanes and ramps. Length of grade separation vertical curves is based on AASHTO standards and related to design speed and vertical clearance.

Another design element is intersection layout. Since major street through traffic is removed from the intersection, the cross street can be given higher priority for green time and phasing can be simplified. There are two options for controlling the resulting traffic demand. A dual configuration has two signals coordinated so vehicles do not experience delay at both intersections. A single point intersection controls all traffic with one signal. These examples are shown in Figure 5.

Intersection geometry should include adequate lanes to satisfactorily accommodate traffic demand. Providing additional green time to the cross street should eliminate extensive intersection flaring requirements. Ramp traffic may be supplied with one left-turn lane, two through lanes, and one right-turn lane. This should be sufficient for traffic demand but variations could include a shared left/through lane or two left lanes.

The final grade separation design consideration is right-of-way requirements. Since entrance and exit ramps are required for cross street access, it is necessary to widen the right of way near the intersection. Strategic arterials are typically retrofit into a developed area so cross sectional specifications are manually condensed. Desirable right-of-way along the strategic arterial is 165 feet and consists of six main lanes, an eight foot median, ten feet between main lanes and ramps, two ramp lanes, and 15 feet lateral clearance to right-of-way line. Minimum dimensions for shoulders and lateral clearance could reduce right-of-way requirement by 30 feet.

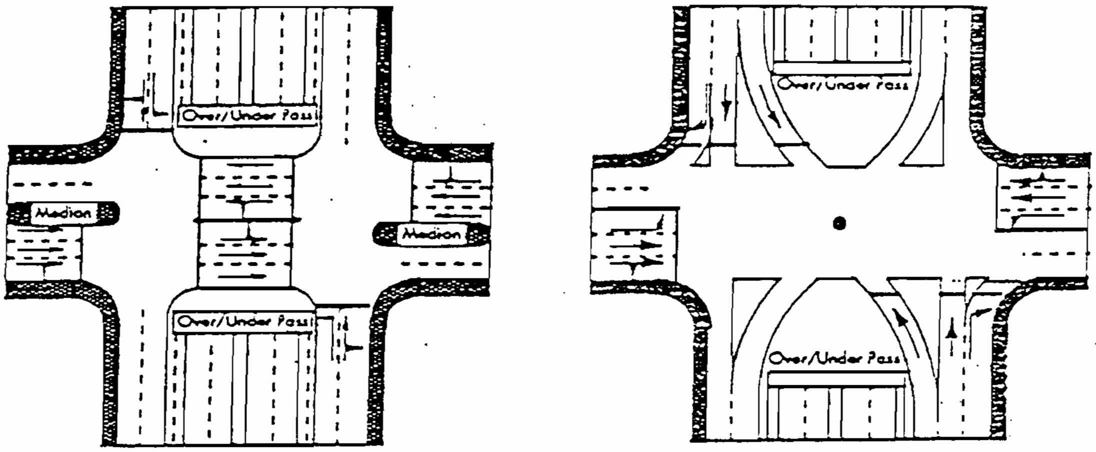


Figure 3.5 Condensed and Single Point Grade Separated Interchanges

SUMMARY

This chapter has provided the design standards and development patterns to recognize and classify strategic arterials. It is important to realize elements which constitute a strategic arterial so proper arterial selection and implementation can fully benefit a community. Based on strategic arterial characteristics identified in this chapter, identification of problems and solutions is enabled. From this, guidelines and analyses determining feasible particular case upgrades may be developed.

CHAPTER 4 LEVEL 1 ANALYSIS

In Chapter 2 Montana Avenue existing conditions were presented. This included an arterial description and a current traffic condition evaluation. In this chapter a number of improvement alternatives are considered for Montana Avenue, including a do-nothing alternative, a half dozen freeway alternatives, and several strategic arterial alternatives. These alternatives are based on the year 2015 forecasted traffic according to the Texas Department of Transportation Large Network Assignment Model.

These initial improvement alternatives are considered the level one alternatives. The level one analysis involves alternatives modeling and model results comparison. Overall benefits and disbenefits of each alternative are also compared. After this broad based level one analysis, a few alternatives are chosen and undergo a more in depth "level two" analysis. The level two analysis, on the selected alternatives, is presented in Chapter Six.

This chapter includes a description of the network modifications, modeling results, and each alternative's benefits and disbenefits. The final section presents comparisons between different alternatives, discussing pros and cons of each in relation to the other alternatives. Before the preceding discussions are presented, a discussion of the model and assignment procedures is given.

TXDOT LARGE NETWORK ASSIGNMENT MODEL DESCRIPTION AND ASSIGNMENT PROCEDURE

The Texas Large Network Assignment Model (TxLNM) [Ref. 13, 14] is part of the Texas Travel Demand Package which consists of a series of computer programs to generate, distribute, and assign roadway trips. TxLNM itself contains a number of computer programs to assign traffic to transportation networks.

Traffic Assignment Description

Traffic assignment forms the last step of the four step modeling process involved in urban transportation planning. The process starts with trip generation which forecasts the number of trips to and from a set of zones (geographical areas) based on various travel related activities. Trip distribution then connects productions and attractions forming trips between zone pairs. The third step involves prediction of the amount of travel by each of the available transportation modes. Lastly, traffic assignment is the process of determining estimated traffic volumes on a transportation network. Traffic assignment results are used to establish design volumes and evaluate alternative facility types and locations.

Traffic assignment output typically comprises volumes of vehicular highway traffic on each transportation network link. Selection of paths by traffic depends upon link impedance such as travel time, distance, cost or a combination. There are different assignment algorithms such as all-or-nothing, capacity restraint, stochastic multipath and equilibrium assignment techniques. The most basic of all is the all-or-nothing procedure which assigns all trips to the shortest path. Other methods are more realistic and take into account various factors such as link capacity limitations and paths with minimal travel time differences.

Assignment Procedure

The model uses an iterative capacity restraint procedure to assign trips to links. Each iteration in this procedure is nothing but a simple all-or-nothing assignment. However, after each assignment iteration the link impedances are modified on the basis of the assigned v/c ratio for the link. Five iterations are performed and the final assigned volume is a weighted average of the five assigned volumes. Therefore, if the same traffic volume increment is added to two links with, respectively, large and small capacities, the large capacity link will exhibit less travel time change than the small capacity link. This is, of course, realistic and provides a means by which the assignment method reflects real network performance. The weights assigned to the different iteration volumes are as below:

$$V(1) = 15,\ V(2) = 15,\ V(3) = 20,\ V(4) = 20,\ V(5) = 30$$

The major model input requirement is the coded transportation network representing links, nodes, and centroid connectors. TxLNM can accommodate a network with up to 99,999 nodes and 256,000 links. Each link in the network has to be assigned capacity and speed on the basis of the number of lanes, functional facility class and the area type in which the facility is located. The 24 hour link capacity is calculated based on factors such as LOS, design hourly volume as a fraction of the Average Daily Traffic (ADT), peak hour factor, directional distribution, percentage of truck traffic, and green time to cycle length ratio.

Output provided by the model includes a printed network description, the assigned link volumes, v/c ratios, travel times and speeds. Other significant output data consists of turning movement volumes, total vehicle miles of travel by functional class and area type, and specific corridor volume summaries.

TxLNM can be used to assign traffic to an existing network based on the current land use pattern and travel behavior or it can be used to predict future traffic on the same network or an updated network. Alternative improvement strategies can be evaluated for a particular corridor for their effect on the corridor itself and on other area facilities.

Evaluating assignment results for existing conditions is easy because they can be field survey checked. Evaluation of future assigned traffic is more difficult and it requires land use patterns insight, travel behavior change concepts. Output results should therefore always be checked and evaluated.

Capacity Definition

Traffic demands and capacities, within the TxDOT assignment methodology represent 24 hour time periods (or average days) rather than peak hours. The concept of a 24 hour highway capacity differs significantly from the Highway Capacity Manual "hourly" definition. The 24 hour "capacity" numbers used in this analysis are based upon a TxDOT procedure which yields a "capacity" which is roughly two-thirds of 24 times the hourly maximum flow. That is, the true maximum traffic flow that could pass over a highway link in 24 hours would be the maximum hourly flow multiplied by 24. A link loaded to this level would experience level of service "E" (v/c ratio = 1.0) during all 24 hours of a typical day. Such severe loading is rarely observed, however, a network is usually considered congested if some links display level "E" during a few (2 to 4) hours daily. Therefore, the TxDOT 24 hour "capacity" approximates the condition of demand equaling or exceeding hourly capacity during the peak 2 to 4 daily hours but, being less than capacity for the other 20 to 22 hours. Therefore, 24 hour volume/capacity ratios greater than 1.0 indicate hourly v/c ratios of roughly 1.0, for more than 2 to 4 daily hours.

LEVEL 1 ALTERNATIVE DESCRIPTIONS

Ten alternative improvement scenarios were considered for Montana Avenue in addition to a no-build alternative. The improvements consist of six freeway alternatives and four strategic arterial upgrades. All these alternatives were modeled using the Texas Large Network Assignment Model package for mainframe computers. The model forecasted volumes, speeds, and v/c ratios for the system links. For all these alternatives the entire, year 2015 El Paso network was used with requisite changes made to Montana Avenue. The same year 2015 trip table was used to assign trips to the network under different improvement scenarios.

Capacity and speeds assigned to facilities on the basis of functional class and location (area type) are consistent with those used for El Paso by the TxDOT planning division. However, in the case of strategic arterial improvements some changes in speed and capacity were made to enable conformity with strategic arterial characteristics. The capacity and speed tables are given in Appendix A.

To analyze different alternatives for their effect on the Montana corridor, I-10, and other facilities, an analysis area around the Montana corridor was identified. This analysis region is depicted in Figure 4.1. Screen lines were selected and assigned volumes, v/c ratios and speeds at these screen lines were posted on analysis area maps for each alternative. These maps are provided in Appendix B. Supporting tables with v/c ratios, speeds, volumes, and corresponding TxLNM links are provided in Appendix B. Appendix C provides maps for the level two analysis, which is

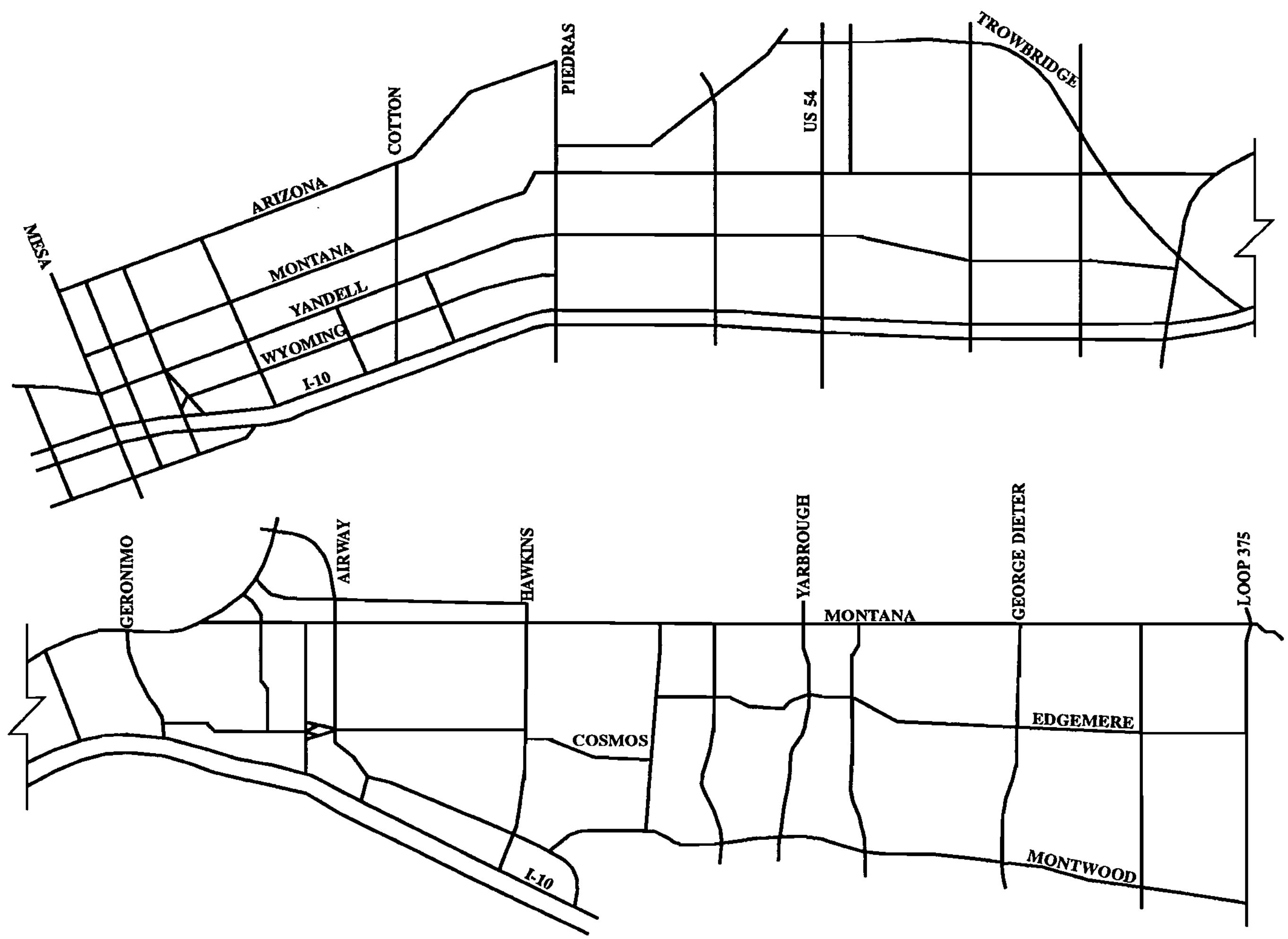


Figure 4.1 Conceptual Project Area Map

discussed in chapter six. While the same network is used for level two analysis, comparisons should not be made between level one and level two modeling results. This comparison is not valid due to changes made in the base network after the completion of the level one analysis. These changes mainly of adjustments in link lengths to make the model network more closely represent the actual street system. This does not mean that the level one results are unusable but only that they should be used as a relative comparison among different alternatives. Therefore level one model results should only be compared with each other and level two model results should only be compared with each other, exclusively.

Brief descriptions of alternatives with positive and negative considerations are discussed below and summarized in Table 4.1. The freeway alternatives consist of new links (new facilities) added to the network. Alternatives 1, 2, and 3, are connected to the network only at their east and west ends and differ only in the location and type of west end connection.

No-Build Alternative

The do-nothing alternative in addition to serving as the base case on which all other improvements are modeled, also provides a basis for comparing alternatives. It can be used to study the travel demand in case no mobility improvements are provided. This alternative uses the year 2015 El Paso network with only those improvements on Montana which are currently projected by TxDOT. At the western end, from Mesa east to west of Brown, Montana is coded as a two-way four-lane undivided primary arterial. From this point Montana changes to a two-way two-lane primary arterial and continues east to just west of Piedras where again it becomes a four-lane facility extending to Paisano. From Paisano eastwards to Loop 375 Montana is coded as a six-ane divided primary arterial.

The main benefit to this alternative is that it requires no capital expenditure. On the negative side though is a user cost increase. This alternative provides no new capacity or improved service to meet forecasted demand increases.

Freeway Alternatives

Alternative 1: No connection Freeway. This six lane freeway is modeled as an elevated or depressed facility all the way from I-10 at Cotton street to Loop 375. The freeway connects directly to I-10 in the vicinity of Cotton street. There are no intermediate access points to the freeway along the entire corridor. Montana Avenue has the same geometrical characteristics as in the base case.

This alternative, along with alternatives two and three, serves only the demand originating east of Loop 375 desiring to reach the downtown area. Since alternatives one, two, and three have network linkage only at the ends, and can be built as either elevated or depressed sections they therefore represent minimal neighborhood impacts and right-of-way requirements. This alternative has various additional benefits including low noise, low travel time, and high speed. There are

TABLE 4.1 CONCEPTUAL DESCRIPTION OF ALTERNATIVES

ALTERNATIVE	DESCRIPTION	PROS	CONS
No Build	Current network with projected improvements and growth adjustment for demand volume.	• No capital expenditure	• Larger user cost
1. Freeway, No Connection	Elevated freeway from I-10 at Cotton Street to Loop 375 along Montana Avenue. Montana and Yandell are two-way east of Piedras. There are no access points along the entire corridor.	• Low noise • Low travel time • High speed • Low ROW requirements	• High cost • No intermediate access • Low vehicular attractiveness • Minimal facility use
2. Freeway Ending East of Piedras	Same as Alternative 1 but terminating with ramps to Montana and Yandell.	• Traffic exits on parallel streets rather than perpendicular • Little disturbance of local neighbourhood	• Disperses Montana freeway traffic to residential streets • High cost • No freeway to freeway connection
3. Freeway, Ending at Piedras	Same as Alternative 1 but terminating on the west end directly into Piedras.	• Does not force freeway traffic directly onto Montana and Yandell	• Piedras operates at low level of service • Montana traffic is distributed to local streets
4. Freeway to I-10 with Six Diamond connections	Freeway from I-10 at Cotton Street to Loop 375 with six diamond interchanges along the Montana	• Greater access • Large reliever of parallel I-10 route than Alternatives 1,2,and 3 •Enhances network connectivity •Better use of capacity	• Expensive • Need additional ROW • Increase in residential disturbances at ramp locations

TABLE 4.1 CONCEPTUAL DESCRIPTIONS OF ALTERNATIVES (CONT)

ALTERNATIVE	DESCRIPTION	PROS	CONS
5. Freeway Into Piedras (Direct) With Five Diamond Connections	Same as Alternative 3 but with connections at five locations as in Alternative 4.	• Many access points • Relief of Edgemere and I-10 traffic	• Expensive • Congestion on Piedras • Need additional ROW • No freeway to freeway connection
6. Freeway to Piedras (Diamond) With Five Diamond Connections	Same as Alternative 2 but with five diamonds as in Alternative 4.	• Enhances network connectivity • Relief of Edgemere and I-10 traffic	• Expensive • No freeway to freeway connection
7. Superstreet With At-Grade Intersections	Upgraded principal arterial with restricted turning movements. One-way pair with Yandell west from Paisano to Mesa. Higher speed. Every cross-street will have a signalized connection.	• Inexpensive • Increase in capacity • Restricts turning movements • Reduces traffic on parallel routes	• Too many access points and conflicts • Travel time higher for all at-grade
8. Superstreet With All Grade Separated Intersections	Same as previous alternative but all cross streets have grade separated intersections.	• No intersection delay • Cheaper than freeway	• Attracts excessive volumes
9. Superstreet With Some Grade Separated Intersections	Same as Alternative 7 with five grade separated intersections.	• Less costly than Alternative 8 • Less neighborhood disturbance than Alternative 8 and freeways	• Introduces some intersection delay • Less capacity than Alternative 8 and freeways • Lower speeds than Alternative 8 and freeways

several negative aspects including high costs, no intermediate access, low vehicular attractiveness, and minimal facility use.

Alternative 2 : Freeway Ending East of Piedras. This alternative is the same as the previous one with the exception that at the western end, it connects via ramps to Montana and Yandell just east of Piedras. The ramps end as signalized intersections on Montana and Yandell

This alternative has many of the same pros and cons as the first alternative. However, it does allow traffic to exit onto parallel streets dispersing the Montana freeway traffic to local streets. Also this alternative, along with alternative three, offers no freeway-to-freeway connection.

Alternative 3 : Freeway Ending at Piedras. This improvement also involves a depressed or elevated freeway with no intermediate connections. The difference from the two previous improvement alternatives is that this freeway ends directly at two signalized intersections on Piedras between Montana and Yandell.

As with the second alternative, this one has many of the same pros and cons as the first. It does not force traffic to exit onto Montana and Yandell but does have the disadvantage of traffic exiting onto perpendicular streets rather then parallel streets. The perpendicular street, Piedras, operates at a low level of service and as in the previous alternative, traffic is distributed to local streets.

Alternative 4 : Freeway to I-10 with Six Diamond Connections. In this alternative an at grade freeway is modeled along the Montana corridor with six intermediate access points through diamond interchanges. The western terminal of this freeway involves a direct connection to I-10 in the vicinity of Cotton street. Between Piedras and Trowbridge, Montana and Yandell function as one-way frontage roads with connecting ramps at diamond interchanges. Beyond Trowbridge to the east, Montana is still modeled as a six lane two-way primary arterial. But conceptually this facility can be viewed as two one-way frontage roads along the freeway. However, because of the two way nature of Montana, the interchange ramps in this section of the freeway are joined to the cross streets. The selection of cross streets for interchanges was based on analysis of existing conditions which identified major cross streets with heavy volumes. Consideration was also given to placing interchanges at fairly regular distances. The six interchanges selected are at Piedras, US 54, Trowbridge, Airway, McRae and Loop 375.

This alternative along with alternatives five and six enhances the connectivity of the freeway over the first three alternatives but creates significant land use impacts. Alternatives four, five, and six also provide greater access and more efficient use of capacity than alternatives one, two, and three. Additional negatives of this alternative include high cost, additional right-of-way requirements, and increased residential disturbances. An additional positive is that this alternative acts as a large reliever of the parallel I-10 route.

Alternative 5: Freeway into Piedras with Five Diamond Connections. This freeway improvement is same as Alternative 4 with the exception of the western freeway terminal. In this case the freeway ends directly into Piedras at two signalized tee intersections. The five interchanges are located at US 54, Trowbridge, Airway, McRae, and Loop 375.

This alternative has most of the same positives and negatives as the fourth alternative, although it does not provide freeway-to-freeway connection. Piedras street, which is the location of the west end of the freeway, is congested due to the freeway termination and freeway traffic to local street dispersal. This freeway alternative does provide relief to Edgemere Boulevard along with I-10.

Alternative 6 : Freeway East of Piedras with Five Interchanges. In this alternative also, the entire freeway with the exception of the western terminal is modeled exactly as the freeways in Alternatives 4 and 5. In this case the freeway ends via ramps onto Montana and Yandell which, as mentioned earlier, act as one way frontage roads.

This alternative also has most of the pros and cons of the fourth alternative. It includes increased connectivity, improved access, better capacity use, and I-10 and Edgemere relief on the positive side, compared to high cost, no freeway-to-freeway connection, distribution of traffic to local streets, and additional right-of-way requirements on the negative side.

Strategic Arterial Upgrades

Alternative 7 : Strategic Arterial with At-Grade Intersections. For this alternative Montana Avenue is modeled as a strategic arterial. Strategic arterial concepts have already been discussed and while modeling this improvement, conformity with those characteristics was maintained as closely as possible.

West of Paisano to Mesa, the strategic arterial consists of a one-way pair with Montana going east and Yandell going west both with three lanes. East of Paisano, Montana is modeled as a six-lane strategic arterial with speeds and capacities higher than those used for a principal arterial. Speeds and capacities for both one-way and two-way strategic arterials fall in the range of what is classed as expressway in the TxDOT El Paso speed and capacity table. Another characteristic of a strategic arterial is the provision of a continuous concrete median barrier down the middle prohibiting left-turns. However, as the current version of the TxLNM used by TxDOT does not allow the use of turn penalties, left-turns from Montana could not be restricted as such in the model. This fact was taken into account when adjusting speeds and capacities for the strategic arterial. No grade separations were modeled for this alternative so it represents a low level strategic arterial.

This alternative has a variety of positives including, it is inexpensive compared to freeway alternatives, increases the capacity and quality of service over the no-build alternative, reduces traffic on parallel routes and restricts turning movements. Negatives include too many access points and conflicts, high travel times since all intersections are at grade, and delays due to increased demands.

Alternative 8 : Strategic Arterial with all Grade Separated Intersections. In this strategic arterial upgrade, all cross streets along the two-way arterial are grade separated. As Montana is a two-way street, grade separations cannot be properly modeled using ramps. So to account for the grade separations the capacities and speeds used were higher than those used in the Alternative 7 strategic arterial.

This alternative possesses strategic arterial benefits mentioned in alternative seven. In addition it eliminates intersection delay and provides lower travel times and higher speeds. On the negative side this alternative is more costly then alternative seven and tends to attract excess volumes.

Alternative 9 : Strategic Arterial with Five Grade Separated Intersections. This alternative presents a compromise solution between an Alternative 7 low level strategic arterial and a cost extensive Alternative 8 high level strategic arterial. Conceptually this strategic arterial has grade separation structures at five of the busiest intersections which would otherwise create bottlenecks if left at-grade. To account for the grade separations, an increase in the capacity of the strategic arterial was made over that of Alternative 7. Other features remain the same.

This alternative also has the strategic arterial pros and cons as in the previous two alternatives. A positive aspect is that it is less costly then alternative eight and the freeways but both capacity and speed are sacrificed. In addition, delay is eliminated at the highest volume intersections through the installation of grade separations but the remaining intersections still experience delay. This alternative also creates less neighborhood disturbance than alternative eight and the freeway.

Alternative 10 : Strategic Arterial Network. This improvement alternative considered a network of arterials upgraded to the strategic arterial level. Apart from Montana Avenue the other arterials selected for upgrading were Montwood, Viscount, and Paisano. Also Edgemere from Airway to Geronimo and Geronimo from Edgemere to Montana. Montwood and Viscount together form an almost parallel facility to Montana from Loop 375 to Airway. Paisano after its intersection with Montana and Yandell, moves west somewhat paralleling Montana and Yandell. In this alternative, Montwood and Viscount are modeled as four-lane strategic arterials from Loop 375 to Airway. Paisano is modeled as a six-lane strategic arterial from Yandell to US 54.

This alternative offers strategic arterial benefits to several streets besides Montana Avenue. While this does improve network flow and connectivity, the required alignments may not be achievable and successful completion of all the upgrades is unlikely. Using the strategic arterial network also lessens the traffic burden on Montana Avenue and Edgemere Boulevard but does cause some overflow onto I-10.

LEVEL 1 RESULTS

In this section a comparison of the alternatives is presented. Many of the alternatives will be deemed infeasible and not carried forward to the second analysis level. Several alternatives and alternative combinations that demonstrate the potential for improving service and seem feasible are carried forward and undergo a level two analysis.

Alternatives one, two, and three demonstrate that there is limited demand for trips from east of Loop 375 to the downtown area. Traffic volumes on the three facilities is approximately the same, regardless of different west end termination. While these alternatives have little impact on the community they also offer little network improvement. They use only a small portion of their capacity making their cost unjustifiable. None of the first three alternatives are carried forward to the more in-depth level two analysis.

Alternatives four, five, and six attract substantially higher traffic volumes than the first three alternatives. These alternatives show that the majority of the demand for any additional capacity on the Montana Corridor originates west of Loop 375. Freeway volumes increase at each grade separation as the facilities are traversed from east to west. This pattern remains until Trowbridge were the volumes remain essentially constant for alternative four and decrease in alternatives five and six. At Piedras there is a drop in traffic volume for alternative four and an increase to local street traffic for alternatives five and six since both alternatives terminate in that area. All three of these facilities adequately use their capacity. A lack of facility usage does not eliminate any of these alternatives from further consideration. The decision as to whether or not to continue considering any of these alternatives is based on implementation feasibility, facility cost, and community impacts and desires. Some portion of these alternatives or slight variations of them are carried forward and discussed in chapter six.

In general all strategic arterial alternatives increase the attractiveness of the Montana corridor but not to the level of the freeway alternatives with intermediate access. Alternative seven with no grade separations provides the least additional capacity and quality of service improvements, then alternative nine with some grade separated intersections, and alternative eight with all grade separated intersections, respectively. Alternative seven is feasible but provides little improvement. It does not offer an adequate solution to the predicted demand increase and therefore does not warrant detailed level two analysis. Alternative eight provides a large increase in capacity and possibly attracts too much traffic to the Montana corridor. The feasibility of successful completion of all the necessary upgrades is low. Therefore this alternative is also not carried forward for further analysis. Alternative nine provides a notable increase in Montana corridor capacity and service quality. Alternative nine is feasible at this level of analysis and therefore a slight variation of it is carried forward to level two analysis.

Alternative ten, the strategic arterial network, is different from the other alternatives in that it provides improvements to streets besides Montana Avenue and the one-way pairs. While this does improve the overall network capacity and quality of service, the likelihood of successfully completing all or even most of the required changes is probably low. It is difficult to gauge the effects on Montana Avenue since the changes modeled may not occur. Therefore this alternative is not considered further in this study. Although when considering an overall long term improvement plan for all of El Paso, a strategic arterial network should be considered as it may be able to play an important role.

SUMMARY

The analysis indicates large 2015 Montana Corridor Demand and with improvements, demand increases. Considering all alternatives, the freeway options with intermediate access appear most effective in providing congestion relief while the freeway options with access only at the ends provide the least. The strategic arterial options provide an intermediate amount of relief, depending on strategic arterial quality. This does not necessarily imply that a freeway would be the best solution and, because freeway construction is extremely expensive, other alternatives such as the strategic arterial, may prove to be more cost effective.

CHAPTER 5 MONTANA AVENUE STRATEGIC ARTERIAL ELEMENT EVALUATION

Many of today's urban transportation networks cannot be significantly expanded. In numerous instances, adjacent property is completely developed and acquiring additional right-of-way is not practical. Improvement options are limited and the designer must seek new methods for increasing capacity. An engineer must learn to apply logical analysis methods to develop improvement plans that require little or no physical construction.

This chapter identifies two analytical techniques of the Montana Avenue Srategic Arterial Project. One set of upgrading techniques is called traffic management. The term traffic management is a process of developing traffic stream order and organization to move a greater number of vehicles through existing facilities. The second group of concepts involve corridor improvements through physical construction beyond extensive traffic management. Geometric improvements may be most effective in partially developed areas because new right-of-way is frequently necessary. The criteria described in this chapter for improving flow are intended to develop a traffic management solution to reduce delay and prepare a geometric improvements plan as necessary.

TRAFFIC MANAGEMENT EVALUATION

The first set of evaluation methods included traffic management techniques and analyzed the existing facility for minor improvement feasibility. The following sections introduce signal optimization, intersection improvements, and one-way pairs and outline procedures for evaluating each technique. All management techniques can be achieved without right-of-way acquisition, however, some intersection improvements may require additional right-of-way. Analytical conclusions are presented in this chapter.

Signal Optimization

For signal optimization, one concept is to provide arterial progression with signal coordination. Traffic volumes were developed using the TxDOT model for year 2015. Volumes were first analyzed using the TEXAS model to give a visual representation of intersection flow and delay identifying which intersections would require detailed analysis. HCM Software provided reliable Level of Service and v/c ratios. Minor intersection alterations improved conditions using trial and error optimization but forecasted volumes were too large to solve problems with minor adjustments.

The next step was to use PASSER II-90 to create signal coordination. PASSER II-90 used stopped delay criteria to optimize signals and summarize solutions with time-space diagrams and tables illustrating optimal signal timing for progression and delay. The program was allowed to determine signal timing parameters producing the least intersection delay. Then, by choosing a series of possible phasing patterns, the algorithm calculated intersection optimal cycle lengths and phasing patterns to provide the best progression with least delay.

The corridor was first optimized without changing any geometrics. This was obviously not the best solution and PASSER II-90 simply selected the best alternative but did not guarantee an acceptable level of service. Many calculated delays were very large but as v/c ratios exceed 1.2, the stopped delay grows exponentially, causing unreasonable results. Further optimization was performed manually by changing cross street phasing patterns (which are fixed for an alternative) and altering geometry. By changing the phasing pattern, dual through movements first or dual lefts first resulted in the least delay. (These two patterns, by the way, contain the same phases but in a different order so delay is the same.) Changing the intersection geometrics is another option and will be explained in the next section with other PASSER II-90 solutions.

One item worth discussing is the effect of each phasing option in PASSER II-90. There are four main phasing patterns, each having an overlap and no overlap condition. Overlap in a cycle indicates the left-turn is protected plus permitted whereas no overlap denotes a protected only phase. It is somewhat intuitive to note that no overlap creates longer delay because turning movements are not given enough green time. Each phasing pattern is a combination of common phases so the final selection should be based on specific intersection demands since large volumes regulate delay magnitude. Table 5.1 illustrates each phasing option with intersection delay comparisons. The optimal timing and vehicle delay data were developed for the intersection of Montana Avenue and Airway Boulevard in El Paso.

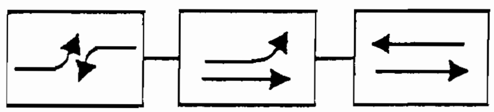
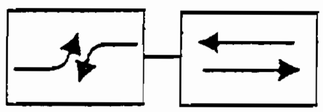
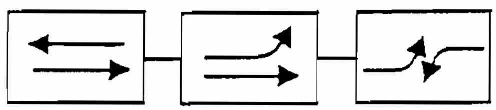
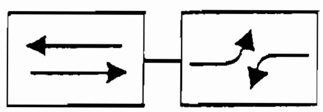
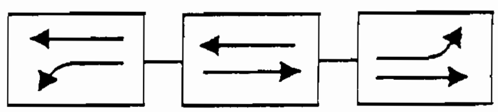
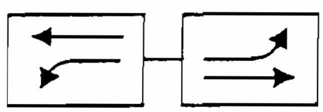
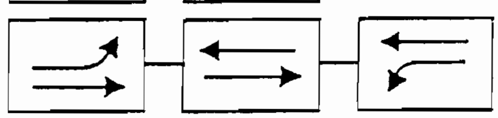
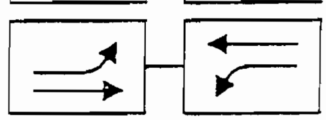
Intersection Improvements

Once signal timing is optimized using phasing patterns, movement delays can be further reduced by intersection improvements. Intersection modifications include lane additions to provide more capacity, redirecting particular movements to simplify phasing, and intersection channelization.

The process of adding an approach lane is relatively simple, with the only concern being whether additional right-of-way is needed or available. After identifying a candidate, the intersection is modeled to observe delay reduction. Reanalyzing with PASSER II-90 identifies corridor progression consistency, whereas HCM Software evaluates individual intersection performance. One major consideration is cross street dual left-turns. When a strategic arterial provides 70 percent available green time to arterial traffic, the cross street often may not get enough green to accommodate demand. As a result, the worst delay may be experienced by cross street left-turns because these movements lack available gaps in opposing traffic during the permitted left-turn phase. Appendix 1 of Chapter 9 in the Highway Capacity Manual states that a left-turn exceeding 300 vph can be considered for dual left-turn lanes, so many Montana Avenue cross streets are dual left-turn lane candidates.

It is important to check intersection limitations for additional lane capability. Intersection flaring may require additional right-of-way (approximately 12 feet wide by 100-200 feet long per lane). Using an existing median or making other approach lanes smaller may reduce additional right-of-way requirements. Either option would be relatively inexpensive and probably one of the most effective intersection delay reduction methods.

TABLE 5.1 EXAMPLES OF INTERSECTION DELAY FOR EACH PHASING OPTION

Phasing Pattern	Phasing Sequence	PASSER II-90 Optimal Timing (seconds)	Intersection Delay (sec/veh)
Dual lefts with overlap		11.3 2.1 67.7	316.83
Dual lefts without overlap		13.4 67.7	328.85
Throughs first with overlap		70.8 2.2 11.8	311.11
Throughs first without overlap		67.6 13.5	325.31
WB left leads with overlap		11.7 59.1 14.0	314.88
WB left leads without overlap		51.9 44.9	1982.66
EB left leads with overlap		12.1 47.9 10.4	334.75
EB left leads without overlap		46.8 54.1	1969.74

Determining the feasibility of increasing capacity through restriping lanes on Montana Avenue involved many techniques described earlier. Restriping can be accomplished by making lane widths narrower. However, additional lanes may require some right-of-way or it may be possible to eliminate existing parking, increasing usable pavement. For instance, if there are five 12 foot lanes in a cross section, the 60 feet may be converted to six 10 foot lanes. This adds another complete approach lane, however, capacities of lanes less than 12 feet wide are somewhat reduced. Table 5.2 shows a factor used in the 1985 Highway Capacity Manual to describe flow rate restrictions based on lane width.

TABLE 5.2 LANE WIDTH ADJUSTMENT FACTOR FOR SATURATION FLOW CALCULATION

Lane Width	Adjustment Factor
8	0.87
9	0.90
10	0.93
11	0.97
12	1.00
13	1.03
14	1.07
15	1.10

Chapter 9, 1985 Highway Capacity Manual

If 12 foot lanes have saturation flows of 1,800 vplph, then 10 foot lanes have flows of 1,674 vplph. Therefore, five 12 foot lanes have a saturation flow of 9,000 vplph while six 10 foot lanes will support 10,000 vplph. However, other factors must be considered for actual saturation flow evaluation. See Chapter 9 of the 1985 Highway Capacity Manual for appropriate procedures.

The final intersection improvement is free right-turns. This is best modeled using HCM Software because it simply involves removing, from the analysis, right-turn volumes. Ignoring these volumes assumes an acceleration lane is provided. Otherwise, as mentioned earlier, the free right-turn will not be effective. If an acceptable solution must provide a level of service "D" or better for every approach, then eliminating right-turns using free turn lanes may produce an acceptable level of service.

One-Way Pairs

The entire analysis to this point has dealt with a two-way cross section. There are two main one-way street issues that require considerable attention. The first is to identify the desired year 2015 facility type. The second issue is determining one-way pair alignment. This was a social impact issue more than a numerical analysis, however, many techniques described earlier can also be applied.

Identifying future facility development needs requires many of the same capacity and level of service techniques described earlier. The first action is to optimize and coordinate all signal timings. One problem at this stage is that one-way street candidates do not currently receive green time priority. High cross street volumes may make it difficult to use 70 percent green time on the one-way street. However, a large improvement in delay will result from converting a two-way street to a one-way street. The conflicting delay observed on a four-leg approach will decrease when the volume on one leg is eliminated. The phasing can also be simplified as exclusive left-turn demand is removed.

The results in Table 5.3 from PASSER II-90 show how delay differs for two-way and one-way streets. The reduction in main street delay results from arterial left-turns no longer requiring a protected phase or having to wait for gaps. Cross street traffic delay remains constant because no additional green time is required and phasing is simplified by eliminating an approach. However, an upgraded facility may attract additional traffic resulting in considerably higher intersection delay.

Once the general strategic arterial was designed, the team recommended possible alignments. Designing end connections, converting from existing facilities, and identifying neighborhood impacts are considerations that established alignment feasibility. The major focus of the analysis involved practical considerations rather than numerical techniques.

GEOMETRIC CONSTRUCTION EVALUATION

The Montana Avenue corridor has many critical midblock locations and congested intersections that influence overall travel time and delay. Extensive evaluation of intersection signal timing and geometric improvements indicate higher impact improvements are necessary to significantly improve traffic conditions. Midblock turning movements require further restriction to reduce traffic friction and numerous intersections continue to have poor levels of service following signal optimization. The next sections describe techniques to identify additional improvements to Montana Avenue and specify procedures for evaluating traffic flow changes resulting from geometric improvements.

Table 5.3 Two-Way and One-Way Intersection Delays for Year 2015 along West End of Montana Avenue

Cross Street	Yandell Avenue Two-Way (sec/veh)	Yandell Avenue One-Way * (sec/veh)
Piedras	51.47	12.41
Copia	18.64	13.80
Gateway	40.44	27.01
Raynolds	8.06	6.51
Chelsea	5.55	6.24
Trowbridge	16.59	10.08
Overall Average	28.0	15.6

* Assumes no increased traffic demand

Concrete Median Barrier

Throughout analysis of Montana Avenue, a center concrete median barrier along the two-way section of the corridor has been planned. There is currently uncontrolled access to businesses along Montana Avenue causing hazardous conditions and reducing midblock turning movements may improve traffic flow.

Considerable difficulty arose in accurately representing characteristics of indirect turns and restricted turning movements. As previously concluded, indirect turns and restricted access cannot be correctly portrayed without manual traffic assignment. Using assignment results for strategic arterial conditions, intersection turning movement volumes were recorded. Volumes originally assigned to a turning movement are manually reassigned to another movement. For instance, left-turn traffic can be diverted through the intersection, around a U-turn, and into opposing traffic as right-turns. Conversely, a jug handle is modeled by converting left-turns to right-turns and adding them to the adjacent through movement. Like free right-turns, jug handles eliminate right-turns from being considered in HCM analysis because the turns do not require signal control. At intersections requiring traffic reassignment, the redirection of left-turns was evaluated and volumes were reassigned to proper new routes. A conceptual example of manual assignment is shown in Figure 5.1.

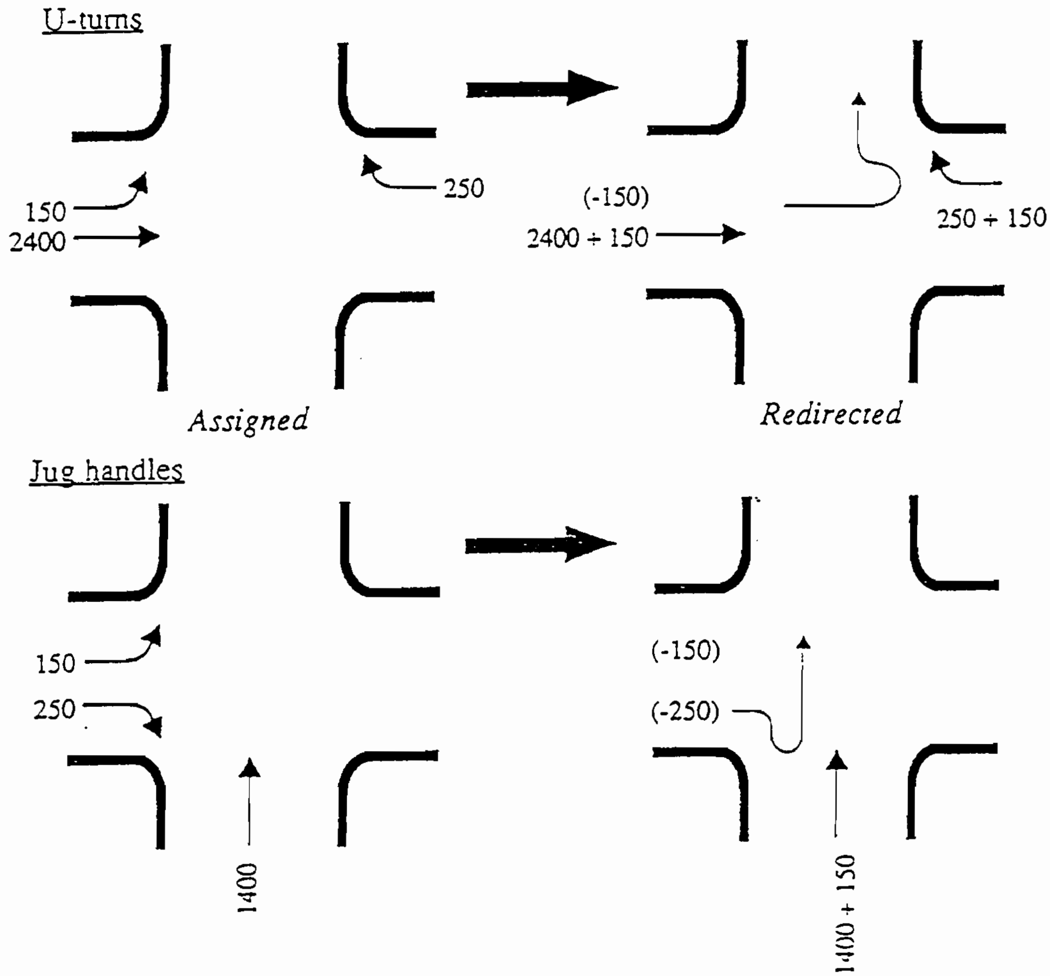


Figure 5.1 Manually Reassigned Volumes for U-turns and Jug Handles

The arrangement of a U-turn is simply a horizontal curve designed to meet AASHTO standards. A U-turn in the median designed as a 25 mph curve to satisfy a WB-50 design vehicle requires a median width of 70 feet including an extended vehicle acceleration lane. The eastern quarter of the Montana Avenue Corridor has a 75 foot median so for a U-turn this is adequate . A right exit can be used to accommodate indirect left-turns when the median area is a constraining factor. Providing a diverging right lane connected to the cross street away from the intersection for storage or to direct vehicles behind the cross street queue for additional storage on the approach will remove left-turns from main stream traffic. The angle of divergence can be estimated by using average queue lengths on the cross street computed by the TEXAS model. Another method is to provide a free right-turn and a turnaround on the cross street or a loop (or cloverleaf) to the far side of the intersection. Most of these options certainly require some right-of-way and the ease of obtaining land will probably determine feasibility.

Another set of volumes requiring redirection is midblock left-turns. The TxDOT model has centroid connectors which link specific areas represented by centroids, to the network. Access to a link is generalized by a centroid connector bisecting a roadway link. Volumes on these connectors are productions and attractions generated by an area. The TxDOT assignment model cannot analyze movement specific traffic characteristics so restricting left-turns and redirecting traffic cannot be modeled.

Midblock traffic movements were reassigned on alternate network routes. It was important to minimize additional delay, so aerial photographs were helpful in identifying logical network alternates because existing streets could be used for indirect turns. Manual traffic assignment on possible routes presented new intersection volumes for concrete median barrier evaluation.

Once all traffic had been reassigned, intersection level of service analyses could be performed comparing before and after scenarios. All intersection analysis packages were used including HCM Software, PASSER II-90, and TEXAS Model. Through traffic levels of service improved because green time previously allocated to protected left-turns was added to through movements. Traffic rerouted through a U-turn did not degrade opposing right-turn levels of service because a free right-turn does not require signal control. On the other hand, jug handles did not improve cross street conditions.

Grade Separated Interchanges

Identifying possible grade separation locations is important for providing significant corridor improvements. Essentially all feasible signalized intersection improvements should first be completed before grade seprations are considered. Grade separated interchanges can be considered as a final element creating a mature strategic arterial street.

Traffic Analysis. Previous analysis identified all intersection traffic conditions following implementation of signal coordination and left-turn restrictions. Using analytical results from turn restrictions, many congested intersections continued to experience significant movement delay. PASSER II-90 showed many v/c ratios remained above 1.2 and average intersection delay along the corridor was nearly three minutes. Critical intersections having delays exceeding five minutes became grade separated interchange candidates.

To evaluate grade separation implementation within a corridor, PASSER II-90 is recommended. It is the easiest method for determining the impact on adjacent intersections since a major concern is that congested traffic is removed from the grade separated intersection and distributed to adjacent intersections. PASSER II-90 provides individual intersection conditions for comparison of grade separation candidates and it is interesting to note that some grade separated interchanges did result in longer delays for adjacent at-grade intersections. Results in Tables 5.4 and 5.5 compare, for numerous scenarios, intersection delays and optimal signal timings at Montana Avenue intersections.

Table 5.4 Intersection Delay for Alternative Scenarios (sec/veh)

Cross Streets	Existing Conditions	No Build	No Grade Separations	Four Lane Strategic Arterial No Grade Sep.	Airway Grade Separation	Hawkins Grade Separation	McRae Grade Separation	Yarbrough Grade Separation
Magruder	-------	223.50	108.24	47.01	104.80	90.47	108.64	119.52
Geronimo	-------	167.99	134.27	44.95	115.95	105.95	109.88	101.28
Airport	-------	-------	26.61	13.94	24.48	26.71	26.61	26.07
Sioux	44.00	72.37	57.07	27.94	48.59	47.32	53.19	51.12
Robert E Lee	8.72	13129.38	17.34	10.88	16.66	16.24	17.30	17.41
Airway	45.51	522.55	142.96	133.08	-------	129.15	142.96	143.00
Hawkins	425.78	259.16	99.44	53.30	93.58	-------	99.44	99.44
McRae	26.90	1702.76	84.59	28.48	44.63	49.28	-------	46.79
Wedgewood	10.43	8422.09	15.56	33.45	25.99	19.44	22.62	24.43
Yarbrough	18.88	1579.86	96.06	39.06	77.06	95.71	96.06	-------
Lee Trevino	22.31	317.49	26.14	25.05	27.87	27.87	26.14	24.16
George Dieter	13.86	1109.79	18.92	13.66	20.89	18.41	18.92	18.92

Note: Montana through traffic is not interrupted where grade separations are provided so no delay is predicted. This condition is signified by ------. Magruder, Geronimo, and Airport intersections are not included in existing condition analyses.

Table 5.4 Intersection Delay for Alternative Scenarios (cont.)

Cross Streets	Lee Trevino Grade Separation	Airway and Hawkins Grade Separation	Airway and Yarbrough Grade Separation	Airway, Hawkins, and Yarbrough Grade Separations	Airway, Hawkins, and Robert E. Lee Grade Separations	Airway, Robert E. Lee, and Yarbrough Grade Separations
Magruder	108.16	110.61	106.24	110.61	110.47	110.47
Geronimo	109.85	100.88	99.73	100.88	100.99	100.99
Airport	26.92	24.27	25.93	24.27	24.03	24.03
Sioux	56.35	42.61	52.86	42.61	45.02	45.02
Robert E Lee	17.68	16.79	16.31	16.79	-------	-------
Airway	143.01	-------	-------	-------	-------	-------
Hawkins	99.44	-------	86.11	-------	-------	86.12
McRae	39.42	111.24	44.63	20.89	111.24	44.63
Wedgewood	16.76	30.77	26.39	44.63	30.77	28.16
Yarbrough	96.05	224.63	-------	-------	224.63	-------
Lee Trevino	-------	106.49	28.47	28.23	106.49	28.47
George Dieter	18.92	19.84	20.89	28.47	19.84	20.89

Table 5.5 PASSER II Summary for 2015 Traffic

Scenario	Average Delay (sec/veh)	Average Speed (mph)	Bandwidth (seconds) (WB/EB)	Cycle Length (seconds)
1. Existing Montana Avenue	90.4	43	23/12	110
2. Strategic Arterial, no build	2264.8	43	29/29	135
3. Strategic Arterial w/ barrier and no grade separations	75.1	46	35/35	110
4. Strategic Arterial w/ barrier, free right turns, and four through lanes	43.7	46	28/29	110
5. Strategic Arterial w/ barrier and grade separations at:				
a. Airway	59.0	45	48/48	130
b. Hawkins (w)*	74.7	43	43/43	115
(e)**	45.0	46	44/45	105
c. McRae	71.9	46	35/35	110
d. Yarbrough	67.5	45	42/42	110
e. Lee Trevino	72.2	46	38/38	110
f. Airway and Hawk. (w)	63.9	43	53/51	130
(e)	109.1	44	70/60	135
g. Airway and Yarbrough	55.0	45	48/48	130
h. Air., Hawk., & REL (w)	74.7	43	52/52	130
(e)	109.1	44	70/60	135
i. Air, Hawk, & Yarb (w)	63.9	43	53/51	130
(e)	31.5	44	54/56	130
j. Airway, Yarb., & REL (w)	74.7	43	52/52	130
(e)	44.6	44	51/53	130

* corridor west of grade separation

** corridor east of grade separation

REL = Robert E. Lee

Grade separations may be modeled with the TxDOT assignment model. The only requirement is that links and nodes be added to the network to represent all ramps and possible interchange movements. This includes through traffic on the main street, one-way on and off ramps, and cross street overpasses. Although this model will provide usable forecasted volumes, other methods are strongly suggested since the TxDOT assignment model is an excellent network level analysis tool that is not intended for such detailed study.

An easier approach to evaluating grade separated intersections is to use an intersection analysis package. The interchange can be split into two signalized intersections and HCM Software or TEXAS Model can be used. Using HCM Software for grade separations is as straight forward as standard three approach intersections. Furthermore, an interchange may be condensed into a single point intersection, which reduces to a standard analysis.

The TEXAS Model, on the other hand, has the capability to analyze the pair of grade separated intersections which compose what is a conventional freeway type diamond interchange. Since it is desirable to coordinate the two signals, the TEXAS Model has predetermined interconnected phasing patterns which minimize delay. The user can input desired timings for a specific application or use default values. The default cycle length is 200 seconds with four phasing pattern options. For the Montana Avenue project, most Montana traffic was assumed to pass through the intersection using the depressed or elevated main lanes. A fraction of the through traffic was diverted through the at-grade diamond interchange. The analytical results are the same as standard signalized intersections and include movement delay and average speed.

Geometric Analysis. Once an intersection is identified as a grade separation candidate, the geometrical aspects must be evaluated and should include desired lane geometry. A typical strategic arterial grade separation may have three through lanes in each direction and two lane ramps. At the intersection, it is desirable to provide four ramp lanes and similar or existing cross street geometry. Typically, a strategic arterial grade separation has a condensed design compared to a freeway grade separation. With shoulders added and clearance to the right-of-way line, desirable right-of-way starts at 165 feet and flares to 190 feet at the intersection (freeways require at least 250 feet of right-of-way). Dense intersection development may limit the extent of grade separation development or shift arterial alignment to achieve right-of-way needs. Many variations of the desirable grade separation design are possible with examples shown in Figures 5.2 - 5.4.

Another important aspect of design is choosing an overpass or underpass. It is desirable to construct a mainline overpass to minimize construction impact and improve driver comfort but right-of-way constraints may prove otherwise. To determine transition length, AASHTO recommends maximum grades for incline and decline of six to seven percent and required vertical

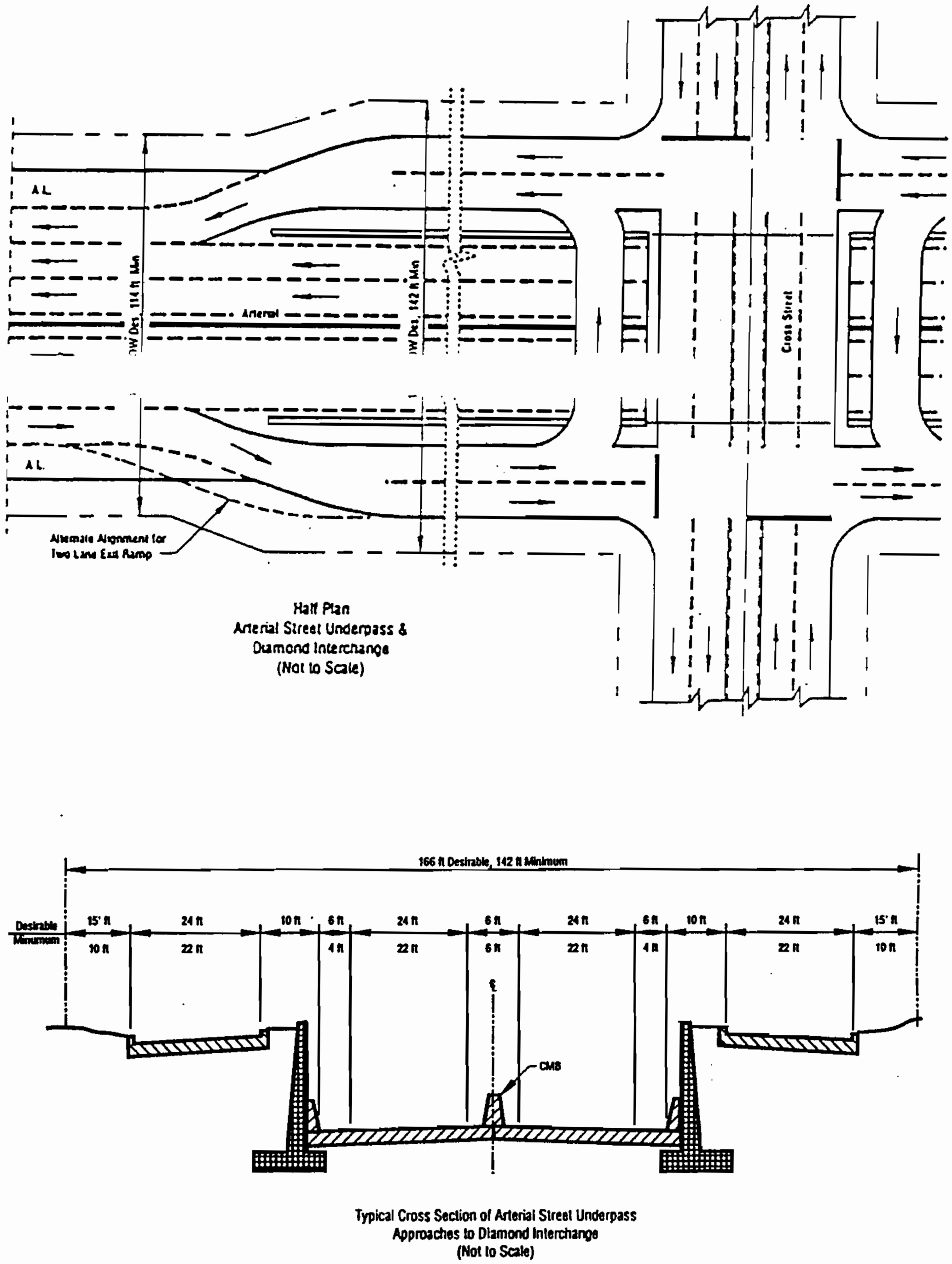


Figure 5.2 Half Plan and Cross Section for Strategic Arterial Grade Separation Overpass or Underpass
Obtained from Reference 7

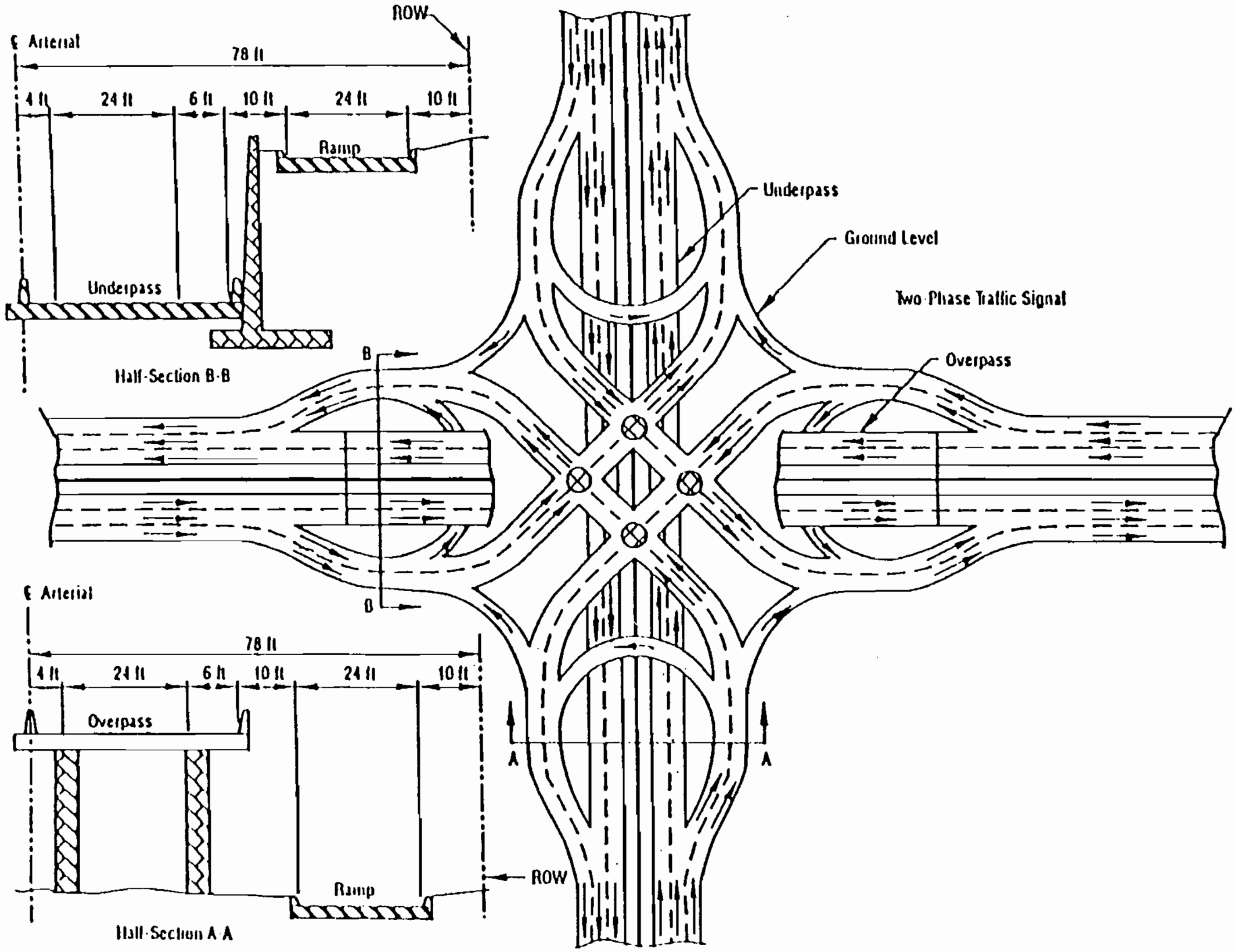


Figure 5.3 Three-Level One Point Interchange
(Not to scale)
Obtained from Reference 7

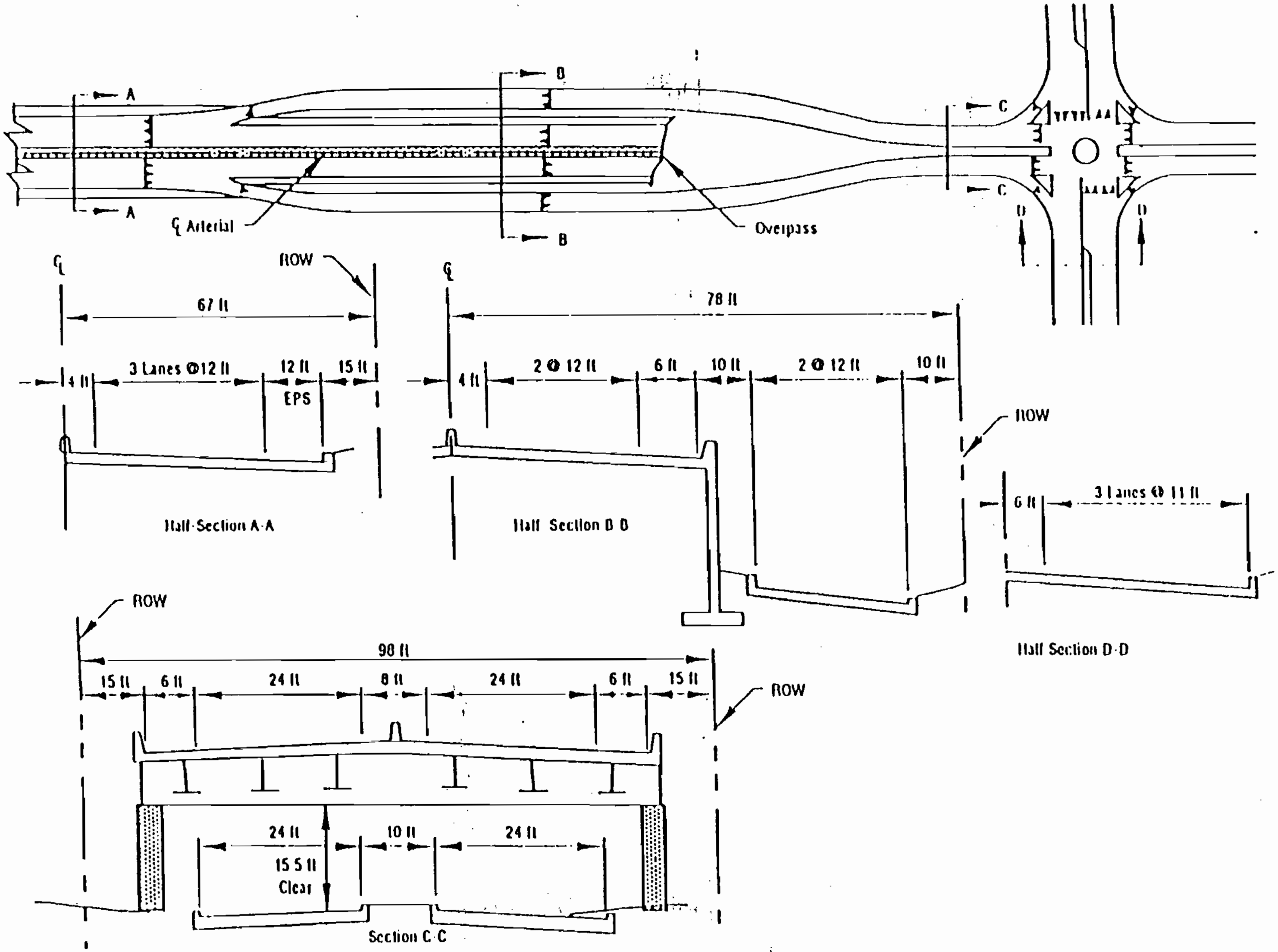


Figure 5.4 Special Diamond Interchange with Minimum Intersection Right-of-Way (Not to scale)
Obtained from Reference 7

clearance is 16.5 feet plus five feet for bridge structure depth. The five feet structure depth is most likely a conservative estimate since recent technology allows thinner structures. With a strategic arterial design speed of 45 mph, minimum desirable length of the entire grade separated structure is 1,500 feet. This may present difficulties in retrofitting a grade separated structure in a fully developed area. In that case, a more cost effective approach may be to keep the main street at grade and depress the cross street. Using the same clearance specifications and design speed of 35 mph, the transition length is reduced to 900 feet along the cross street (Ref. 1, p. 285-292). It is also possible to design a compromise. Complete transition restrictions on both streets may allow for one street to be partially elevated and the other street partially depressed. Grade separated structures may be achieved in this manner without costs greater than a standard overpass.

SUMMARY

As traffic demand increases on metropolitan freeways, it is imperative to develop alternative routes to divert freeway traffic and relieve congestion. Traffic management techniques can be very useful in attempting to improve arterial flow. As demonstrated in this chapter, simple techniques can provide cost effective traffic flow improvements. Identifying the proper technique is dependent on needs and expansion restrictions. Regardless of which technique is chosen, the improvements discussed in this chapter are the best management techniques for providing traffic congestion relief.

Geometric construction techniques must be considered when previous attempts to improve traffic conditions with minimal cost alternatives have failed. Since many traffic management techniques are often temporary solutions, geometric construction provides permanent improvements and long term solutions. This chapter revealed feasible solutions and showed the impact these improvements have on traffic flow. Concrete median barriers and grade separated structures are classic strategic arterial elements that may significantly improve the quality of service on a strategic arterial.

CHAPTER 6 LEVEL 2 ANALYSIS

In Chapter Four a number of broad-based improvement alternatives were evaluated under what is termed level one analysis. The purpose of level one analysis was to study a wide range of possible upgrades without limiting consideration to any predetermined improvement solutions. Evaluation of level one alternatives resulted in selection of alternatives for evaluation at a detailed level as feasible Montana Avenue upgrades. In this chapter a description and evaluation of these alternatives is presented. In addition to general analysis on the basis of travel time improvements, the alternatives are discussed in terms of implementation costs and social and economic impacts.

DESCRIPTION OF LEVEL TWO ALTERNATIVES

Variations of five of the ten level one alternatives (including the no-build option) have been carried forward to the detailed analysis phase. Below is a brief summary of alternative descriptions with basic positive and negative factors. Appendix C provides maps and tables with v/c ratios, speeds, capacities, and volumes on various links for level two alternatives.

No Build Alternative

The do-nothing alternative in addition to serving as the base case on which all other improvements are modeled, also provides a basis for comparing alternatives. It can be used to study the travel demand in case no mobility improvements are provided. This alternative uses the year 2015 El Paso network with only those improvements on Montana which are currently projected by TxDOT. At the western end, from Mesa east to west of Brown, Montana is coded as a two-way four-lane undivided primary arterial. From this point Montana changes to a two-way two-lane primary arterial and continues east to just west of Piedras where again it becomes a four-lane facility extending to Paisano. From Paisano eastwards to Loop 375 Montana is coded as a six-ane divided primary arterial.

Recall, this is a no cost alternative used purely for a base comparison. Forecasted future demand increases are not accommodated in this alternative, so user costs increase.

Freeway Alternatives

Alternative 1: Freeway with Direct I-10 Connection at Piedras. This six lane freeway is modeled as an elevated or depressed facility from Loop 375 to Piedras with five intermediate diamond interchange connections. This alternative is essentially the same as alternative four in the level one analysis. The only major change is that I-10 connection is moved from the vicinity of Cotton street to Piedras. This move was a TxDOT recommendation. There exist several difficulties with freeway connection to I-10 at Cotton street and the feasibility of the alternative is improved by moving the connection to Piedras.

Providing a direct freeway connection to I-10 will benefit the network with an alternate freeway route and I-10 traffic relief between Paisano and Piedras. In addition, overall network connectivity will be enhanced by offering reduced travel times on alternate freeway routes.

A disadvantage to a direct freeway is the obvious high construction cost for elevated or depressed freeways. There are large sections of developed right-of-way needed which will make this alternative very costly. Another disadvantage is traffic overflow potential on I-10 west of Piedras, due to two freeway sections merging at a single location.

Alternative 2: Freeway to Piedras Connecting to a One-Way Pair. This six lane facility also has five or six diamond interchange locations along an elevated or depressed freeway from Loop 375 to Piedras. It is also possible for either this alternative or alternative 1 to be built at ground level but this will greatly increase right-of-way requirements. The west end termination is a transition to a one-way pair with desirable strategic arterial characteristics along Montana/Yandell. It is also possible in this alternative to use Yandell/Wyoming west of Piedras as the one-way pair. Access to Piedras would be through ramps while main lanes pass over the arterial. This alternative is a combination of alternatives five and six in the level one analysis. The main differences being the through lanes of the freeway extend beyond Piedras Street and the possibility of using Yandell/Wyoming as the one-way pair instead of Montana/Yandell.

The main benefit of this alternative is the potential for greater I-10 traffic relief since the alternate route provides comparable travel times for a longer length. Furthermore, connectivity to the central business district is enhanced with direct improved service from the east.

This alternative suffers in that it does not provide a direct freeway-to-freeway connection. This forces drivers to find an appropriate route back to I-10 if Montana Avenue is used as an alternate route. The one-way pair may also experience high congestion levels due to the Montana freeway distributing onto an arterial street.

Strategic Arterial Alternatives

Alternative 3: Strategic Arterial with Montana/Yandell One-Way Pair. The strategic arterial is a six lane divided facility from Loop 375 to Paisano. A transition at Paisano leads to a one-way pair to Mesa along existing Montana and Yandell arterials. The west end connection to I-10 is an existing westbound Yandell entrance ramp for Montana Avenue traffic, and a required eastbound overpass constructed for Yandell access. This alternative is a carry forward of alternative nine in the level 1 analyses, a strategic arterial street alternative with grade separated interchanges at congested intersections.

Improving Montana Avenue to strategic arterial level will be much less costly and right-of-way intensive than either freeway alternative but will provide smaller increases in capacity and lower travel speeds. Community disturbance will also be less than that of a freeway. A disadvantage is that in developed areas it may be difficult to achieve the required level of access control.

Overall cost can be minimized by using Montana/Yandell as the one-way streets since no right-of-way is necessary for transition as is required in Alternative 4. However, traffic flow will be unconventional flow (opposing traffic is to the right) possibly causing frustrated and disoriented drivers.

Alternative 4: Strategic Arterial with Wyoming/Yandell One-Way Pair. This alternative is very similar to the previous strategic arterial street. An alignment transition occurs at Piedras so the one-way pair includes Wyoming (Eastbound) and Yandell (Westbound). For network continuity the west end I-10 connections with the westbound existing and proposed ramps are also necessary.

An alternative evaluation of benefits focused on the one-way section. The clearest advantage over Alternative 3 is the one-way alignment west of Piedras. Alternative 4 offers a more natural traffic flow condition.

In both strategic arterial alternatives, levels of service, dictated by v/c ratios, improved throughout the corridor. At most locations, the assigned volume still increased with reduced v/c ratio. Furthermore, traffic volumes on all parallel routes decreased, indicating that traffic was diverted to the improved strategic arterial facility. Both alternatives have the characteristics and the benefits and disbenefits of strategic arterials as previously discussed.

Travel Times for Selected Paths

Travel times for selected corridor paths have been computed and are presented in Table 6.1 and Figure 6.1. These data provide an additional criterion for comparing alternatives. One must remember that all travel times are based on the level two network. Travel times for level one alternatives and this network will be different than previously noted due to link length changes. Therefore, direct travel time comparisons between level one and two analyses cannot be made.

Interesting results in Table 6.1 reveal that all alternatives provide shorter travel times than the no build situation. It is intuitive to note again that, based on relative travel times, freeways always provide shorter travel times than strategic arterials. However, the I-10 and Montwood/Viscount parallel routes offer nearly identical travel times when paralleled by freeways and strategic arterial streets. Also notice that travel times significantly improved along Edgemere, which is parallel to the east end of Montana Avenue, even though no improvements were ever made to Edgemere. This is an indication of traffic diversion from residential streets.

Comparison of similar alternatives resulted in some intriguing discoveries. The two strategic arterial street alternatives were used as a comparison of one-way street alignment options. For every selected path throughout the network, the travel times were nearly identical. This clearly indicates that alignment is not dependent on minimum travel times but will depend on other factors

Table 6.1 Travel Time for Selected Paths

Alternative	#	Montana Avenue from Loop 375 to Airport	Montana Avenue from Paisano to Mesa	I-10 from Paisano to Mesa	Montwood/Viscount from Loop 375 to Geronimo	Edgemere/Cosmos from Loop 375 to Geronimo
No Build (Travel Time, minutes) (Percent decrease)		20.26	16.33	10.25	31.97	32.24
Montana Freeway with direct connections to I-10 at Piedras	1	13.41 34%	9.98 39%	8.87 13%	24.17 24%	23.09 28%
Montana Freeway connecting to a Montana/Yandell one-way pair	2	13.41 34%	9.28 43%	8.5 17%	24.22 24%	23.08 28%
Superstreet with one-way pair being Montana/Yandell	3	17.06 16%	10.54 35%	8.73 15%	25.83 19%	27.88 14%
Superstreet with one-way pair being Wyoming/Yandell	4	17.08 16%	11.07* 32%	8.73 15%	25.55 20%	27.34 15%

* Travel time based on Wyoming Avenue

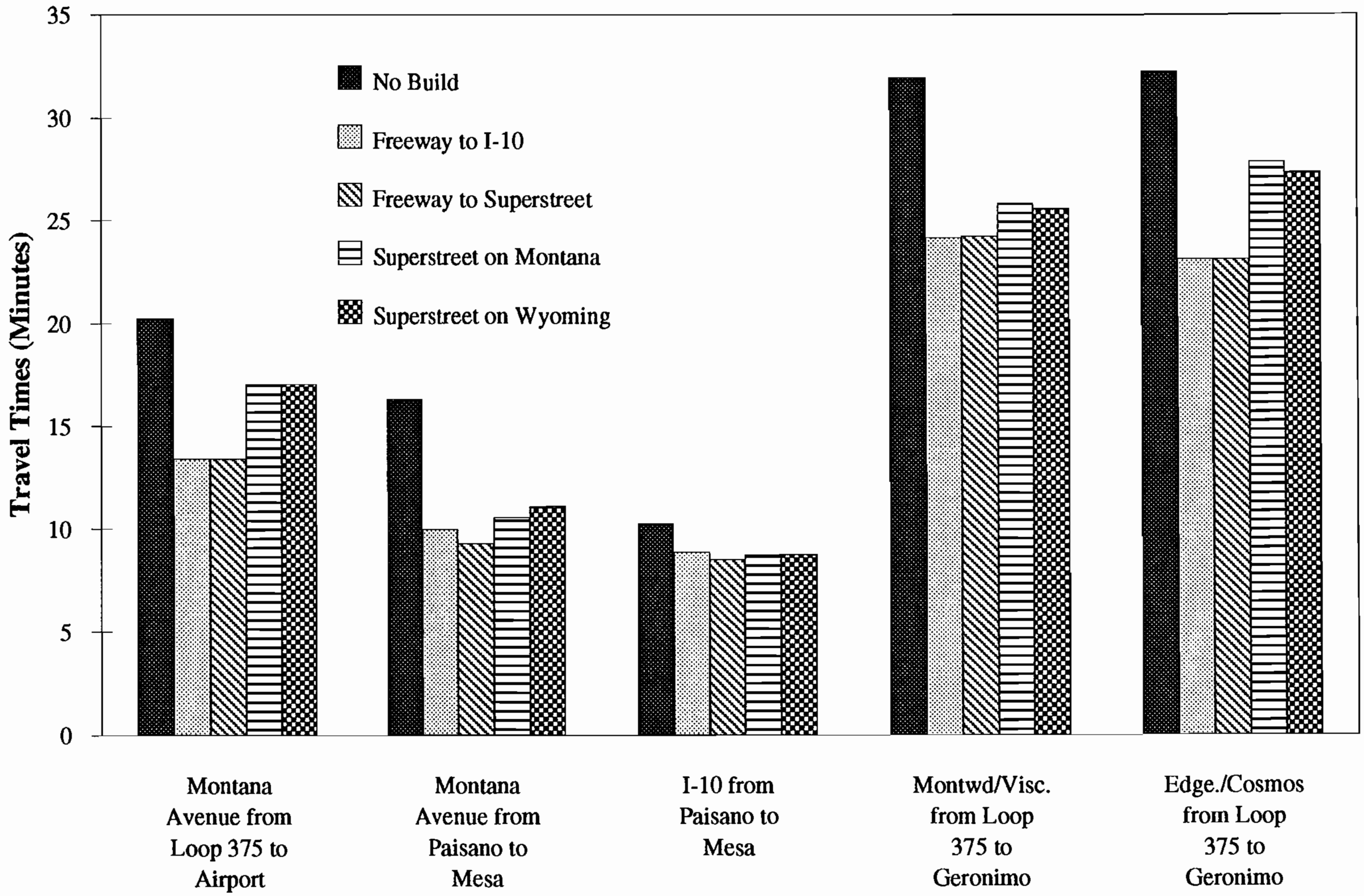


Figure 6.1 Travel Times for Selected Paths

such as right-of-way limitations. Comparison of freeway alternatives similarly indicates that travel times are also nearly identical. Therefore, the west end connection does not control travel times. This may be an important conclusion since I-10 access is by completely different means. The decision becomes an issue of cost invested in a strategic arterial or freeway since travel becomes mostly an intuitive evaluation. The two strategic arterial alternatives produce nearly identical travel time savings. Likewise, the two freeway alternatives are virtually identical. Although the freeways provide greater travel time savings than the strategic arterials, the magnitude of the differences are small. The decision as to which strategic arterial alternatives is best or which freeway alternative is best is not based on performance but on implementation feasibility, community impacts, and costs.

Implementation Costs

For cost analysis the level two alternatives may be split into two groups. These are freeway alternatives and strategic arterial alternatives. At this level of analysis it is difficult to determine cost differences within a group since their are no engineering design plans. To precisely predict the construction and right-of-way costs of the various alternatives it would be necessary to prepare preliminary engineering design plans outlining exact right-of-way needs and construction. This section is meant to be a relative comparison between alternatives and not an estimation of total right-of-way or construction costs.

Two major implementation costs of any of the options are right-of-way and construction costs. Of course, there are other costs including items such as engineering planning and natural variation in costs between different areas. These other items will be relatively small compared to total project costs and will not vary much between different alternatives. Therefore the main comparisons between alternatives fall in the right-of-way and construction areas.

Of the two cost areas, construction costs are the more straight forward . In general, the cost of a mile of freeway will be approximately 4 to 6 times that of a mile of strategic arterial. Although this estimate must be taken cautiously since it may vary widely due to many unknown factors. One such factor is the amount of existing roadway that is salvageable when implementing the strategic arterial. As the lane miles requiring reconstruction increase and those requiring rehabilitation decrease the cost differences between the freeway and strategic arterial lessens. The number of grade separations is also critical. The strategic arterial alternatives have relatively few grade separations compared to the freeway alternatives. This can make a difference of millions of dollars per additional grade separation. As the difference in the number of grade separations grows or shrinks between the freeway and strategic arterial alternatives there is a corresponding substantial difference in cost between alternatives. A final point that can be made concerns freeway frontage roads. With the addition of frontage roads, the cost of the freeway substantially increases. Frontage roads can potentially make the freeway cost a multiple of ten or more times that of a strategic arterial.

The second cost item affecting the comparison between freeway options and strategic arterial options is right-of-way. At this stage right-of-way requirements are not known in detail for any of the alternatives. However, the freeway requirements are substantially more than strategic arterials. The difference in right-of-way cost ratio between the facilities could vary anywhere from four to twenty, possibly more. The west end of the Montana corridor also has historic buildings which could substantially increase freeway right-of-way cost. While some historic properties may be affected by potential strategic arterial upgrades, this can for the most part, be avoidable. The strategic arterial has the advantage of being able to avoid acquiring some expensive properties. By using designs such as jug handles, U-turns, and side street redirection, it is possible to do some pick and choose among various properties. If the corridor is thoroughly studied for differences in potential property acquisition costs this aspect of a strategic arterial can lower the overall cost. The freeway options do not tend to have the same leeway. The installation of a freeway unavoidably forces the purchasing of many properties. This problem is only exacerbated by frontage roads. Of course frontage roads also greatly increase the amount of right-of-way required.

While it is not possible, within the scope of the study, to give exact dollar values to the alternatives, comparisons are possible. From the above discussion, conservative estimate has the freeway costing five times that of the strategic arterial. The possibility of the disparity between the two options being much greater should be considered.

Social and Economic Impacts

The comparison of the alternative social and economic impacts is performed between the strategic arterial alternatives and the freeway alternatives. In addition a comparison of the strategic arterial alternatives to each other and a comparison of the two freeway alternatives to each other is presented.

In general, the strategic arterial alternatives will be much less intrusive than the freeway alternatives. The amount of required right-of-way and construction is much less for the strategic arterial alternatives. The impact on the local community will be much less if a strategic arterial is implemented as opposed to a freeway. Strategic arterials offer the advantage of having design leeway and the ability to avoid potentially costly and sensitive properties. The strategic arterial alternatives will probably be more desirable to the local community than the freeway alternatives.

On the central and western portions of Montana Avenue, implementation of the strategic arterial would have little effect on the current land use characteristics. This is due to the development maturity along the arterial and the strategic arterial adaptability. Although implementing a strategic arterial on the eastern portion of the arterial will probably encourage commercial instead of residential development. This is due to the currently undeveloped nature of the land. The freeways by comparison will affect land use characteristics along the entire arterial. The large volume increase will probably drive land use towards high density commercial development. Existing residential developments adjacent to the freeway will be adversely affected by increased traffic volumes and noise levels. Also the construction of a freeway will be much more disruptive than that of a strategic arterial.

Short term commercial business losses have been experienced where strategic arterial concepts had been implemented. But within a couple of years, many businesses had reported increases over pre strategic arterial levels (Ref. 4). Freeways also tend to improve business activity adjacent to the frontage roads. In most cases freeways will provide more potential business than a strategic arterial. Of course there will be some individual business that will be adversely affected by a freeway. However, there should not be many existing businesses adversely affected in the long term by the strategic arterial since there will be little change in land use characteristics. Exceptions to this may occur, especially near grade separations.

The second possible comparison is a comparison between the two freeway alternatives and a comparison between the two strategic arterial alternatives. In general this is simply a matter of deciding where the improvements are implemented. That is, the two strategic arterial alternatives will have essentially the same impacts except, alternative 3 will affect Montana and Yandell while Alternative 4 will affect Yandell and Wyoming. The freeway alternatives also have basically the same impacts until Piedras Street. At this point alternative two terminates into the one way pair increasing local traffic. This will probably be viewed negatively by the local residential communities but positively by local commercial properties. Alternative one with the direct connection to I-10 will continue to affect the corridor in the manner of general freeway alternatives as discussed before.

SUMMARY

In this chapter a detailed evaluation of feasible improvements for Montana Avenue was presented. In general, as far as improvements in travel times are considered, the freeway alternatives provide the best travel times. However, in terms of total costs the strategic arterial alternatives provide less expensive solutions while improving mobility. Also community impacts are much less in case of strategic arterials as they complement existing land use patterns. Selection of a particular improvement alternative must be based on consideration of all factors discussed in this chapter.

CHAPTER 7 RECOMMENDATIONS AND CONCLUSIONS

This chapter is a summary of recommendations based on previously discussed procedures. A detailed description of the Strategic Arterial upgrade with geometric improvements and traffic management techniques is provided. Also discussed is the feasibility of further improvements after strategic arterial implementation. All figures referenced in this chapter are collected in Appendix D. Note that the drawings are not to scale.

RECOMMENDATIONS

Strategic arterial cross section

Specifications for design have been obtained from previous strategic arterial research projects and expert recommendations. Minimum design conditions suggest 115 feet right-of-way width. Minimum cross sections include three 11 foot lanes in each direction, a six foot median, ten foot shoulders/auxiliary lanes, and ten foot clearance to the ROW line. At some intersections, flaring can provide right-turn lanes reducing traffic stream friction. Desirable cross sections consist of three 12 foot lanes in each direction (although 11 foot lanes are acceptable), one 12 foot auxiliary lane in each direction, an eight foot median, and fifteen feet clearance for 135 feet total right-of-way width. Auxiliary lanes may be used for additional through lanes during peak periods or when warranted. Figure D1 illustrates minimum and desirable strategic arterial cross sections.

Due to existing pavement widths, the strategic arterial one-way pair section has been designed for desirable conditions only. The recommended one-way street design is three 12 foot through lanes and one 11 foot auxiliary lane on each side for a 58 foot pavement width. Auxiliary lanes may be used for turning movements, additional lanes during peak periods, reserved for transitways, or to accommodate parking requirements. It is also permissible to have four 11 foot lanes if parking is necessary.

Indirect Left-Turns

All left-turns on and off Montana Avenue have been eliminated and replaced with indirect turns. One such design is a median U-turn. Examples can be seen in Figures D8 and D11 on the eastern end of the corridor and Figure D2 at the intersection of Montana Avenue and Paisano. AASHTO standards suggest a minimum outer radius of 71 feet for the WB-50 design vehicle; the grass median on the east end is adequate for U-turns.

Jug handle indirect left-turns exit from the right lane and either terminate into the cross street or curve to intersect the major street. For the cross street, the jug handle intersecting point is approximated using average queue lengths given by TEXAS model. Jug handle length is estimated using a suggested deceleration distance. Ideally, jug handle alignment has a reverse curve to intersect the cross street at a right angle, however, it may be dependent on existing buildings and available right-of-way. Figure D7 shows a jug handle alignment at Hawkins behind commercial buildings.

A final option for indirect turns is a reverse loop, best described as an at-grade cloverleaf. This alternative is used with restrictive right-of-way in adjacent intersection quadrants. Densely developed intersection property is common and parcel acquisition may be difficult. Using AASHTO design recommendations, a 25 mph loop must have an inside radius of 150 feet so reverse loops are not a common Montana Avenue design. Figure D10 shows an example of a reverse loop at Yarbrough.

Right-Turn Lanes

Portions of the cross section design include right-turn provisions. Many Montana Avenue intersections do not currently have right-turn lanes. To reduce vehicle friction between decelerating right-turns and through traffic, it is necessary to construct right-turn lanes and, in some cases, free right-turn movements with acceleration lanes. Figure D6 contains examples of an added westbound right-turn lane and northbound free right-turn at Airway Boulevard.

Cross street geometry

At most cross street approaches, improved geometry is necessary to accommodate future demands. PASSER II-90 and Highway Capacity Manual Software evaluation following upgraded geometry indicate many intersections still do not provide satisfactory conditions. Since the attempt was to minimize construction and right-of-way acquisition as well, service levels are sacrificed. Community acceptance will regulate the extent of construction. Figure D7 shows Hawkins with improved cross street geometry .

Grade Separations

Future intersection traffic demands at numerous oversaturated intersections require grade separation consideration. Locations identified based on PASSER II-90 analysis indicate Airway and Yarbrough have current and forecasted overall levels of service F for all movements so grade separations are recommended. General grade separation cross sections require 170 feet minimum right-of-way at the intersection including six 11 foot main lanes and four 11 foot off ramp lanes. The cross street intersection has a single point signal. Strategic arterial grade separations have a compressed design, as opposed to the wide freeway grade separated cross section, since obtaining right-of-way is usually difficult. Minimum and desirable strategic arterial grade separations can be seen in Figure D27.

Vertical clearance transition is a limiting factor along Montana Avenue. AASHTO standards for grade separations suggest a 16.5 foot vertical clearance and six to seven percent maximum grade. Using an assumed design speed of 50 mph, lengths are on the order of 1800 feet. Right of way requirements are reduced if grade separated structures are built for the cross street which has lower design speeds.

An area of grade separation concern is the vicinity of Airway and Robert E. Lee. Since grade separations require large horizontal distances for elevation transition, as well as a railroad crossing at Robert E. Lee, it may be necessary to elevate or depress the roadway from east of Airway to west of Sioux, possibly further.

Another grade separated structure site is at Montana Avenue and Airport/Mescalero in Figures D3 and D4. Eastbound Montana Avenue traffic turning left onto Airport is significant, causing long westbound approach delays. Therefore, the recommendation to construct an underpass below Montana Avenue would relieve turning conflicts and minimize environmental impact. An overpass, on the other hand, would have greater property impact. This route may become an attractive airport route rather than Airway Boulevard, thereby reducing congestion at Montana/Airway. Conservative grade separation design standards were taken from AASHTO.

One other major location requiring grade separation consideration is the vicinity of Yandell and Paisano in Figure D15. To provide greater strategic arterial continuity, it is desirable to design a direct one-way street to two-way street connection. This requires a moderate 500 foot radius curve for a 50 mph design speed (AASHTO), thereby intruding on numerous residential and commercial properties. The separation must pass over Paisano and Trowbridge so transition length may result in a costly design.

The recommended compressed grade separation cross section was taken from a report on design considerations by Ward (Ref. 7). Freeway grade separation specifications were taken from the AASHTO Green Book (Ref. 1). The freeway designs appear to be conservative and may be compressed for more comparable strategic arterial design.

Access Management

It is necessary to restrict access onto Montana Avenue by eliminating driveways. There is an abundance of driveways which introduce numerous vehicular conflicts and disrupt corridor continuity. The easiest method of access control is driveway consolidation. Businesses at intersections typically have four driveways (two on the major street and two on the minor street), so one major street driveway could be eliminated. At mid-block locations, many driveways can be eliminated to provide one shared driveway. If sufficient right-of-way is available, an additional access road can be constructed to better accommodate each business such as the design in Figure D22 at Wedgewood Drive .

Cul-de-sacs are proposed to limit residential access points. Figure D17 shows a cross street converted to a cul-de-sac. Cul-de-sac location criteria is based on alternate route availability and minimal travel time increases.

Access control impact has not been fully analyzed. Auxiliary lanes may be used to absorb ingress and egress because driveway consolidation may impose legal aspects beyond the project scope. Auxiliary lanes are justified by maintaining three through lanes at all times and acceleration and deceleration provisions.

Transit terminals

Conceptual designs for transit locations are specified below. Design standards exceed minimum recommendations from AASHTO regarding length and width of terminal. Figure D10 includes approximate locations and dimensions for roadside bus terminals, while other locations may utilize existing parking lots or access roads.

Possible Bus Stop Locations

- West of George Dieter (2)
- West of Lee Trevino (2)
- East of Wedgewood (2)
- East of Golf Course near McRae (2)
- West of Hawkins on access roads (2)
- East of Airway on access roads (2)
- West of Airway (2)
- West of Sioux (2)
- At Mescalero/Airport (2)
- Between Geronimo and Magruder (2)
- At Chelsea, Raynolds, US 54, Copia, Piedras, Cotton, Brown (2 each)

STAGING IMPLEMENTATION

Montana Avenue recommendations are based on year 2015 forecasted volumes and the Texas Department of Transportation Large Network Assignment Model. Since development is progressive, all recommendations are not immediately required. This project may be used as a basis for staged implementation with the following suggestions:

1) *Signal Coordination.* Creating Montana Avenue signal progression is the first recommended solution and should be implemented immediately. An evaluation of existing conditions indicate many intersections are currently operating at poor levels of service including Airway Boulevard and the vicinity of Bassett Center Shopping Mall. Significant intersection delays cannot be solved by signal retiming alone but coordination may provide an immediate, albeit temporary, cost effective solution.

2) *Intersection Improvements.* As demand creates undesired levels of service, intersection improvements may provide additional intersection capacity. All intersections must contain right-turn lanes as a minimum. Furthermore, high volume approaches should include free right-turns with acceleration and deceleration provisions. Numerous left-turn movements suffer significant vehicle delay so dual left-turns should be considered for turning movements greater than 300 vehicles per hour. If right-of-way constraints prohibit intersection flaring, restriping or median paving may create additional lanes.

3) *One-Way Pairs.* Immediate one-way street conversion is recommended between the CBD to Paisano creating a continuous strategic arterial route. Westbound alignment is Montana Avenue from Paisano to Piedras transitioning to Yandell Avenue from Piedras and directly connect to Interstate 10 near the CBD. Eastbound alignment is Wyoming Avenue from Interstate 10 near the CBD to Piedras transitioning to Yandell Avenue from Piedras to Paisano. Historical buildings may restrict specific transition alignment.

4) *Concrete Median Barrier.* A concrete median barrier is suggested along the entire two-way section of Montana Avenue following signal and intersection development. The barrier will restrict all mid-block turning movements so gradual development may be necessary. In addition, intersection left-turns should be replaced by indirect turns. Developing indirect turns before installing a barrier is advisable so drivers can locate alternate routes to minimize confusion.

5) *Grade Separations.* Grade separations are costly solutions recommended in final stage development. Airway and Yarbrough should be constructed immediately since existing conditions are oversaturated. Others should be considered as demand is justified.

Minimum cross section design requirements indicate upgrading Montana Avenue to strategic arterial classification can be virtually accomplished with existing pavement widths, however, the middle corridor section does not maintain minimum lateral clearance. Supplying desirable conditions can eliminate extensive driveway consolidation because auxiliary lanes could be used for acceleration and deceleration. The eastern quarter of Montana Avenue has adequate right-of-way for all desirable conditions and, since development is relatively sparse, should be considered as a potential freeway section immediately.

FEASIBILITY OF IMPROVEMENTS AFTER STRATEGIC ARTERIAL IMPLEMENTATION

In Figures C1 through C10 the results from the Texas Large Network Assignment model for the second level Montana Avenue alternatives are presented. These alternatives are described in-depth in Chapter 6. Recall that first a no-build scenario is considered. That is, no improvements to Montana Avenue or the network over today's existing condition except for those improvements or changes already planned. The first alternative is a freeway alternative with direct connection to I-10 in the vicinity of Piedras. The second alternative is also a freeway alternative but instead of a connection to I-10 it continues west on a one-way pair. The third is a strategic arterial alternative with Montana and Yandell one-way pairs at the western end. The last alternative is also a strategic arterial alternative with one-way pairs being Yandell and Wyoming. Included in Appendix C are maps and tables for each alternative containing selected volumes, v/c ratios, speeds.

From studying the figures, several conclusions may be made. The most striking is that, as a rule, whatever capacity is supplied it is used. Many sections along Montana Avenue have v/c ratios of one or greater. For example, the v/c ratio east of Airway is 1.3 with a volume of 54810 in the no-build case. (Note section in Chapter 4 for review of capacity in Texas Large Network Assignment Model.) East of Hawkins the situation is worse with a v/c of 1.8 and a volume of 69155. The model tends to predict the expected. It is clear that improvements are needed along the corridor and whatever improvements are made will be fully used.

If a strategic arterial is deemed to be the most desirable alternative, at this time, consideration must be given to long term Montana Avenue plans. According to the long term forecasting, traffic demands requiring more capacity than the recommended strategic arterial can provide are likely.

There are several possible future planning options. One is to upgrade or replace the strategic arterial with a freeway. Since the freeway would be installed many years in the future it will probably be necessary to include frontage roads due to the extensive development. Most of this development will have been dependent on access to the strategic arterial and would require freeway access.

The other option is to continually upgrade the strategic arterial over time until it approaches freeway level. This would provide a facility with higher capacities and speeds than current strategic arterial plans but less than a freeway. This ultimate strategic arterial would be a fully controlled access facility. All at grade intersections would be replaced by grade separations or cross street traffic termination. This facility will have no signalization, no parking, continuous flow, and possess all other freeway aspects with the exception of lower design standards.

General Discussion

The following section is a discussion based on the assumption of strategic arterial implementation. This section reviews the feasibility of upgrading a strategic arterial to a freeway or ultimate strategic arterial along portions of Montana Avenue. First is a general discussion of strategic arterial upgrade consideration factors.

Right-of-Way. Right-of-way is probably one of the most important, if not the most important, factor affecting any continual upgrading. It is the ability or inability to attain the necessary right-of-way that can doom any project. As the amount of existing right-of-way decreases and/or the cost of additional right-of-way increases, the feasibility of upgrading a strategic arterial to a fully controlled access facility decreases. Through wise planning, early in arterial development, future improvement feasibility can be greatly increased. Wise planning is not only acquiring currently needed right-of-way, but also purchasing as much right-of-way as reasonably possible. This simple guide can prevent many difficult future problems and make possible a highway system more capable of adjusting to meet user demand.

Development . Development is also very important. Firstly, as development adjacent to the roadway grows, the right-of-way cost increases. Secondly, but just as important, is the development pattern effect. Different facility types support very different development patterns. An example is that a strategic arterial has the highest development attractions along abutting properties while a freeway without frontage roads has highest development attractions along grade separated cross streets. This must be accounted for in any upgrade or improvement. If a strategic arterial development pattern is allowed to become well established, the feasibility of certain upgrades is essentially eliminated. The best way to solve the development problem is to plan early enough in the arterial life to be able to adequately influence the development type so it positively affects future improvements and upgrades.

Political, Public, and Commercial Reactions and Impacts. In areas where the community is active and involved in many local decisions, satisfying community needs and questions is very important. If a neighborhood through which the strategic arterial passes is not assured that their concerns are being addressed the residents may oppose project development. Residents will often have worries about safety, high speeds, and increases in traffic through their neighborhood. If these fears are not addressed and relieved, political pressure and legal action by the community may be able to eliminate any upgrade or put enough limits on the upgrade that it is no longer worthwhile.

An active community can benefit any project if it is involved in the process and allowed to make meaningful contributions. By involving the community from the start many problems can be avoided. The more decisions made without community involvement and input, the more decisions that are likely to upset people and create unwanted tensions. Much of the upgrade will depend on political backing of community leaders who tend to be very sensitive to constituents' feelings and fears.

Along with residents, commercial business will also be affected, in some cases dramatically, by any upgrades. Great care must be taken to show the business community that their concerns are addressed. Business must be informed of the long term benefits and realize that if they are adversely affected they will be compensated. If a large portion of the business community is against arterial improvements they can cause many problems. This is understandable if owners are not well treated and feel their livelihood is threatened. These owners are often politically powerful and well financed. Communities have been able to stop improvements such as grade separations and if this occurs the upgrade may essentially become impossible.

If communities affected by the upgrade are not included in the process, problems may arise. Community involvement from the start is the best method to avoid and alleviate these problems. Of course community involvement will not alleviate all problems or even guarantee community agreement. It will, however, allow authorities to identify problems much sooner, increasing the chances of a successful response. The community may remain against the upgrade, despite their involvement, but this will be known early and appropriate decisions can be made. If the project is abandoned, a great deal of time and effort can be saved for other projects.

Montana Avenue Upgrades after Strategic Arterial Implementation

Loop 375 to McRae Boulevard. This section is most favorable toward upgrading a strategic arterial to a freeway. This section relies on many favorable factors including plenty of right-of-way and low development, allowing for a wide planning option range. Included within this section is Loop 375, Saul Kleinfeld, George Dieter Road, Lee Trevino, Yarbrough, Wedgewood, and McRae.

1) *Upgrade to a Freeway.* If a strategic arterial is implemented now, it is feasible to consider upgrading this section to a freeway with frontage roads in the future. In order for this upgrade to occur it is imperative that existing right-of-way be maintained. It is possible to build a freeway in the 200 feet of existing right-of-way but it would be desirable to purchase additional right-of-way allowing for a less constricted freeway. There are no sight distance or sharp curvature problems along this section.

If a freeway is a future option, then it is possible to build strategic arterial lanes in a manner today allowing for their continued use in the future. That is, to have the strategic arterial lanes placed either where the freeway main lanes or frontage roads are to be placed. The salvagability of the strategic arterial will be maximized if both the strategic arterial and freeway follow the same alignment.

More important than lane placement are grade separations. As previously noted, a strategic arterial may be able to use smaller grade separations but long term savings would be provided if freeway grade separations can be built now. This can be done by implementing high standard grade separations today or easily upgradeable grade separations. Grade separations can be one of the most costly aspects of a project and not accounting for that now could be extremely costly in the future.

In addition to the structure itself it is imperative that necessary intersection right-of-way is purchased or controlled as soon as possible. In general, grade separations require more right-of-way than main lanes. If this right-of-way is not controlled now, then freeway implementation at a later date will be difficult regardless of how well the right-of-way between the intersections is preserved. In the short term, this additional right-of-way may be used to improve the strategic arterial by placing free right-turns, higher speed jug handles, and other features which improve traffic flow.

Over time, if uncontrolled, intersections will be the first areas to be developed. Intersection right-of-way acquisition costs will rise at a higher rate than the rest of the roadway. It is possible to allow intersection corners to be developed although great care must be taken to insure the developments are set back far enough that they will not be adversely affected by grade separations. All potential developers of intersection corners, and elsewhere along the arterial, should be informed of the freeway possibility and grade separations before they improve the properties. This will help to increase the likelihood that arterial development will be friendly toward the upgrade, should it occur. Although it must be made clear that the freeway is only a possibility, otherwise people may develop properties expecting a freeway. This could also cause many problems.

2) Upgrade to an Ultimate Strategic Arterial. Not discussed thus far is the feasibility of upgrading the strategic arterial to an ultimate level. If it is feasible to upgrade to a freeway with frontage roads, it is also feasible to upgrade to an ultimate strategic arterial. Care and planning are still needed regarding access control and grade separations but planning does not have to be as rigid as with a freeway. The real questions arise with community desires. If it is guaranteed that a freeway is not wanted in the future then the extra property acquisition, planning work, and other expenses required for a freeway would be wasted. But in this section, not allowing for the possibility of a freeway would be unwise. Allowing for the possibility should not greatly increase costs, but once eliminated and right-of-way lost, the probability of successfully upgrading to a freeway is greatly reduced.

3) Summary. This arterial section has great potential. This is an ideal situation because of low and sparse development and wide existing right-of-way. These two factors allow for planning far into the future. Although this planning must be done soon due to expected development, it can avoid a host of future problems.

McRae Boulevard to Airport Road. This section is the central part of the arterial and it ranges from McRae to Airport and includes Hawkins, Airway, Robert E. Lee, and Sioux. While the possibility of an upgrade from a strategic arterial to a freeway still exists, the feasibility is greatly reduced and the costs substantially increased. This section of arterial does not have either a low level of development or a wide right-of-way.

1) Upgrade to a Freeway with Frontage Roads. The upgrade to a freeway with frontage roads from a strategic arterial on this section would be difficult. This section does not already have the required freeway right-of-way. Therefore it would be necessary to buy the required right-of-way either at the time of strategic arterial implementation or at time of the freeway upgrade. Currently the required freeway right-of-way is already developed making acquisition difficult. The overall cost of the strategic arterial implementation would be substantially increased if the freeway right-of-way is purchased. If the decision is made to purchase the right-of-way in the future the costs will only increase. By implementing a strategic arterial without right-of-way controls, the development will only intensify over time making the abutting properties more valuable. This will be seen most intensely at the intersections which will experience the highest property value increases. Unfortunately intersections are the most crucial part of the project due to needed grade separations.

As in the eastern section, building grade separations today that are acceptable for the future freeway will substantially improve overall feasibility. Also strategic arterial lanes and other features should be designed for freeway application. Decreasing the design differences between the two facility types increases the degree to which the strategic arterial that can be reused and salvaged.

The right-of-way constrictions and high concentration of developments limit possible planning options. While the freeway with frontage roads could be planned at this time it would be difficult and costly. Whether or not it is feasible to keep a freeway as a viable option in the future depends mainly on the financial situation and political will of the deciding authorities. If it is definitely known that a freeway is wanted, it may be more feasible to skip the strategic arterial and just try to implement a freeway. This is because there may be a greater likelihood of success if all energy is put towards a freeway instead of expending financial assets and political strength to implement a strategic arterial first.

2) Upgrade to an Ultimate Strategic Arterial. For this section of roadway this is probably the most attainable goal. The existing right-of-way between the intersections for the most part is already acceptable for continual strategic arterial upgrading. This is especially true between Airway and Hawkins where there are short access roads which are ideal for strategic arterials. Along the entire central section there are only a few buildings that would probably have to be purchased in upgrading to an ultimate strategic arterial.

Along this central section the number of driveways should be reduced by merging wherever possible. If done now, it should also be possible to redesign many driveways for higher speed turns allowing better ingress and egress. If this is not done, the properties may become too densely developed making higher speed turns difficult.

The major problems exist at the intersections. All intersections should be grade separated. In some places this will be expensive and difficult. One prime example is Airway with a large hotel built very close to the intersection. But it must be remembered that a grade separation on a strategic arterial does not need to supply the quality of service of that on a freeway. Using more creative designs, such as the single point diamond interchange, it is still possible to separate all intersections. The possibility of using underpasses instead of overpasses and only separating the through movement should also be considered. In some instances, Airway probably being one, a decision will have to be made and some corners acquired. If planned now it should be possible to restrict the intersection developments and reserve the right-of-way for future grade separations without spending exorbitant amounts. If this is not done and small developments at the corners are replaced by large ones, such as another hotel, future costs will go up and the feasibility down.

3) *Summary.* As already seen, this section has many problems affecting the ability to make long term plans. A major factor in the final plan for this section will be the political will and strength of the deciding authorities. If a path of least resistance is chosen, then the freeway with frontage roads alternative will be eliminated and possibly even upgrading to an ultimate strategic arterial.

One topic not discussed in either option is community involvement and desires. These will affect the feasibility of both options and unfortunately at this point they are largely unknown. Great care should be taken to get the community and local business involved in deciding on which option is chosen and in supporting the option. A great deal of public and business opposition can cause almost any project to quickly become infeasible.

Airport Road to Mesa Street. This section is the western end of the arterial. It ranges from Airport to Mesa and includes Magruder, Paisano, Huckleberry, Raynolds, US 54, Pershing Dr., Piedras and Cotton, along with various other local streets. This section has developed to a point where any improvement becomes difficult. This section suffers from narrow right-of-way and dense development making future planning and current changes very difficult and costly.

The majority of this section consists of a one-way pair. From Airport Road to the Paisano/Montana split, the strategic arterial would be a two-way facility. At the Paisano/Montana split, Montana Avenue will continue as a one-way street west bound. The east bound direction will be on Yandell which intersects Paisano approximately 1500 ft from the Montana/Paisano intersection. The one-way pair switches to Yandell and Wyoming in the Piedras vicinity.

1) *Upgrade to a Freeway.* This section is the least feasible situation for upgrading to a freeway with frontage roads. The amount of right-of-way available at this time makes planning for a freeway nearly impossible. The two-way part of this arterial section would need at least double the existing right-of-way and desirably triple. This would require purchasing a majority of the development abutting the arterial. This would in almost all cases be infeasible when implementing the strategic arterial due to the substantial cost increase. If money to purchase all required right-of-way exists, then the freeway should just be installed at the same time. Installing a strategic arterial without acquiring the additional right-of-way would offer no advantage to future freeway implementation.

The future freeway would probably become less attractive if the strategic arterial is implemented without additional right-of-way. Costs would increase since prices usually increase over time. Increases in development would further increase right-of-way acquisition costs. Little of the money, time, and effort spent on the strategic arterial would aid the freeway. If the desire is to implement a freeway it should be done at the present time. This does not mean that implementing a strategic arterial precludes later freeway construction, only that there may be no expected benefits to freeway implementation derived through the strategic arterial.

The one-way pair creates some different freeway problems. There is obviously not enough right-of-way on either street for future freeway installation. Since the amount of additional right-of-way needed is so great, both sides of one of the streets will need to be purchased. Having the one-way pair in place will not make this any easier in the future. As in the previous paragraph, costs will only increase over time, development will probably increase, and none of the money and effort spent on the one way pair will be salvageable. Using this scenario, there is no advantage to the strategic arterial one-way pair. Whether or not increased costs of a future freeway are worth the short term problem alleviation through the one-way pair, can only be decided by the local community and governing bodies.

There is a second option for an upgrade to freeway with frontage roads. One-way pairs of arterials could be used as frontage roads. This would require at some later date purchase of the necessary right-of-way between the one way pairs for the freeway main lanes. All that property will be developed and expensive. Also, this plan would permit continued and enhanced commercial and residential development between main lanes and frontage roads. Using the one way pair as frontage roads will reduce the required additional right-of-way somewhat and use strategic arterial elements in the freeway. But there will be added difficulties and costs in placing ramps and purchasing the main lane right-of-way. Also it would be possible to use Montana and Yandell as frontage roads in a freeway installation without first implementing the strategic arterial. Whether or not this is a feasible option will depend on the particular right-of-way cost and comparisons to freeway implementation along one of the one-way streets.

2) *Upgrade to an Ultimate Strategic Arterial*

While this alternative offers some possibilities it is still a difficult challenge. The first large problem is the transition from the two way section to the one way pair. Continuous flow through this transition could be provided through long grade separations that would require a great deal of right-of-way. This transition alone would be a costly endeavor through one of the most densely developed areas. There is also a transition problem at Piedras St. requiring long, right-of-way intensive, grade separation structures.

There are also many cross streets along the one-way pair. All of these would require either grade separation or cross street termination. With the limited right-of-way there may be many corner property acquisitions. To handle all of these cross streets would quickly become expensive and difficult.

Another problem is parking on the existing streets. It would have to be eliminated. Unfortunately this is also the only parking available for many properties and any attempt to remove it would most likely be opposed. Many of these areas are residential and would resist the speeds desired on an ultimate strategic arterial. If the local community is able to impose speed limits of 30 mph or less, many of the strategic arterial benefits would be lost.

The main difficulty with the ultimate strategic arterial is the number of changes that would be required. As mentioned above, there are the cross streets, parking, and speed limit problems to name just a few. Whether or not all of these changes can be made is dependent on the local political structures and interests. Most likely there would be too many opposing forces and the ultimate strategic arterial level would not be reached. The process by which strategic arterial improvements are implemented slowly over a long period of time, needing continual political and public support, is its greatest weakness.

3) Summary. The western section's greatest problem is that implementation of the strategic arterial is coming too late in the arterial's life to allow adequate and economical long term planning. This is a case where the strategic arterial is being used as a remedy to existing problems and not as part of a plan for preventing future problems. Whether or not there is any overall advantage or disadvantage to implementing a strategic arterial as a step toward any type of freeway facility is highly dependent on the expectation of right-of-way availability and cost. Due to the number of problems at this period in the arterial's life, it is unlikely that there will be any appreciable benefit to implementing a strategic arterial now if the final goal is a freeway. It is likely that the strategic arterial could make freeway implementation in the future even more difficult.

SUMMARY

If meeting the expected traffic demand is the only criterion, the freeway is the best alternative. However, other factors must be taken into account including cost, right-of-way, existing development, community impacts, and political desires. Considering these elements may make a strategic arterial the more attractive alternative. If the strategic arterial is implemented now, will upgrading to a fully controlled access facility later be feasible?

If the desire is to upgrade the strategic arterial to a freeway with frontage roads, it is probably not feasible. The middle and western sections have too many right-of-way and development problems making the likelihood of success very low. Since one of the reasons a strategic arterial is being considered is that a freeway is an unpopular community option, the odds of overcoming this will not be improved by the strategic arterial. Even though the western and central sections have many problems, the necessary eastern section right-of-way should still be acquired. In this area it is still undeveloped and relatively inexpensive. By purchasing the right-of-way now, this section should be able to avoid the problems of the other two sections. Development can never be predicated with complete certainty and, not buying the right-of-way now, may be cause for many future regrets.

A more feasible option for Montana Avenue is the ultimate strategic arterial. While this will still be difficult in the central and western sections it should be possible over time. If a constant effort is made with continuous improvements over time the ultimate strategic arterial is not out of reach. Some grade separations will be costly and unpopular but needed for arterial continuity. Though difficult, if the deciding authorities, including the Texas Department of Transportation and City of El Paso, are willing to commit to the project for the long term, it should be possible.

If it is certain that a freeway is desired on the Montana corridor, it may be best to not implement a strategic arterial but to implement the freeway as soon as possible. A strategic arterial will only make the development and community problems worse when freeway implementation is finally attempted. If a freeway is not desired as a future option the strategic arterial should be implemented as soon as possible. Since the number of freeway problems are already so great, the ultimate strategic arterial is probably the best option. Furthermore, even if all strategic arterial upgrades are never completely installed, at least some improvements will have been made and these will increase quality of service.

Finally, regardless of what decision is made for Montana Avenue it must be made soon. As development continues unmonitored, the problems only increase. If action is delayed for a significant period of time even the likelihood of strategic arterial success is decreased. Montana Avenue unfortunately is already highly developed. This is working against all alternatives and will only worsen with time.

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APPENDIX A

Table A1. Existing Intersection Geometrics (Lane Configuration by Approach)

Intersection	Eastbound			Westbound			Northbound			Southbound		
	L	S	R	L	S	R	L	S	R	L	S	R
Cotton	Sh.	2	Sh.	Sh.	2	Sh.	Sh.	2	Sh.	Sh.	2	Sh.
Piedras	1	2	Sh.	1	2	Sh.	1	2	Sh.	1	2	Sh.
Raynor	Sh.	2	-	-	2	Sh.	Sh.	2	1	-	-	-
Copia	1	2	Sh.	1	2	Sh.	1	2	Sh.	Sh.	2	1
Gateway South	-	2	1	1	2	-	-	-	-	Sh.	3	Sh.
Gateway North	1	2	-	-	2	1	Sh.	3	Sh.	-	-	-
Raynolds	1	2	Sh.	1	2	Sh.	Sh.	2	Sh.	Sh.	2	Sh.
Huckleberry	1	2	Sh.	1	2	Sh.	Sh.	1	1	Sh.	1	1
Chelsea	1	2	Sh.	1	2	Sh.	Sh.	2	Sh.	Sh.	2	Sh.
Trowbridge	-	2	1	-	2	1	1	2	-	1	2	-
Paisano	-	2	-	-	-	-	-	-	-	-	2	-
Magruder	1	3	1	1	3	Sh.	Sh.	2	Sh.	Sh.	2	Sh.
Geronimo	1	3	Sh.	2	3	Sh.	1	2	1	1	2	1
Mescalero	1	3	Sh.	-	3	Sh.	Sh.	1	1	Sh.	1	1
Sioux	1	3	Sh.	1	3	Sh.	Sh.	2	Sh.	Sh.	2	Sh.
Robert E. Lee	1	3	Sh.	1	3	Sh.	1	-	1	1	-	1
Airway	1	3	Sh.	1	3	Sh.	2	3	Sh.	2	3	1
Hawkins	1	3	1	1	3	1	1+Sh.	2	1	1+Sh.	2	1
Rutherglen	1	3	Sh.	1	3	Sh.	Sh.	1	1	Sh.	1	Sh.
McRae	1	3	1	1	3	Sh.	1+Sh.	1	1	1	1	1
Wedgewood	1	3	1	1	3	Sh.	1+Sh.	1	1	Sh.	1	Sh.
Yarbrough	-	2	1	1	3	-	2	-	1	-	-	-
Lee Trevino	-	2	1	1	2	-	2	-	1	-	-	-
George Dieter	1	2	1	1	2	1	1	-	1	-	-	1

Sh. : Indicates Movement Shared with Through Traffic

Table A2. Existing (1992) Turning Movement Counts (AM Peak)

Intersection	Eastbound			Westbound			Northbound			Southbound		
	L	S	R	L	S	R	L	S	R	L	S	R
Cotton	15	243	15	57	373	46	43	481	46	48	319	28
Piedras	37	222	2	54	396	56	21	189	26	83	466	44
Raynor	4	315	-	-	443	24	53	140	37	-	-	-
Copia	41	326	33	52	324	48	30	318	106	46	398	29
Gateway South	-	388	14	57	534	-	-	-	-	154	171	131
Gateway North	66	420	-	-	537	100	35	88	37	-	-	-
Raynolds	30	452	53	66	542	26	73	108	72	43	140	37
Huckleberry	4	360	14	21	449	12	14	2	16	21	10	7
Chelsea	59	531	9	12	441	25	47	61	52	10	86	11
Trowbridge	-	424	109	-	523	196	81	101	-	238	159	-
Paisano	-	735	-	-	-	-	-	-	-	-	428	-
Magruder	180	1010	42	43	1112	75	4	67	293	67	70	69
Geronimo	35	748	109	64	830	49	112	277	15	19	149	28
Mescalero	331	744	25	-	1098	85	22	37	30	89	39	29
Sioux	21	644	40	61	1046	73	49	145	65	75	136	18
Robert E. Lee	4	626	33	76	1377	6	65	-	40	1	-	6
Airway	86	439	76	150	1374	718	203	984	78	285	337	77
Hawkins	2	465	70	207	2024	1022	218	257	126	207	42	7
Rutherglen	14	684	34	14	3108	5	140	17	5	2	1	9
McRae	7	523	116	38	2584	5	505	94	15	4	10	24
Wedgewood	2	640	36	20	2200	66	263	32	14	18	10	34
Yarbrough	-	422	128	50	1981	-	546	-	37	-	-	-
Lee Trevino	-	379	149	46	1109	-	1050	-	32	-	-	-
George Dieter	79	187	74	33	272	1	459	-	24	-	-	1

- Indicates Movement Does Not Exist

Table A3. Existing (1992) Turning Movement Counts (Noon Peak)

Intersection	Eastbound			Westbound			Northbound			Southbound		
	L	S	R	L	S	R	L	S	R	L	S	R
Cotton	30	415	29	63	370	46	41	457	108	91	382	33
Piedras	60	509	9	85	387	82	23	203	55	115	437	64
Raynor	14	595	-	-	484	23	76	126	93	-	-	-
Copia	47	508	51	117	390	65	45	371	132	61	356	21
Gateway South	-	715	28	45	565	-	-	-	-	203	120	109
Gateway North	129	759	-	-	532	165	51	94	68	-	-	-
Raynolds	26	690	69	92	589	22	77	58	139	52	62	58
Huckleberry	7	830	60	49	692	11	89	13	58	8	18	13
Chelsea	70	745	13	41	795	40	76	79	98	17	86	28
Trowbridge	-	748	156	-	638	199	124	153	-	209	122	-
Paisano	-	1016	-	-	-	-	-	-	-	-	527	-
Magruder	167	1183	50	86	1224	120	72	114	33	159	113	32
Geronimo	42	1005	139	200	936	130	114	171	204	55	110	29
Mescalero	431	1318	37	-	1034	54	17	11	34	92	13	51
Sioux	19	902	42	54	902	61	32	98	63	109	84	23
Robert E. Lee	7	1152	54	37	1052	1	51	-	23	7	-	2
Airway	155	848	167	197	742	407	309	877	166	298	654	199
Hawkins	8	972	232	224	800	431	195	169	270	307	119	6
Rutherglen	42	1065	8	13	1242	53	67	7	14	19	7	11
McRae	16	1124	197	114	1171	11	239	33	54	8	47	14
Wedgewood	7	957	90	21	819	19	122	19	35	37	25	16
Yarbrough	-	663	423	43	551	-	351	-	65	-	-	-
Lee Trevino	-	306	238	42	287	-	288	-	40	-	-	-
George Dieter	32	195	91	19	204	1	141	-	27	-	-	1

- Indicates Movement Does Not Exist

Table A4. Existing (1992) Turning Movement Counts (PM Peak)

Intersection	Eastbound			Westbound			Northbound			Southbound		
	L	S	R	L	S	R	L	S	R	L	S	R
Cotton	23	467	36	35	380	66	43	566	91	105	447	38
Piedras	42	509	9	53	442	75	40	277	49	118	525	48
Raynor	8	614	-	-	448	32	108	204	132	-	-	-
Copia	58	653	73	78	456	73	27	498	143	65	450	15
Gateway South	-	854	58	94	600	-	-	-	-	207	159	114
Gateway North	176	869	-	-	645	246	35	207	70	-	-	-
Raynolds	20	823	76	70	673	24	101	103	143	35	114	36
Huckleberry	2	803	34	55	672	13	68	9	41	13	13	21
Chelsea	26	822	60	95	688	8	11	122	28	74	97	98
Trowbridge	-	862	200	-	671	267	145	208	-	286	234	-
Paisano	-	1308	-	-	-	-	-	-	-	-	710	-
Magruder	191	1413	36	79	1528	87	55	76	33	164	114	49
Geronimo	20	1179	188	273	1205	35	161	140	50	82	248	35
Mescalero	332	1971	28	-	1298	65	9	21	27	276	39	37
Sioux	15	1504	48	113	1072	36	38	94	59	223	273	17
Robert E. Lee	1	1560	102	92	1155	2	72	-	79	3	-	10
Airway	79	1248	118	184	741	252	297	642	170	538	863	63
Hawkins	1	1725	241	190	727	379	128	105	330	794	234	1
Rutherglen	47	1061	5	29	2481	60	55	2	6	25	7	9
McRae	20	2222	443	94	898	8	220	16	56	23	79	18
Wedgewood	10	1991	232	24	984	9	145	10	46	99	44	14
Yarbrough	-	1445	483	56	565	-	285	-	78	-	-	-
Lee Trevino	-	972	612	70	407	-	291	-	55	-	-	-
George Dieter	15	449	354	51	294	1	147	-	55	-	-	4

- Indicates Movement Does Not Exist

Table A5. El Paso Speed Table (2015 System)

JUR \ FC	CONN	BORDER HWY	FRWYR	EXPY	PARTD	PARTU	DART	UART	COLLD	COLLU	LOCL	FRTG	RAMP	TRANS MTN	FRWYC
CBD	15	32	37	32	11	11	11	12	11	11		16	20		37
CBD_FRG	25	29	34	29	24	24	18	19	17	18	20	19	18		34
URBAN_E	26	32	35	32	29	30	26	25	25	22	24	24	23		35
URBAN_N	29	32	34	32	30	32	27	24	24	19	19	23	22		34
URBAN_W	26	32	35	32	29	30	26	25	25	22	24	24	23		35
SUB_N	35	36	42	36	31	38	27	32	28	30		38	34		42
SUB_W	35	37	42	37	33	36	29	28		28		34	34	20	42
SUB_E	33	37	44	37	31	33	30	28		25		33	31		44
RURAL	40	47	50	47	45	45	40	39		38		38	40	20	50

FC : Fuctional Classification

JUR : Jurisdiction (Area Type)

Source: TxDOT Planning Division

Table A6. El Paso Capacity Table (2015 System)

(24-Hour Per Lane Capacity)

FC / JUR	BORDER HWY	FRWYR	EXPY	PARTD	PARTU	DART	UART	COLLD	COLLU	LOCL	FRTG *	RAMP	TRANS MTN	FRWYC
CBD	13100	17250	13100	8350	7550	7250	6600	6200	5700	5700	13500	18000		17250
CBD_FRG	11750	19550	11750	7500	6800	6500	5950	5550	5100	5100	13500	18000		19550
URBAN_E	11350	19550	11350	7100	6400	5500	5050	4650	430	430	13500	18000		19550
URBAN_N	11350	19550	11350	7100	6400	5500	5050	4650	4300	4300	13500	18000		19550
URBAN_W	11350	19550	11350	7100	6400	5500	5050	4650	4300	4300	13500	18000		19550
SUB_N	10250	11750	10250	6250	5600	4050	3750	3350	3150	3150	7500	18000		11750
SUB_W	10250	11750	10250	6250	5600	4050	3750	3350	3150	3150	7500	18000		11750
SUB_E	10250	11750	10250	6250	5600	4050	3750	3350	3150	3150	7500	18000		11750
RURAL	6300	7600	6300	4400	3900	2550	2400	1800	1700	1700	5500	18000	12000	7600

* : Total Capacity

FC : Fuctional Classification

JUR : Jurisdiction (Area Type)

Source: TxDOT Planning Division

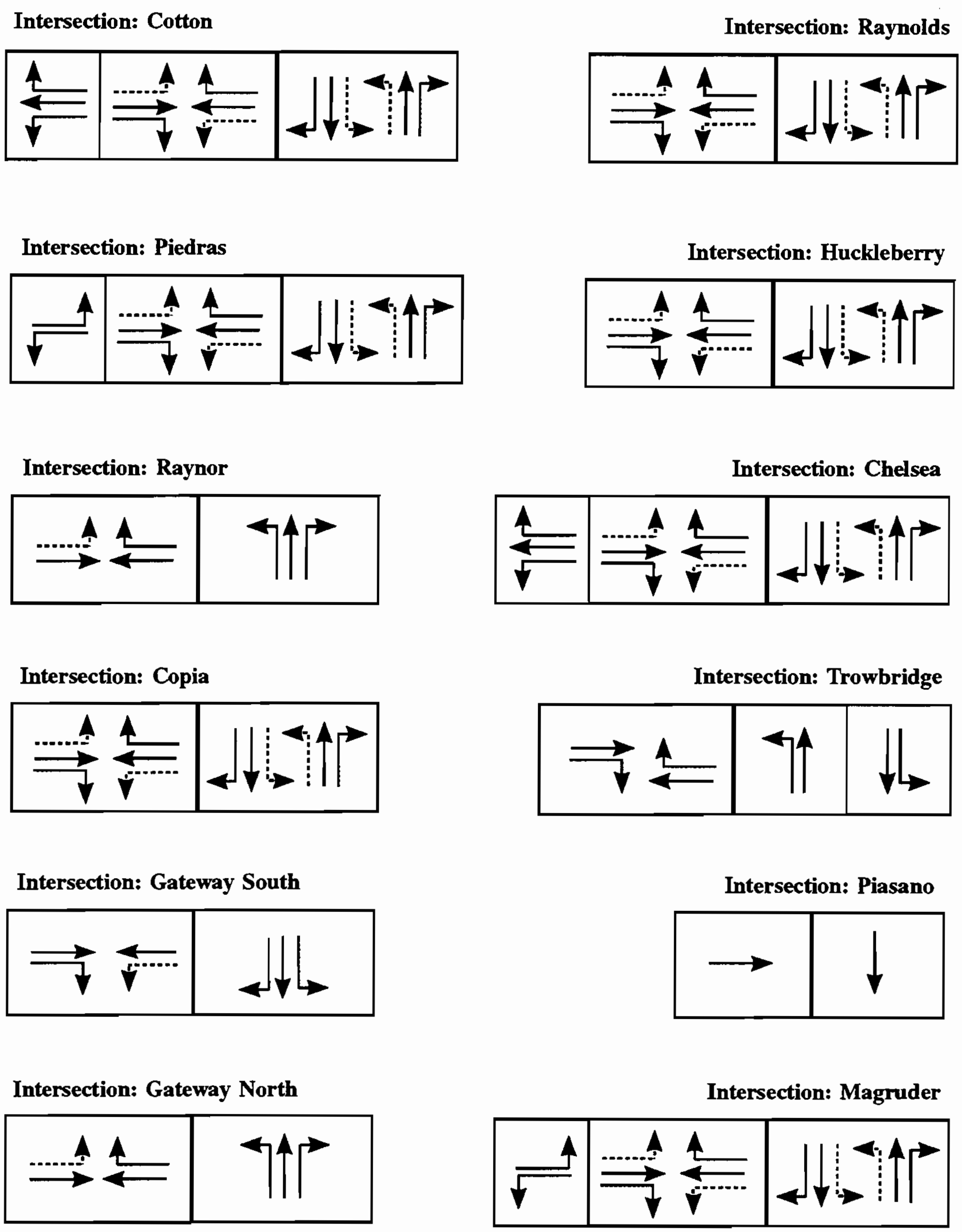

Figure A1. Existing Intersection Phase Patterns and Sequences

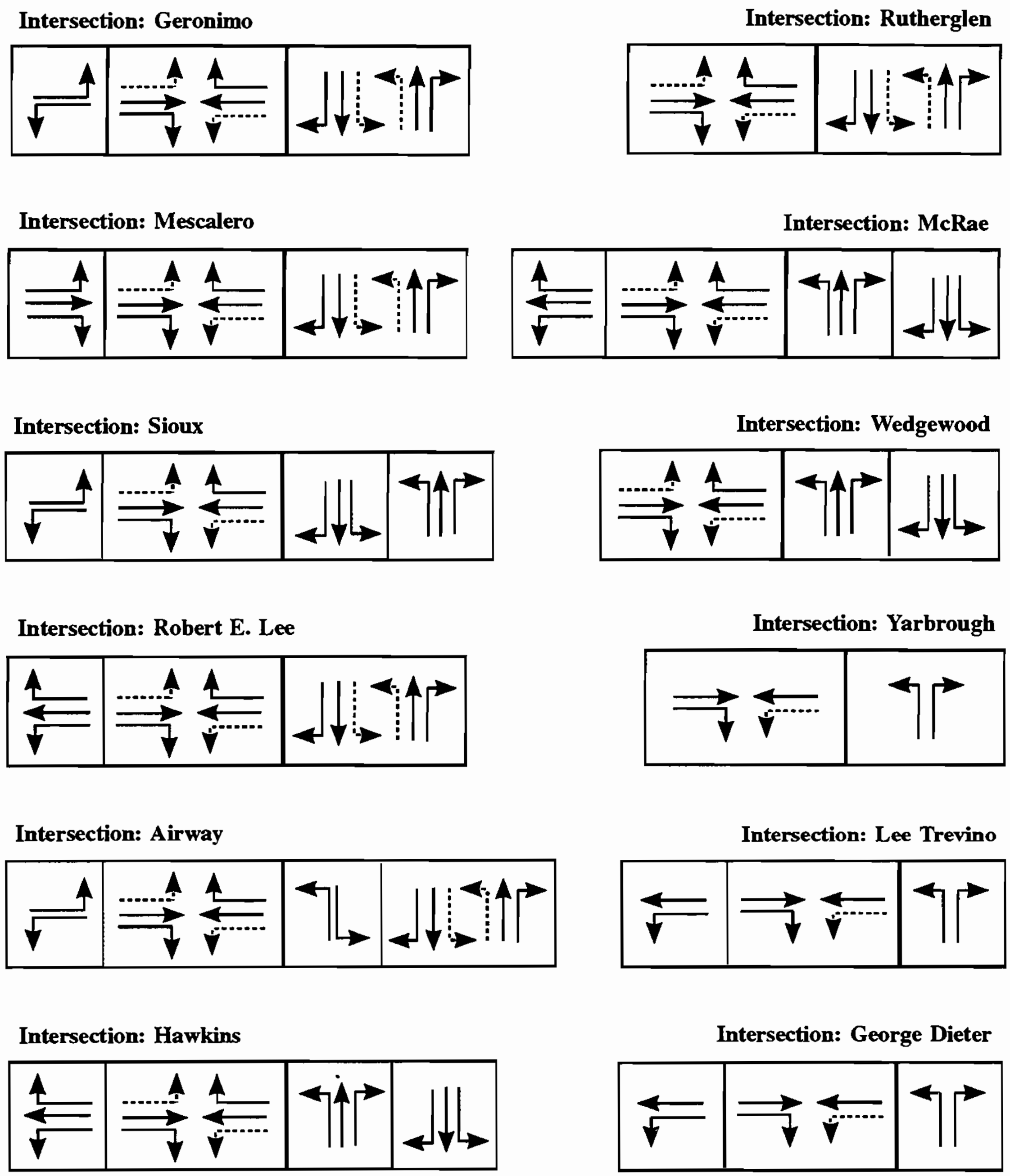

Figure A1. Existing Intersection Phase Patterns and Sequences (Contd.)

APPENDIX B

Table B1. Link List - No-Build Alternative

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	20783	1.2	19.6
767-766	Arizona West of Brown	16482	0.4	25.5
759-764	Montana West of Brown	2448	0.2	25.5
760-762	Yandell West of Brown	2892	0.2	20.0
1021-1013	I-10 Westbound at Brown	111868	1.1	30.0
1012-1022	I-10 Eastbound at Brown	114820	1.2	30.8
780-804	Arizona East of Cotton	31142	0.7	24.7
783-790	Montana East of Cotton	4878	0.4	25.7
4051-787	Yandell East of Cotton	8141	0.5	20.0
1021-1030	I-10 Westbound at Cotton	111868	1.1	30.0
1031-1022	I-10 Eastbound at Cotton	105565	1.1	31.9
798-1287	Pershing East of Piedras	30108	1.1	21.1
796-1288	Montana East of Piedras	1282	0.0	25.9
794-1289	Yandell East of Piedras	3123	0.3	20.2
796-797	Piedras North of Montana	30023	1.3	14.1
794-793	Piedras South of Yandell	29152	0.6	19.1
8011-8019	Montana Freeway Westbound East of Piedras	N/A	N/A	N/A
8018-8010	Montana Freeway Eastbound East of Piedras	N/A	N/A	N/A
1042-1035	I-10 Westbound at Piedras	112782	1.2	30.0
1041-1034	I-10 Eastbound at Piedras	107436	1.1	31.5
1361-1364	Trowbridge West of Raynolds	10945	0.8	18.4
1375-1376	Montana West of Raynolds	5329	0.2	25.7
1381-1380	Yandell West of Raynolds	8279	0.7	19.6
1002-2352	I-10 Westbound at Raynolds	106814	1.4	25.3
2351-1000	I-10 Eastbound at Raynolds	107233	1.4	25.1
1496-4012	Montana East of Geronimo	71576	1.6	15.3
4013-8011	Montana Freeway Westbound at Geronimo	N/A	N/A	N/A
8010-4022	Montana Freeway Eastbound at Geronimo	N/A	N/A	N/A
915-971	I-10 Westbound at Geronimo	93815	1.2	29.5
970-916	I-10 Eastbound at Geronimo	91280	1.2	29.1
4021-1497	Geronimo South of Montana	15416	0.6	18.4
1510-3949	Montana East of Airway	51698	1.2	21.6
3948-3951	Montana Freeway Westbound at Airway	N/A	N/A	N/A
3952-3956	Montana Freeway Eastbound at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	15992	0.7	17.6
929-923	I-10 Westbound at Airway	81878	1.0	32.2
922-928	I-10 Eastbound at Airway	80101	1.0	31.5
1478-3610	Boeing East of Airway	17617	0.9	25.8
1478-1510	Airway North of Montana	55601	1.2	16.7
1510-3954	Airway South of Montana	48637	1.1	20.9
2035-3941	Montana West of McRae	69251	1.8	17.8
2039-3965	McRae South of Montana	10453	0.8	25.5
2081-3937	Montana West of Yarbrough	54686	1.4	23.4
2077-2091	Edgemere West of Yarbrough	10259	0.5	26.4
3921-3923	Montana West of George Dieter	45908	1.1	28.9
3933-3369	George Dieter South of Montana	10711	0.4	31.3
2155-2186	Edgemere West of George Dieter	16576	0.8	22.5
3916-8009	Montana West of Loop 375	43954	1.0	28.3
3917-3919	Montana Freeway Westbound at Loop 375	N/A	N/A	N/A
3935-3910	Montana Freeway Eastbound at Loop 375	N/A	N/A	N/A
2199-2628	Loop 375 South of Montana	13489	1.1	26.4
2191-3908	Edgemere West of Loop 375	16901	0.6	30.3

Table B2. Link List - Alternative 1 - No Connection Freeway to I-10

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	21162	1.2	19.6
767-766	Arizona West of Brown	15695	0.3	25.5
759-764	Montana West of Brown	3003	0.2	25.5
760-762	Yandell West of Brown	2832	0.2	20.0
1021-1013	I-10 Westbound at Brown	119267	1.2	28.8
1012-1022	I-10 Eastbound at Brown	119934	1.2	29.7
780-804	Arizona East of Cotton	30803	0.7	24.7
783-790	Montana East of Cotton	4336	0.3	25.7
4051-787	Yandell East of Cotton	7785	0.4	20.0
1021-1030	I-10 Westbound at Cotton	112155	0.8	35.5
1031-1022	I-10 Eastbound at Cotton	103055	0.8	34.5
798-1287	Pershing East of Piedras	25605	0.9	21.4
796-1288	Montana East of Piedras	1116	0.0	25.9
794-1289	Yandell East of Piedras	2659	0.2	20.2
796-797	Piedras North of Montana	28130	1.2	14.1
794-793	Piedras South of Yandell	28055	0.6	19.1
8011-8013	Montana Freeway Westbound East of Piedras	7104	0.1	36.6
8012-8011	Montana Freeway Eastbound East of Piedras	7812	0.1	36.6
1042-1035	I-10 Westbound at Piedras	111897	1.1	30.0
1041-1034	I-10 Eastbound at Piedras	105841	1.1	31.5
1361-1364	Trowbridge West of Raynolds	10487	0.8	18.0
1375-1376	Montana West of Raynolds	6285	0.2	25.7
1381-1380	Yandell West of Raynolds	7915	0.7	20.0
1002-2352	I-10 Westbound at Raynolds	104302	1.3	25.7
2351-1000	I-10 Eastbound at Raynolds	107179	1.4	24.2
1496-4012	Montana East of Geronimo	67821	1.5	15.9
4013-8011	Montana Freeway Westbound at Geronimo	7104	0.1	36.7
8010-4022	Montana Freeway Eastbound at Geronimo	7812	0.1	36.4
915-971	I-10 Westbound at Geronimo	92659	1.2	29.5
970-916	I-10 Eastbound at Geronimo	89420	1.1	29.5
4021-1497	Geronimo South of Montana	15354	0.6	18.0
1510-3949	Montana East of Airway	47110	1.1	22.5
3948-3951	Montana Freeway Westbound at Airway	7104	0.1	37.9
3952-3956	Montana Freeway Eastbound at Airway	7812	0.1	37.9
1512-1520	Edgemere East of Airway	16673	0.8	18.2
929-923	I-10 Westbound at Airway	82958	1.1	32.2
922-928	I-10 Eastbound at Airway	79417	1.0	31.5
1478-3610	Boeing East of Airway	18422	0.9	25.4
1478-1510	Airway North of Montana	57020	1.3	16.6
1510-3954	Airway South of Montana	47610	1.1	20.0
2035-3941	Montana West of McRae	65905	1.7	18.7
2039-3965	McRae South of Montana	10221	0.8	26.2
2081-3937	Montana West of Yarbrough	51327	1.3	24.3
2077-2091	Edgemere West of Yarbrough	9826	0.5	26.6
3921-3923	Montana West of George Dieter	34798	0.8	29.7
3933-3369	George Dieter South of Montana	7699	0.3	31.3
2155-2186	Edgemere West of George Dieter	21062	1.0	24.2
3916-8009	Montana West of Loop 375	44704	1.0	28.0
3917-3919	Montana Freeway Westbound at Loop 375	7104	0.1	37.6
3935-3910	Montana Freeway Eastbound at Loop 375	7812	0.1	37.6
2199-2628	Loop 375 South of Montana	15135	1.2	20.8
2191-3908	Edgemere West of Loop 375	16446	0.6	30.5

Table B3. Link List - Alternative 2 -No Connection Freeway Ending East of Piedras

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	21226	1.2	19.6
767-766	Arizona West of Brown	17203	0.4	25.5
759-764	Montana West of Brown	3155	0.2	25.5
760-762	Yandell West of Brown	2848	0.2	20.0
1021-1013	I-10 Westbound at Brown	111625	1.1	30.0
1012-1022	I-10 Eastbound at Brown	113120	1.2	31.1
780-804	Arizona East of Cotton	32237	0.7	24.7
783-790	Montana East of Cotton	6677	0.5	25.7
4051-787	Yandell East of Cotton	8309	0.5	20.0
1021-1030	I-10 Westbound at Cotton	111625	1.1	30.2
1031-1022	I-10 Eastbound at Cotton	103604	1.1	31.9
798-1287	Pershing East of Piedras	23228	0.9	23.5
796-1288	Montana East of Piedras	7929	0.3	26.1
794-1289	Yandell East of Piedras	11544	1.0	18.7
796-797	Piedras North of Montana	25873	1.1	16.0
794-793	Piedras South of Yandell	33396	0.7	19.1
8011-8019	Montana Freeway Westbound East of Piedras	7459	0.1	36.5
8018-8010	Montana Freeway Eastbound East of Piedras	8868	0.2	36.3
1042-1035	I-10 Westbound at Piedras	111494	1.1	30.0
1041-1034	I-10 Eastbound at Piedras	103976	1.1	31.5
1361-1364	Trowbridge West of Raynolds	10792	0.8	17.6
1375-1376	Montana West of Raynolds	5535	0.2	25.7
1381-1380	Yandell West of Raynolds	8125	0.7	19.6
1002-2352	I-10 Westbound at Raynolds	104357	1.3	25.7
2351-1000	I-10 Eastbound at Raynolds	105195	1.3	24.2
1496-4012	Montana East of Geronimo	66691	1.5	16.2
4013-8011	Montana Freeway Westbound at Geronimo	7459	0.1	36.7
8010-4022	Montana Freeway Eastbound at Geronimo	8868	0.2	37.1
915-971	I-10 Westbound at Geronimo	92921	1.2	29.5
970-916	I-10 Eastbound at Geronimo	89736	1.1	29.5
4021-1497	Geronimo South of Montana	15231	0.6	18.4
1510-3949	Montana East of Airway	47608	1.1	20.6
3948-3951	Montana Freeway Westbound at Airway	7459	0.1	37.9
3952-3956	Montana Freeway Eastbound at Airway	8868	0.2	37.9
1512-1520	Edgemere East of Airway	16322	0.7	18.9
929-923	I-10 Westbound at Airway	82786	1.1	32.2
922-928	I-10 Eastbound at Airway	79957	1.0	31.9
1478-3610	Boeing East of Airway	18189	0.9	25.6
1478-1510	Airway North of Montana	56962	1.3	16.6
1510-3954	Airway South of Montana	47608	1.1	20.0
2035-3941	Montana West of McRae	64707	1.7	18.8
2039-3965	McRae South of Montana	10235	0.8	26.2
2081-3937	Montana West of Yarbrough	50322	1.3	24.7
2077-2091	Edgemere West of Yarbrough	8776	0.4	26.6
3921-3923	Montana West of George Dieter	36247	0.9	29.9
3933-3369	George Dieter South of Montana	7581	0.3	31.3
2155-2186	Edgemere West of George Dieter	18021	0.9	24.2
3916-8009	Montana West of Loop 375	43379	1.0	28.3
3917-3919	Montana Freeway Westbound at Loop 375	7459	0.1	37.6
3935-3910	Montana Freeway Eastbound at Loop 375	8868	0.2	37.6
2199-2628	Loop 375 South of Montana	15653	1.2	20.4
2191-3908	Edgemere West of Loop 375	15990	0.6	30.5

Table B4. Link List - Alternative 3 -No Connection Freeway Ending at Piedras

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	21296	1.2	19.6
767-766	Arizona West of Brown	16609	0.4	25.5
759-764	Montana West of Brown	2378	0.2	25.5
760-762	Yandell West of Brown	2892	0.2	20.0
1021-1013	I-10 Westbound at Brown	112737	1.2	29.6
1012-1022	I-10 Eastbound at Brown	115110	1.2	30.8
780-804	Arizona East of Cotton	31302	0.7	24.7
783-790	Montana East of Cotton	5324	0.4	25.7
4051-787	Yandell East of Cotton	9707	0.5	20.0
1021-1030	I-10 Westbound at Cotton	112737	1.2	29.8
1031-1022	I-10 Eastbound at Cotton	105861	1.1	31.9
798-1287	Pershing East of Piedras	28320	1.0	21.4
796-1288	Montana East of Piedras	1736	0.1	25.9
794-1289	Yandell East of Piedras	3834	0.3	20.2
796-797	Piedras North of Montana	28978	1.2	14.1
794-793	Piedras South of Yandell	37963	0.8	18.3
8011-8013	Montana Freeway Westbound East of Piedras	7911	0.2	36.5
8012-8010	Montana Freeway Eastbound East of Piedras	8920	0.2	36.5
1042-1035	I-10 Westbound at Piedras	110515	1.1	30.5
1041-1034	I-10 Eastbound at Piedras	105403	1.1	31.5
1361-1364	Trowbridge West of Raynolds	10359	0.8	18.4
1375-1376	Montana West of Raynolds	5986	0.2	25.7
1381-1380	Yandell West of Raynolds	7930	0.7	20.0
1002-2352	I-10 Westbound at Raynolds	104013	1.3	25.7
2351-1000	I-10 Eastbound at Raynolds	107132	1.4	24.2
1496-4012	Montana East of Geronimo	66665	1.5	16.2
4013-8011	Montana Freeway Westbound at Geronimo	7911	0.1	36.7
8010-4022	Montana Freeway Eastbound at Geronimo	8920	0.2	37.1
915-971	I-10 Westbound at Geronimo	92672	1.2	30.0
970-916	I-10 Eastbound at Geronimo	89907	1.1	29.5
4021-1497	Geronimo South of Montana	15240	0.6	18.4
1510-3949	Montana East of Airway	45950	1.1	22.5
3948-3951	Montana Freeway Westbound at Airway	7911	0.1	37.9
3952-3956	Montana Freeway Eastbound at Airway	8920	0.2	37.9
1512-1520	Edgemere East of Airway	16279	0.7	19.1
929-923	I-10 Westbound at Airway	82585	1.1	32.2
922-928	I-10 Eastbound at Airway	79937	1.0	31.5
1478-3610	Boeing East of Airway	18237	0.9	25.4
1478-1510	Airway North of Montana	566666	1.3	16.6
1510-3954	Airway South of Montana	47485	1.1	20.0
2035-3941	Montana West of McRae	64709	1.7	19.0
2039-3965	McRae South of Montana	10264	0.8	26.2
2081-3937	Montana West of Yarbrough	50130	1.3	24.7
2077-2091	Edgemere West of Yarbrough	9241	0.5	26.6
3921-3923	Montana West of George Dieter	36347	0.9	29.9
3933-3369	George Dieter South of Montana	7582	0.3	31.3
2155-2186	Edgemere West of George Dieter	17877	0.9	24.4
3916-8009	Montana West of Loop 375	43768	1.0	28.3
3917-3919	Montana Freeway Westbound at Loop 375	7911	0.1	37.8
3935-3910	Montana Freeway Eastbound at Loop 375	8920	0.2	37.6
2199-2628	Loop 375 South of Montana	15949	1.2	20.1
2191-3908	Edgemere West of Loop 375	16092	0.6	30.5

Table B5. Link List - Alternative 4 - Freeway to I-10 with Six Diamond Interchanges

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	20544	1.1	19.6
767-766	Arizona West of Brown	13580	0.3	25.5
759-764	Montana West of Brown	2895	0.2	25.5
760-762	Yandell West of Brown	2952	0.1	20.0
1021-1013	I-10 Westbound at Brown	125913	1.3	27.0
1012-1022	I-10 Eastbound at Brown	124813	1.3	28.3
780-804	Arizona East of Cotton	28650	0.6	25.5
783-790	Montana East of Cotton	4582	0.3	25.7
4051-787	Yandell East of Cotton	5159	0.3	20.7
1021-1030	I-10 Westbound at Cotton	76544	0.8	35.0
1031-1022	I-10 Eastbound at Cotton	72927	0.7	35.0
798-1287	Pershing East of Piedras	25631	0.9	20.8
796-1288	Montana East of Piedras	12106	0.4	26.1
794-1289	Yandell East of Piedras	14005	1.2	14.6
796-797	Piedras North of Montana	37262	1.6	9.2
794-793	Piedras South of Yandell	19217	0.4	20.0
8042-8019	Montana Freeway Westbound East of Piedras	48221	0.8	33.7
8018-8043	Montana Freeway Eastbound East of Piedras	49170	0.8	34.2
1042-1035	I-10 Westbound at Piedras	82881	0.8	34.4
1041-1034	I-10 Eastbound at Piedras	79734	0.8	34.4
1361-1364	Trowbridge West of Raynolds	5059	0.4	19.1
1375-1376	Montana West of Raynolds	2138	0.1	25.7
1381-1380	Yandell West of Raynolds	2225	0.2	20.4
1002-2352	I-10 Westbound at Raynolds	91626	1.2	29.4
2351-1000	I-10 Eastbound at Raynolds	85320	1.1	30.7
1496-4012	Montana East of Geronimo	34225	0.8	24.4
4013-8011	Montana Freeway Westbound at Geronimo	46866	0.8	34.6
8010-4022	Montana Freeway Eastbound at Geronimo	48760	0.8	34.2
915-971	I-10 Westbound at Geronimo	82972	1.1	31.7
970-916	I-10 Eastbound at Geronimo	83012	1.1	31.5
4021-1497	Geronimo South of Montana	15225	0.6	18.6
1510-3949	Montana East of Airway	21435	0.5	30.0
3948-3951	Montana Freeway Westbound at Airway	39396	0.7	36.0
3952-3956	Montana Freeway Eastbound at Airway	48760	0.8	36.0
1512-1520	Edgemere East of Airway	7138	0.3	27.8
929-923	I-10 Westbound at Airway	79521	1.0	32.6
922-928	I-10 Eastbound at Airway	77925	1.0	32.4
1478-3610	Boeing East of Airway	7471	0.4	26.7
1478-1510	Airway North of Montana	61842	1.4	16.6
1510-3954	Airway South of Montana	73914	1.6	10.0
2035-3941	Montana West of McRae	30275	0.8	30.6
2039-3965	McRae South of Montana	21869	1.7	10.4
2081-3937	Montana West of Yarbrough	49759	1.3	23.7
2077-2091	Edgemere West of Yarbrough	9149	0.5	26.6
3921-3923	Montana West of George Dieter	29481	0.7	30.7
3933-3369	George Dieter South of Montana	11103	0.4	31.3
2155-2186	Edgemere West of George Dieter	15965	0.8	23.9
3916-8009	Montana West of Loop 375	32767	0.8	30.4
3917-3919	Montana Freeway Westbound at Loop 375	14068	0.2	37.6
3935-3910	Montana Freeway Eastbound at Loop 375	15015	0.3	37.6
2199-2628	Loop 375 South of Montana	16986	1.3	17.8
2191-3908	Edgemere West of Loop 375	13421	0.5	30.8

Table B6. Link List - Alternative 5 - Freeway Ending at Piedras with Five Diamond Interchanges

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	21837	1.2	20.0
767-766	Arizona West of Brown	15694	0.3	25.5
759-764	Montana West of Brown	2515	0.2	25.5
760-762	Yandell West of Brown	3144	0.2	20.0
1021-1013	I-10 Westbound at Brown	111971	1.1	30.0
1012-1022	I-10 Eastbound at Brown	112916	1.2	31.1
780-804	Arizona East of Cotton	30527	0.7	25.5
783-790	Montana East of Cotton	8317	0.6	24.3
4051-787	Yandell East of Cotton	8476	0.5	20.0
1021-1030	I-10 Westbound at Cotton	111971	1.1	30.4
1031-1022	I-10 Eastbound at Cotton	103166	1.1	32.3
798-1287	Pershing East of Piedras	20246	0.7	22.9
796-1288	Montana East of Piedras	20872	0.8	23.1
794-1289	Yandell East of Piedras	19231	1.6	8.0
796-797	Piedras North of Montana	31037	1.3	12.6
794-793	Piedras South of Yandell	34652	0.8	18.3
8042-8019	Montana Freeway Westbound East of Piedras	7459	0.1	36.5
8018-8043	Montana Freeway Eastbound East of Piedras	8868	0.2	36.3
1042-1035	I-10 Westbound at Piedras	106055	1.1	31.5
1041-1034	I-10 Eastbound at Piedras	100823	1.0	32.6
1361-1364	Trowbridge West of Raynolds	5668	0.4	19.1
1375-1376	Montana West of Raynolds	1998	0.1	25.7
1381-1380	Yandell West of Raynolds	2092	0.2	20.4
1002-2352	I-10 Westbound at Raynolds	101302	1.3	26.2
2351-1000	I-10 Eastbound at Raynolds	99764	1.3	27.1
1496-4012	Montana East of Geronimo	34373	0.8	24.4
4013-8011	Montana Freeway Westbound at Geronimo	46119	0.8	34.6
8010-4022	Montana Freeway Eastbound at Geronimo	47008	0.8	34.2
915-971	I-10 Westbound at Geronimo	83500	1.1	31.1
970-916	I-10 Eastbound at Geronimo	82064	1.0	31.5
4021-1497	Geronimo South of Montana	15918	0.6	18.9
1510-3949	Montana East of Airway	21651	0.5	30.0
3948-3951	Montana Freeway Westbound at Airway	39417	0.7	36.0
3952-3956	Montana Freeway Eastbound at Airway	47008	0.8	36.0
1512-1520	Edgemere East of Airway	7765	0.4	27.8
929-923	I-10 Westbound at Airway	82592	1.1	32.6
922-928	I-10 Eastbound at Airway	79325	1.0	32.4
1478-3610	Boeing East of Airway	7234	0.4	26.7
1478-1510	Airway North of Montana	61752	1.4	16.6
1510-3954	Airway South of Montana	73783	1.6	10.0
2035-3941	Montana West of McRae	30301	0.8	31.3
2039-3965	McRae South of Montana	27494	2.1	11.4
2081-3937	Montana West of Yarbrough	46054	1.2	24.0
2077-2091	Edgemere West of Yarbrough	13055	0.6	26.8
3921-3923	Montana West of George Dieter	27892	0.7	30.7
3933-3369	George Dieter South of Montana	11334	0.4	31.3
2155-2186	Edgemere West of George Dieter	17828	0.9	23.9
3916-8009	Montana West of Loop 375	32601	0.8	30.4
3917-3919	Montana Freeway Westbound at Loop 375	13992	0.2	37.6
3935-3910	Montana Freeway Eastbound at Loop 375	14173	0.2	37.6
2199-2628	Loop 375 South of Montana	16904	1.3	18.3
2191-3908	Edgemere West of Loop 375	13241	0.5	30.8

Table B7. Link List - Alternative 6 - Freeway Ending East of Piedras with Five Diamond Interchanges

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	22145	1.2	20.0
767-766	Arizona West of Brown	15486	0.3	25.5
759-764	Montana West of Brown	2668	0.2	25.5
760-762	Yandell West of Brown	3291	0.2	20.0
1021-1013	I-10 Westbound at Brown	111673	1.1	29.6
1012-1022	I-10 Eastbound at Brown	114255	1.2	31.1
780-804	Arizona East of Cotton	32338	0.7	25.5
783-790	Montana East of Cotton	9569	0.7	24.3
4051-787	Yandell East of Cotton	10075	0.6	20.0
1021-1030	I-10 Westbound at Cotton	111673	1.1	30.0
1031-1022	I-10 Eastbound at Cotton	104295	1.1	32.3
798-1287	Pershing East of Piedras	17358	0.6	24.5
796-1288	Montana East of Piedras	1113	0.0	26.1
794-1289	Yandell East of Piedras	1945	0.2	20.7
796-797	Piedras North of Montana	30006	1.3	12.6
794-793	Piedras South of Yandell	45522	1.0	17.5
8042-8019	Montana Freeway Westbound East of Piedras	31434	0.5	35.8
8018-8043	Montana Freeway Eastbound East of Piedras	32347	0.6	36.1
1042-1035	I-10 Westbound at Piedras	99826	1.0	32.1
1041-1034	I-10 Eastbound at Piedras	95777	1.0	32.6
1361-1364	Trowbridge West of Raynolds	5344	0.4	19.1
1375-1376	Montana West of Raynolds	2194	0.1	25.7
1381-1380	Yandell West of Raynolds	2152	0.2	20.4
1002-2352	I-10 Westbound at Raynolds	96253	1.2	26.7
2351-1000	I-10 Eastbound at Raynolds	92160	1.2	27.6
1496-4012	Montana East of Geronimo	34859	0.8	24.4
4013-8011	Montana Freeway Westbound at Geronimo	46439	0.8	34.6
8010-4022	Montana Freeway Eastbound at Geronimo	48458	0.8	34.2
915-971	I-10 Westbound at Geronimo	82785	1.1	31.7
970-916	I-10 Eastbound at Geronimo	80906	1.0	31.5
4021-1497	Geronimo South of Montana	16191	0.6	18.9
1510-3949	Montana East of Airway	21639	0.5	30.0
3948-3951	Montana Freeway Westbound at Airway	39615	0.7	36.0
3952-3956	Montana Freeway Eastbound at Airway	48458	0.8	36.0
1512-1520	Edgemere East of Airway	6954	0.3	27.8
929-923	I-10 Westbound at Airway	82163	1.1	32.6
922-928	I-10 Eastbound at Airway	79003	1.0	32.4
1478-3610	Boeing East of Airway	7240	0.4	26.7
1478-1510	Airway North of Montana	61695	1.4	16.6
1510-3954	Airway South of Montana	73780	1.6	10.0
2035-3941	Montana West of McRae	30032	0.8	30.6
2039-3965	McRae South of Montana	28376	2.2	11.4
2081-3937	Montana West of Yarbrough	45218	1.2	24.0
2077-2091	Edgemere West of Yarbrough	14185	0.7	26.8
3921-3923	Montana West of George Dieter	28312	0.7	30.7
3933-3369	George Dieter South of Montana	11788	0.4	31.3
2155-2186	Edgemere West of George Dieter	17258	0.9	23.9
3916-8009	Montana West of Loop 375	32521	0.8	30.4
3917-3919	Montana Freeway Westbound at Loop 375	13947	0.2	37.6
3935-3910	Montana Freeway Eastbound at Loop 375	14595	0.2	37.6
2199-2628	Loop 375 South of Montana	16895	1.3	18.3
2191-3908	Edgemere West of Loop 375	13219	0.5	30.8

Table B8. Link List - Alternative 7 - Strategic Arterial with All At-Grade Intersections

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	24062	1.3	16.7
767-766	Arizona West of Brown	9309	0.2	25.5
759-764	Montana West of Brown	8220	0.3	30.8
760-762	Yandell West of Brown	26747	0.9	24.9
1021-1013	I-10 Westbound at Brown	104214	1.1	31.8
1012-1022	I-10 Eastbound at Brown	111926	1.1	31.4
780-804	Arizona East of Cotton	27931	0.6	25.5
783-790	Montana East of Cotton	10291	0.3	31.0
4051-787	Yandell East of Cotton	28186	0.9	22.2
1021-1030	I-10 Westbound at Cotton	104214	1.1	31.9
1031-1022	I-10 Eastbound at Cotton	103375	1.1	32.2
798-1287	Pershing East of Piedras	26092	1.0	21.3
796-1288	Montana East of Piedras	8098	0.3	31.3
794-1289	Yandell East of Piedras	22176	0.7	26.7
796-797	Piedras North of Montana	31582	1.3	12.6
794-793	Piedras South of Yandell	22348	0.5	19.1
8011-8019	Montana Freeway Westbound East of Piedras	N/A	N/A	N/A
8018-8010	Montana Freeway Eastbound East of Piedras	N/A	N/A	N/A
1042-1035	I-10 Westbound at Piedras	104266	1.1	32.1
1041-1034	I-10 Eastbound at Piedras	105335	1.1	32.2
1361-1364	Trowbridge West of Raynolds	9111	0.7	19.1
1375-1376	Montana West of Raynolds	16999	0.6	30.9
1381-1380	Yandell West of Raynolds	26775	0.9	27.0
1002-2352	I-10 Westbound at Raynolds	103365	1.3	26.2
2351-1000	I-10 Eastbound at Raynolds	103587	1.3	26.0
1496-4012	Montana East of Geronimo	85809	1.4	19.0
4013-8011	Montana Freeway Westbound at Geronimo	N/A	N/A	N/A
8010-4022	Montana Freeway Eastbound at Geronimo	N/A	N/A	N/A
915-971	I-10 Westbound at Geronimo	92725	1.2	29.5
970-916	I-10 Eastbound at Geronimo	91231	1.2	28.6
4021-1497	Geronimo South of Montana	17704	0.7	17.7
1510-3949	Montana East of Airway	63187	1.1	25.7
3948-3951	Montana Freeway Westbound at Airway	N/A	N/A	N/A
3952-3956	Montana Freeway Eastbound at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	18027	0.8	23.1
929-923	I-10 Westbound at Airway	83423	1.1	31.8
922-928	I-10 Eastbound at Airway	80971	1.0	31.5
1478-3610	Boeing East of Airway	13988	1.0	21.8
1478-1510	Airway North of Montana	52394	1.2	17.7
1510-3954	Airway South of Montana	46946	1.0	20.0
2035-3941	Montana West of McRae	85987	1.4	21.6
2039-3965	McRae South of Montana	13164	1.0	25.5
2081-3937	Montana West of Yarbrough	64286	1.1	26.1
2077-2091	Edgemere West of Yarbrough	6411	0.3	26.9
3921-3923	Montana West of George Dieter	48856	0.8	29.2
3933-3369	George Dieter South of Montana	8685	0.3	31.3
2155-2186	Edgemere West of George Dieter	15503	0.8	22.9
3916-8009	Montana West of Loop 375	45111	0.8	29.3
3917-3919	Montana Freeway Westbound at Loop 375	N/A	N/A	N/A
3935-3910	Montana Freeway Eastbound at Loop 375	N/A	N/A	N/A
2199-2628	Loop 375 South of Montana	13307	1.0	22.6
2191-3908	Edgemere West of Loop 375	16115	0.6	30.5

Table B9. Link List - Alternative 8 - Strategic Arterial with All Grade-Separated Intersections

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	24779	1.4	15.3
767-766	Arizona West of Brown	8395	0.2	25.5
759-764	Montana West of Brown	8461	0.2	30.8
760-762	Yandell West of Brown	30213	0.9	25.5
1021-1013	I-10 Westbound at Brown	102674	1.1	32.2
1012-1022	I-10 Eastbound at Brown	111827	1.1	31.4
780-804	Arizona East of Cotton	26472	0.6	25.5
783-790	Montana East of Cotton	10691	0.3	31.0
4051-787	Yandell East of Cotton	31730	0.9	23.1
1021-1030	I-10 Westbound at Cotton	102764	1.1	32.2
1031-1022	I-10 Eastbound at Cotton	103397	1.1	32.2
798-1287	Pershing East of Piedras	25296	0.9	21.3
796-1288	Montana East of Piedras	8478	0.2	31.3
794-1289	Yandell East of Piedras	25100	0.7	27.3
796-797	Piedras North of Montana	31969	1.3	12.0
794-793	Piedras South of Yandell	22346	0.5	19.1
8011-8019	Montana Freeway Westbound East of Piedras	N/A	N/A	N/A
8018-8010	Montana Freeway Eastbound East of Piedras	N/A	N/A	N/A
1042-1035	I-10 Westbound at Piedras	102296	1.0	32.1
1041-1034	I-10 Eastbound at Piedras	104907	1.1	32.1
1361-1364	Trowbridge West of Raynolds	9235	0.7	19.1
1375-1376	Montana West of Raynolds	17777	0.5	30.9
1381-1380	Yandell West of Raynolds	29633	0.8	27.7
1002-2352	I-10 Westbound at Raynolds	101692	1.3	26.2
2351-1000	I-10 Eastbound at Raynolds	106761	1.4	24.6
1496-4012	Montana East of Geronimo	100187	1.4	20.5
4013-8011	Montana Freeway Westbound at Geronimo	N/A	N/A	N/A
8010-4022	Montana Freeway Eastbound at Geronimo	N/A	N/A	N/A
915-971	I-10 Westbound at Geronimo	89964	1.2	30.0
970-916	I-10 Eastbound at Geronimo	86388	1.1	31.0
4021-1497	Geronimo South of Montana	17441	0.7	17.5
1510-3949	Montana East of Airway	75415	1.1	28.4
3948-3951	Montana Freeway Westbound at Airway	N/A	N/A	N/A
3952-3956	Montana Freeway Eastbound at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	12892	0.6	24.6
929-923	I-10 Westbound at Airway	82677	1.1	32.2
922-928	I-10 Eastbound at Airway	79301	1.0	32.4
1478-3610	Boeing East of Airway	17236	0.9	21.9
1478-1510	Airway North of Montana	54374	1.2	17.7
1510-3954	Airway South of Montana	48323	1.1	20.0
2035-3941	Montana West of McRae	96950	1.4	24.1
2039-3965	McRae South of Montana	14135	1.1	26.2
2081-3937	Montana West of Yarbrough	75781	1.1	28.6
2077-2091	Edgemere West of Yarbrough	5420	0.3	26.9
3921-3923	Montana West of George Dieter	59586	0.9	32.7
3933-3369	George Dieter South of Montana	15328	0.5	31.3
2155-2186	Edgemere West of George Dieter	14543	0.7	24.2
3916-8009	Montana West of Loop 375	47560	0.7	33.2
3917-3919	Montana Freeway Westbound at Loop 375	N/A	N/A	N/A
3935-3910	Montana Freeway Eastbound at Loop 375	N/A	N/A	N/A
2199-2628	Loop 375 South of Montana	13949	1.1	24.8
2191-3908	Edgemere West of Loop 375	14828	0.5	30.8

Table B10. Link List - Alternative 9 - Strategic Arterial with Five Grade-Separated Intersections

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	24812	1.4	15.0
767-766	Arizona West of Brown	8596	0.2	25.5
759-764	Montana West of Brown	8639	0.2	30.8
760-762	Yandell West of Brown	29867	0.8	25.5
1021-1013	I-10 Westbound at Brown	104165	1.1	32.2
1012-1022	I-10 Eastbound at Brown	112126	1.1	31.4
780-804	Arizona East of Cotton	26491	0.6	25.5
783-790	Montana East of Cotton	10666	0.3	31.0
4051-787	Yandell East of Cotton	31774	0.9	23.1
8011-8019	Montana Freeway Westbound East of Piedras	N/A	N/A	N/A
8018-8010	Montana Freeway Eastbound East of Piedras	N/A	N/A	N/A
1021-1030	I-10 Westbound at Cotton	104165	1.1	32.2
1031-1022	I-10 Eastbound at Cotton	103749	1.1	32.2
798-1287	Pershing East of Piedras	26737	1.0	21.4
796-1288	Montana East of Piedras	8427	0.2	31.3
794-1289	Yandell East of Piedras	24978	0.7	27.0
796-797	Piedras North of Montana	33064	1.4	12.0
794-793	Piedras South of Yandell	23293	0.5	19.1
1042-1035	I-10 Westbound at Piedras	103856	1.1	32.1
1041-1034	I-10 Eastbound at Piedras	104328	1.1	32.1
1361-1364	Trowbridge West of Raynolds	8622	0.7	19.1
1375-1376	Montana West of Raynolds	17254	0.5	30.9
1381-1380	Yandell West of Raynolds	28427	0.8	28.4
1002-2352	I-10 Westbound at Raynolds	103881	1.3	25.7
2351-1000	I-10 Eastbound at Raynolds	103737	1.3	26.0
1496-4012	Montana East of Geronimo	89280	1.3	20.5
4013-8011	Montana Freeway Westbound at Geronimo	N/A	N/A	N/A
8010-4022	Montana Freeway Eastbound at Geronimo	N/A	N/A	N/A
915-971	I-10 Westbound at Geronimo	91007	1.2	29.5
970-916	I-10 Eastbound at Geronimo	90380	1.2	29.1
4021-1497	Geronimo South of Montana	16595	0.6	18.2
1510-3949	Montana East of Airway	67765	1.0	27.0
3948-3951	Montana Freeway Westbound at Airway	N/A	N/A	N/A
3952-3956	Montana Freeway Eastbound at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	15271	0.7	26.3
929-923	I-10 Westbound at Airway	83319	1.1	31.8
922-928	I-10 Eastbound at Airway	82371	1.1	31.5
1478-3610	Boeing East of Airway	18543	0.9	25.4
1478-1510	Airway North of Montana	50354	1.1	18.1
1510-3954	Airway South of Montana	45894	1.0	20.7
2035-3941	Montana West of McRae	90722	1.3	22.8
2039-3965	McRae South of Montana	13698	1.1	24.7
2081-3937	Montana West of Yarbrough	69112	1.0	26.9
2077-2091	Edgemere West of Yarbrough	5777	0.3	26.9
3921-3923	Montana West of George Dieter	50287	0.7	29.4
3933-3369	George Dieter South of Montana	9266	0.3	31.3
2155-2186	Edgemere West of George Dieter	15167	0.8	23.5
3916-8009	Montana West of Loop 375	45561	0.7	29.6
3917-3919	Montana Freeway Westbound at Loop 375	N/A	N/A	N/A
3935-3910	Montana Freeway Eastbound at Loop 375	N/A	N/A	N/A
2199-2628	Loop 375 South of Montana	13316	1.0	22.6
2191-3908	Edgemere West of Loop 375	16227	0.6	30.5

Table B11. Link List - Alternative 10 - Strategic Arterial Network

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	25032	1.4	15.0
767-766	Arizona West of Brown	8464	0.2	25.5
759-764	Montana West of Brown	8545	0.2	30.8
760-762	Yandell West of Brown	30111	0.9	25.5
1021-1013	I-10 Westbound at Brown	103961	1.1	32.2
1012-1022	I-10 Eastbound at Brown	111561	1.1	31.4
780-804	Arizona East of Cotton	26428	0.6	25.5
783-790	Montana East of Cotton	10564	0.3	31.0
4051-787	Yandell East of Cotton	31746	0.9	23.1
1021-1030	I-10 Westbound at Cotton	103961	1.1	32.2
1031-1022	I-10 Eastbound at Cotton	103035	1.1	32.2
798-1287	Pershing East of Piedras	24928	0.9	21.4
796-1288	Montana East of Piedras	8308	0.2	31.3
794-1289	Yandell East of Piedras	24971	0.7	27.3
796-797	Piedras North of Montana	31955	1.3	12.0
794-793	Piedras South of Yandell	22281	0.5	19.1
8011-8019	Montana Freeway East of Piedras	N/A	N/A	N/A
1042-1035	I-10 Westbound at Piedras	103534	1.1	32.1
1041-1034	I-10 Eastbound at Piedras	104771	1.1	32.1
1361-1364	Trowbridge West of Raynolds	8699	0.7	19.1
1375-1376	Montana West of Raynolds	16558	0.5	31.8
1381-1380	Yandell West of Raynolds	26837	0.8	29.2
1002-2352	I-10 Westbound at Raynolds	102171	1.3	26.2
2351-1000	I-10 Eastbound at Raynolds	105272	1.3	25.1
1496-4012	Montana East of Geronimo	100911	1.4	20.5
4013-8011	Montana Freeway Westbound at Geronimo	N/A	N/A	N/A
8010-4022	Montana Freeway Eastbound at Geronimo	N/A	N/A	N/A
915-971	I-10 Westbound at Geronimo	90814	1.2	30.0
970-916	I-10 Eastbound at Geronimo	88027	1.1	31.0
4021-1497	Geronimo South of Montana	17408	0.7	17.5
1510-3949	Montana East of Airway	73358	1.1	28.4
3948-3951	Montana Freeway at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	12507	0.6	25.0
1513-1515	Viscount East of Airway	31717	0.9	28.8
929-923	I-10 Westbound at Airway	83174	1.1	32.2
922-928	I-10 Eastbound at Airway	80285	1.0	32.4
1478-3610	Boeing East of Airway	15159	0.8	26.1
1478-1510	Airway North of Montana	53484	1.2	17.7
1510-3954	Airway South of Montana	49883	1.1	20.0
2035-3941	Montana West of McRae	91240	1.3	24.7
2048-2051	Montwood West of McRae	48775	1.4	23.5
2039-3965	McRae South of Montana	13417	1.0	26.2
2081-3937	Montana West of Yarbrough	71647	1.1	29.5
2077-2091	Edgemere West of Yarbrough	4826	0.2	26.9
3921-3923	Montana West of George Dieter	55034	0.8	32.7
3933-3369	George Dieter South of Montana	11076	0.4	31.3
2155-2186	Edgemere West of George Dieter	15293	0.8	26.0
2196-2195	Montwood West of George Dieter	45057	1.3	22.6
3916-8009	Montana West of Loop 375	47803	0.7	33.2
3935-3910	Montana Freeway at Loop 375	N/A	N/A	N/A
2199-2628	Loop 375 South of Montana	12333	1.0	24.7
2191-3908	Edgemere West of Loop 375	15311	0.5	30.8

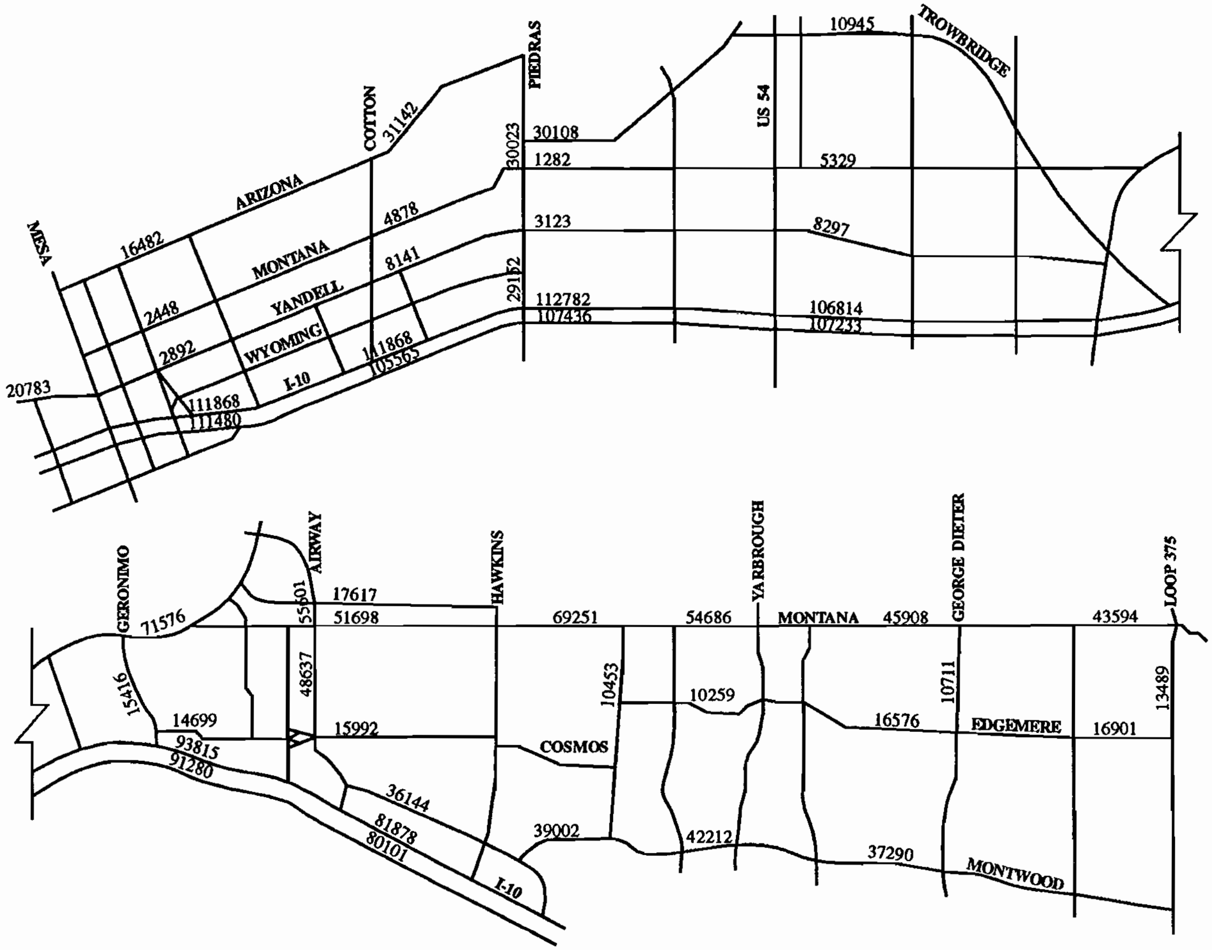

Figure B1a. No-Build Alternative (Year 2015 Volumes)

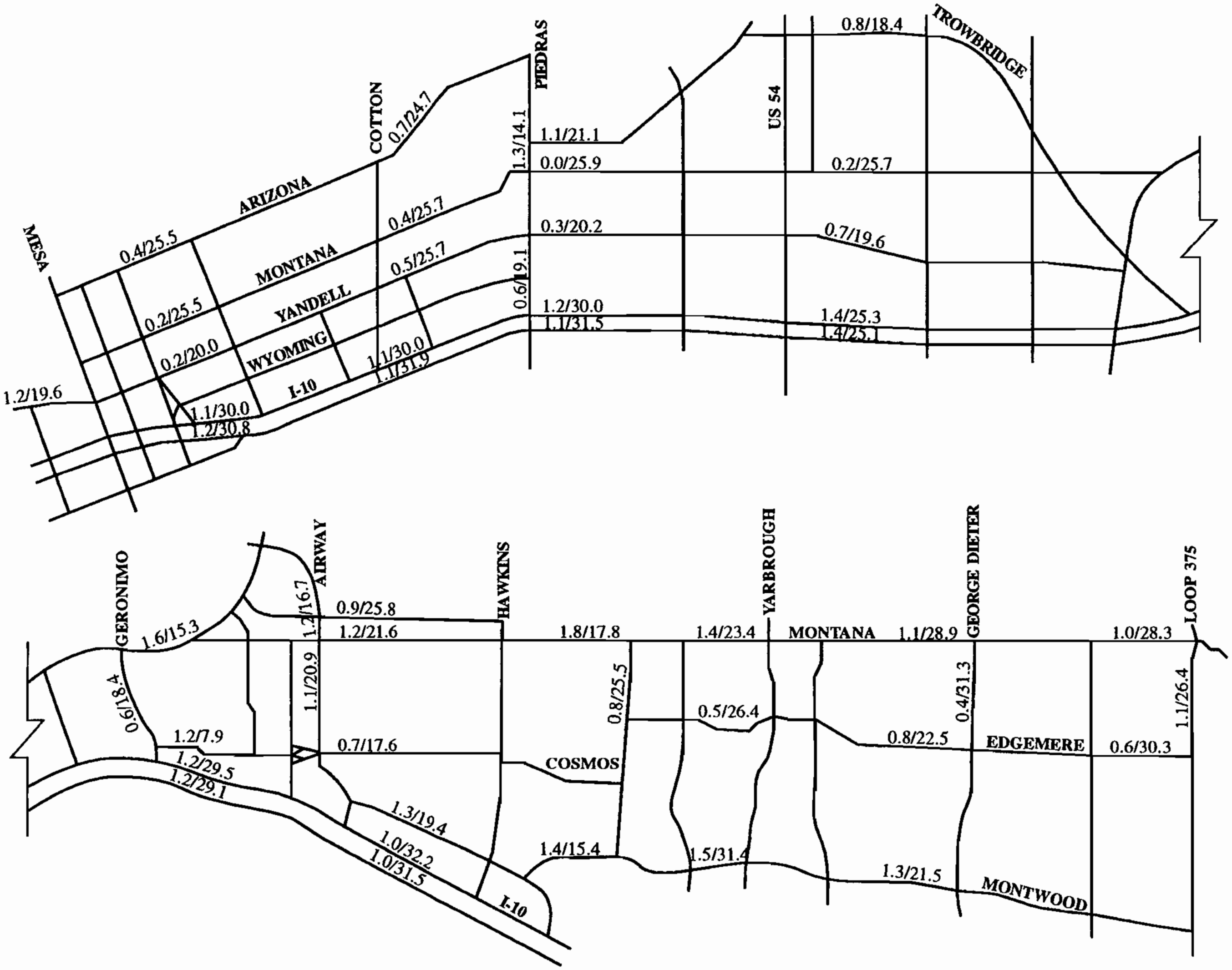

Figure B1b. No-Build Alternative (V/C Ratios and Speeds)

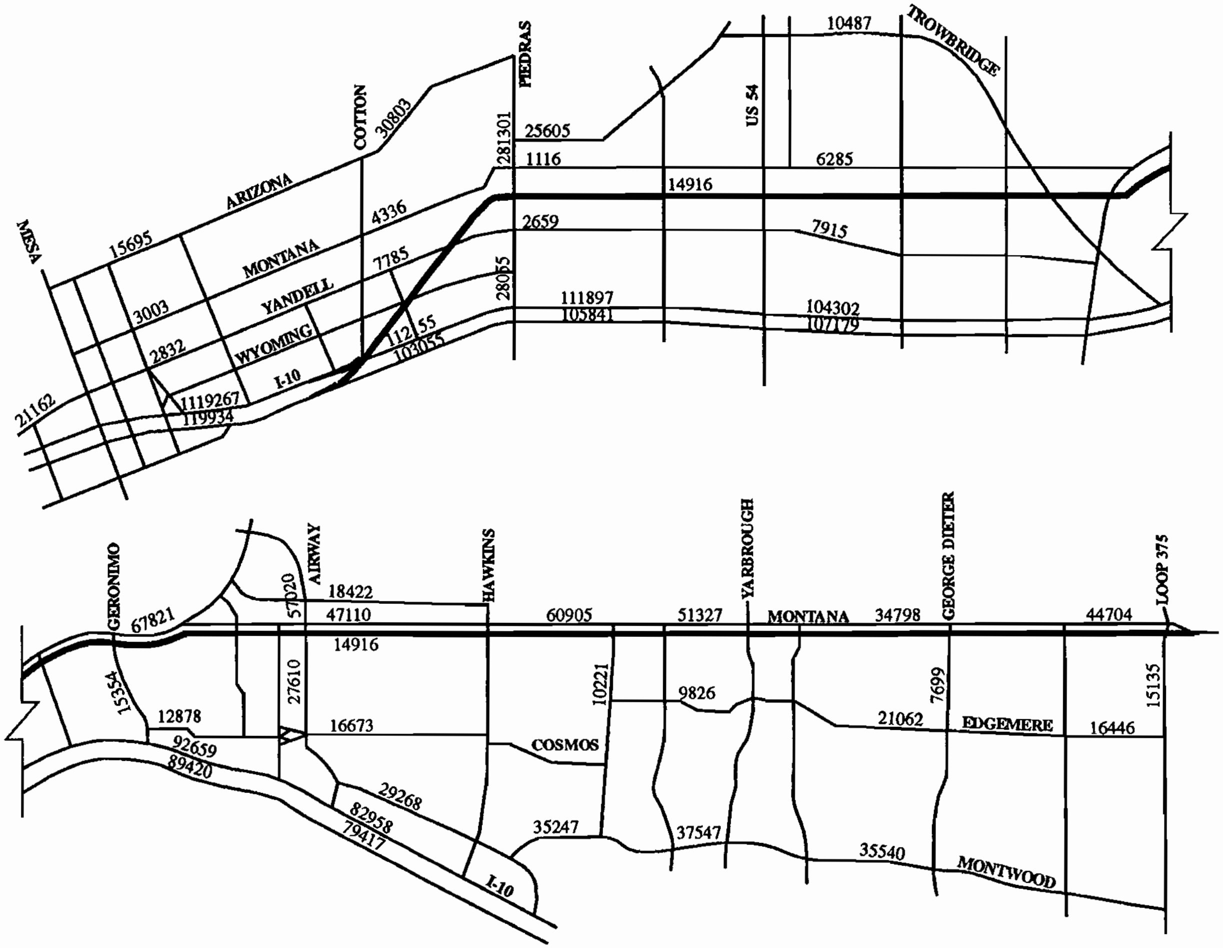

Figure B2a. Alternative 1 - No Connection Freeway to I-10
(Year 2015 Volumes)

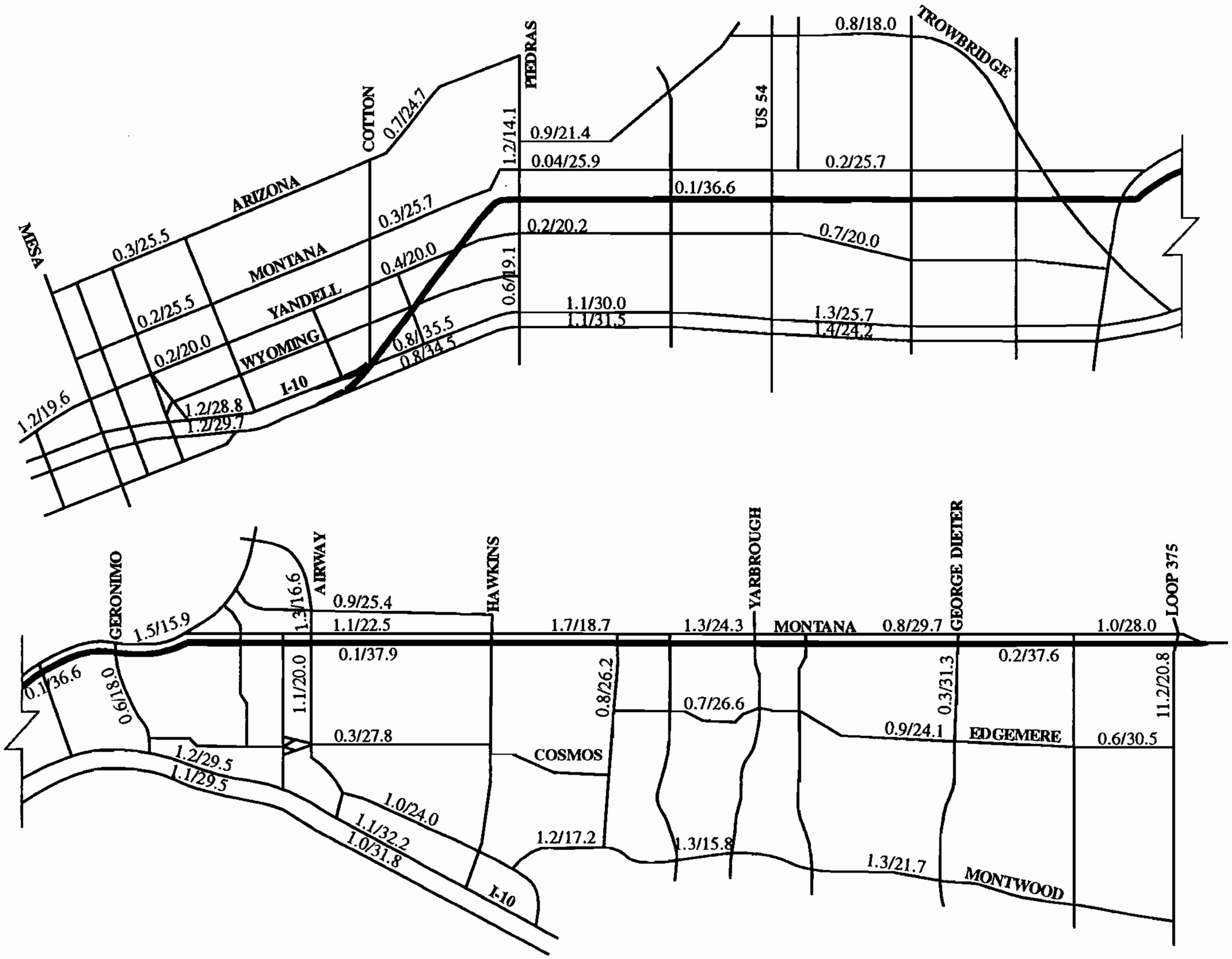

Figure B2b. Alternative 1 - No Connection Freeway (V/C Ratios and Speeds)

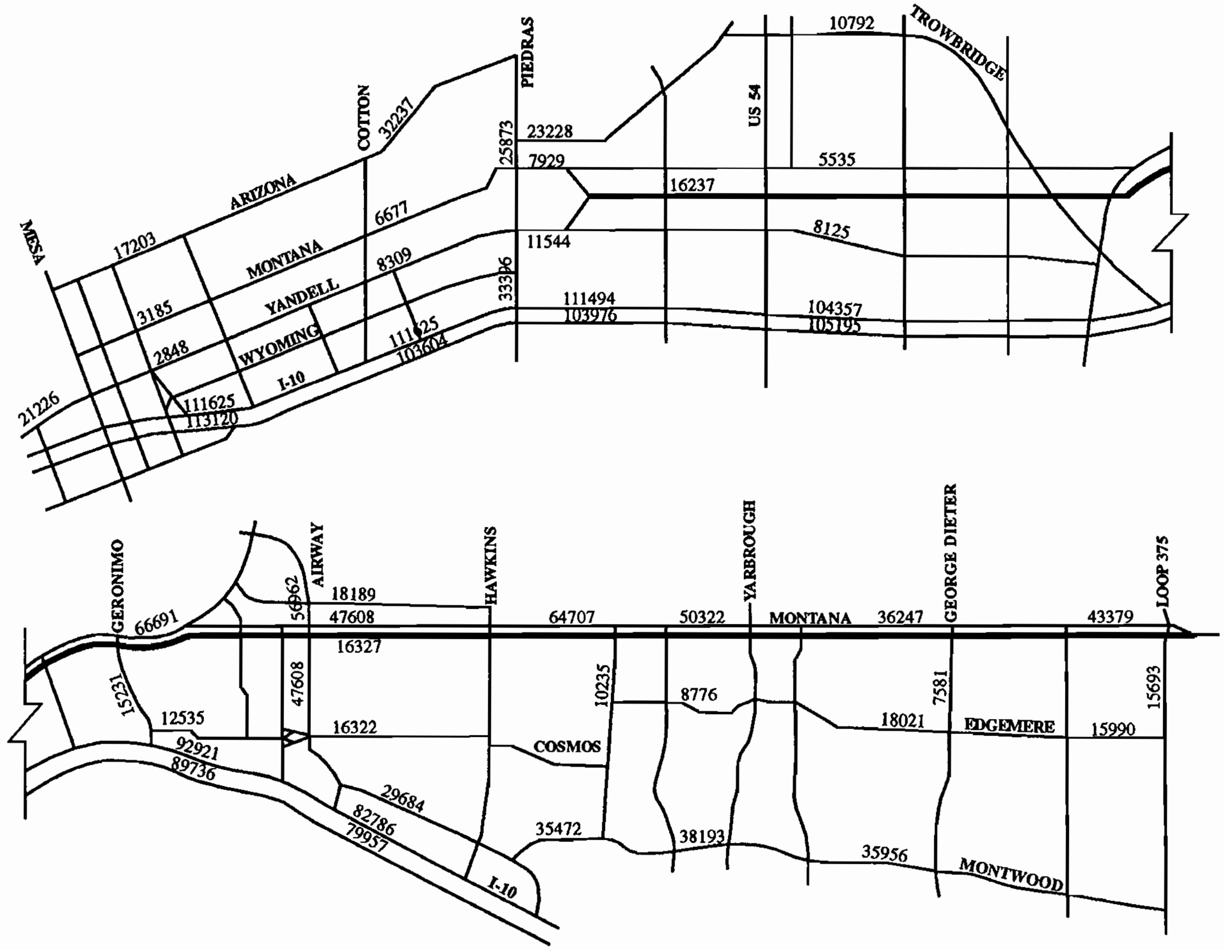

Figure B3a. Alternative 2 - Freeway Ending East of Piedras
(Year 2015 Volumes)

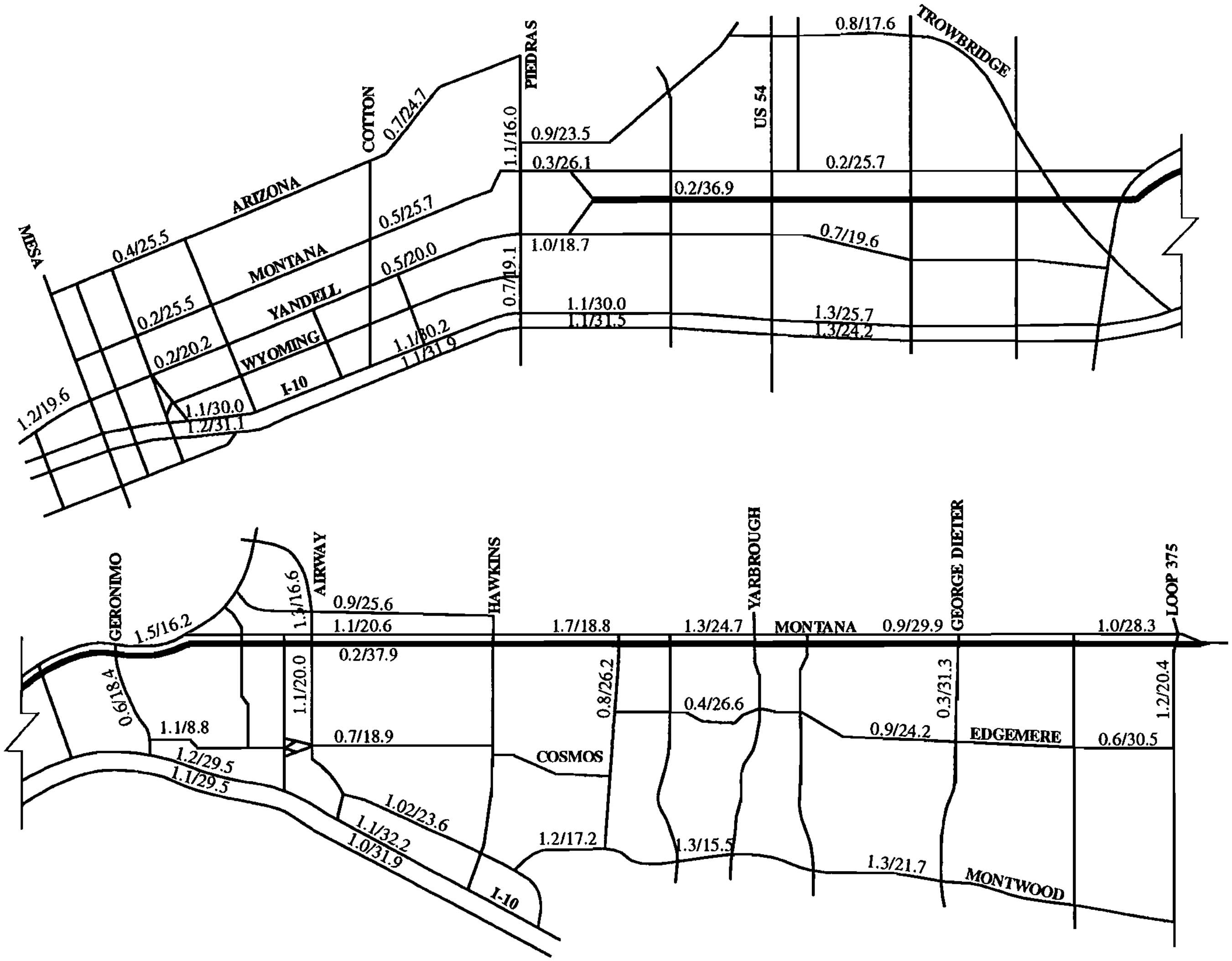

Figure B3b. Alternative 2 - Freeway Ending East of Piedras (V/C Ratio and Speeds)

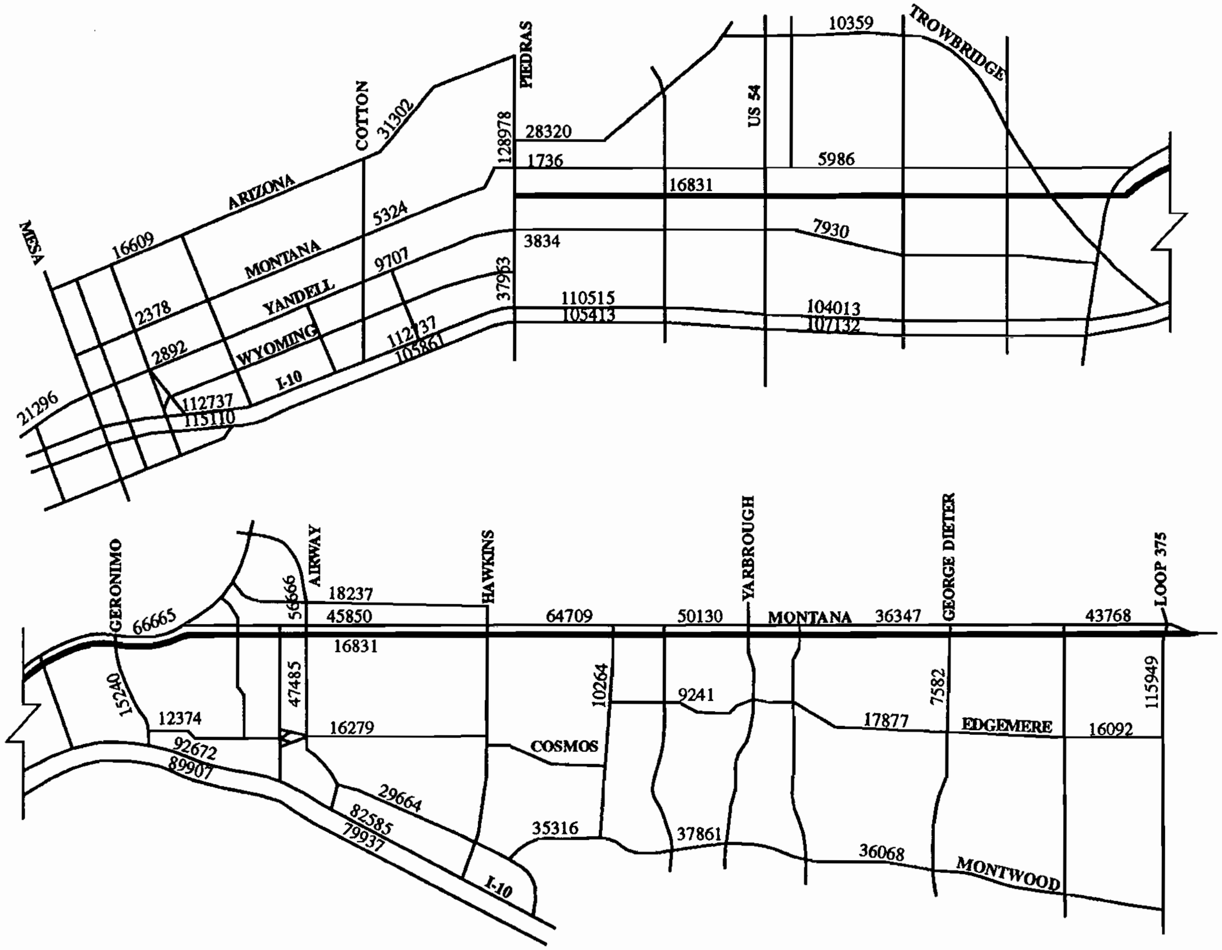

Figure B4a. Alternative 3 - Freeway Ending at Piedras (Year 2015 Volumes)

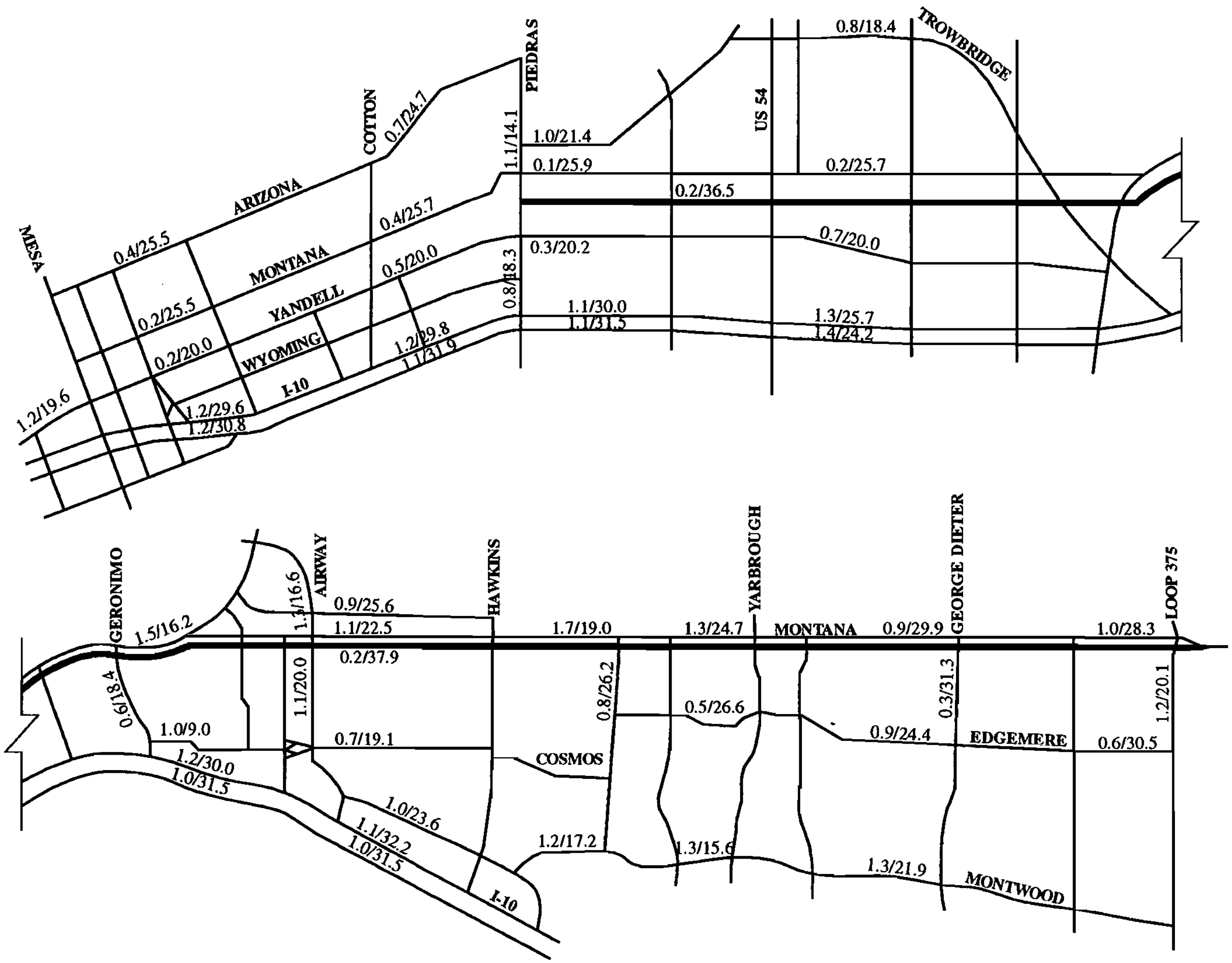

Figure B4b. Alternative 3 - Freeway Ending at Piedras (V/C Ratio and Speeds)

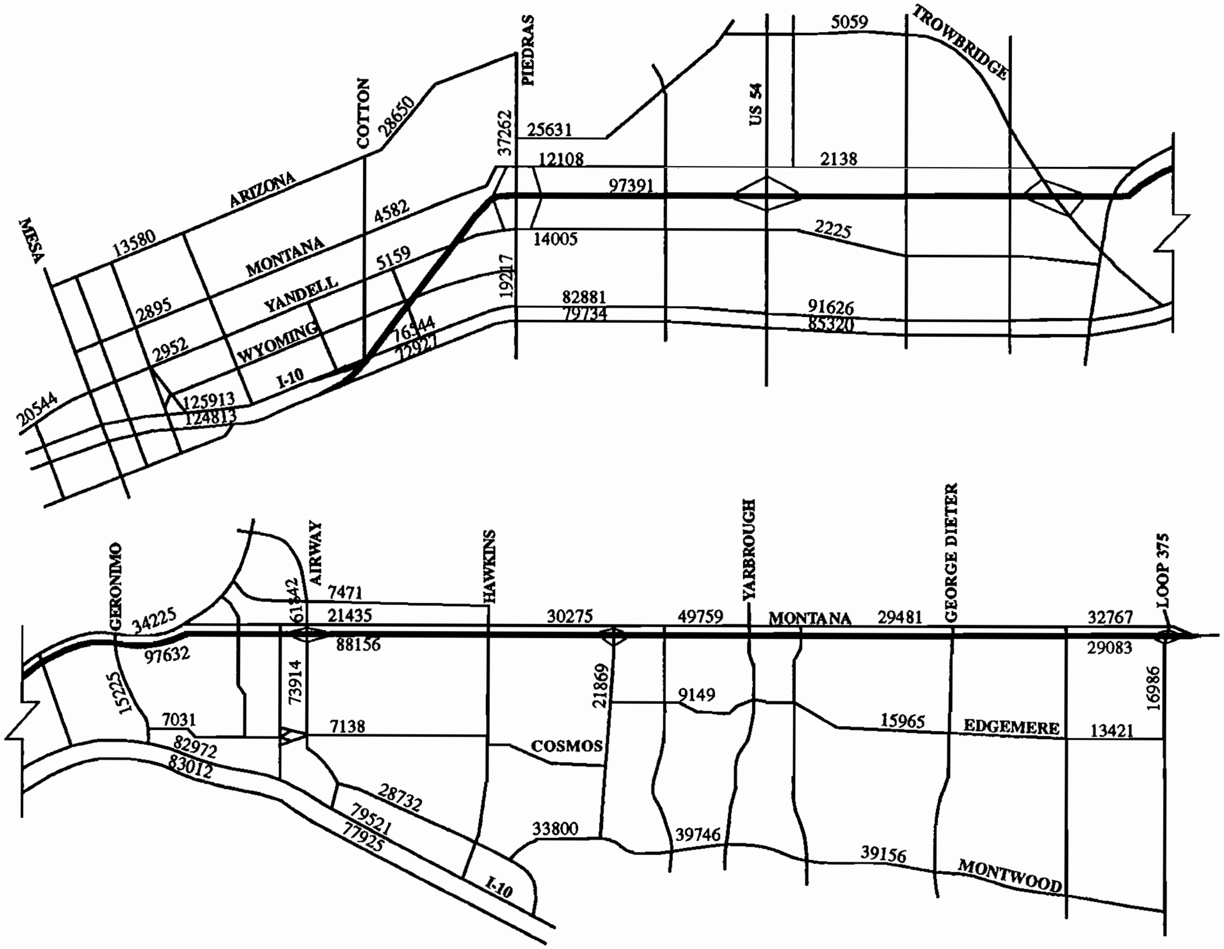

Figure B5a. Alternative 4 - Freeway to I-10 with Six Diamond Connections (Year 2015 Volumes)

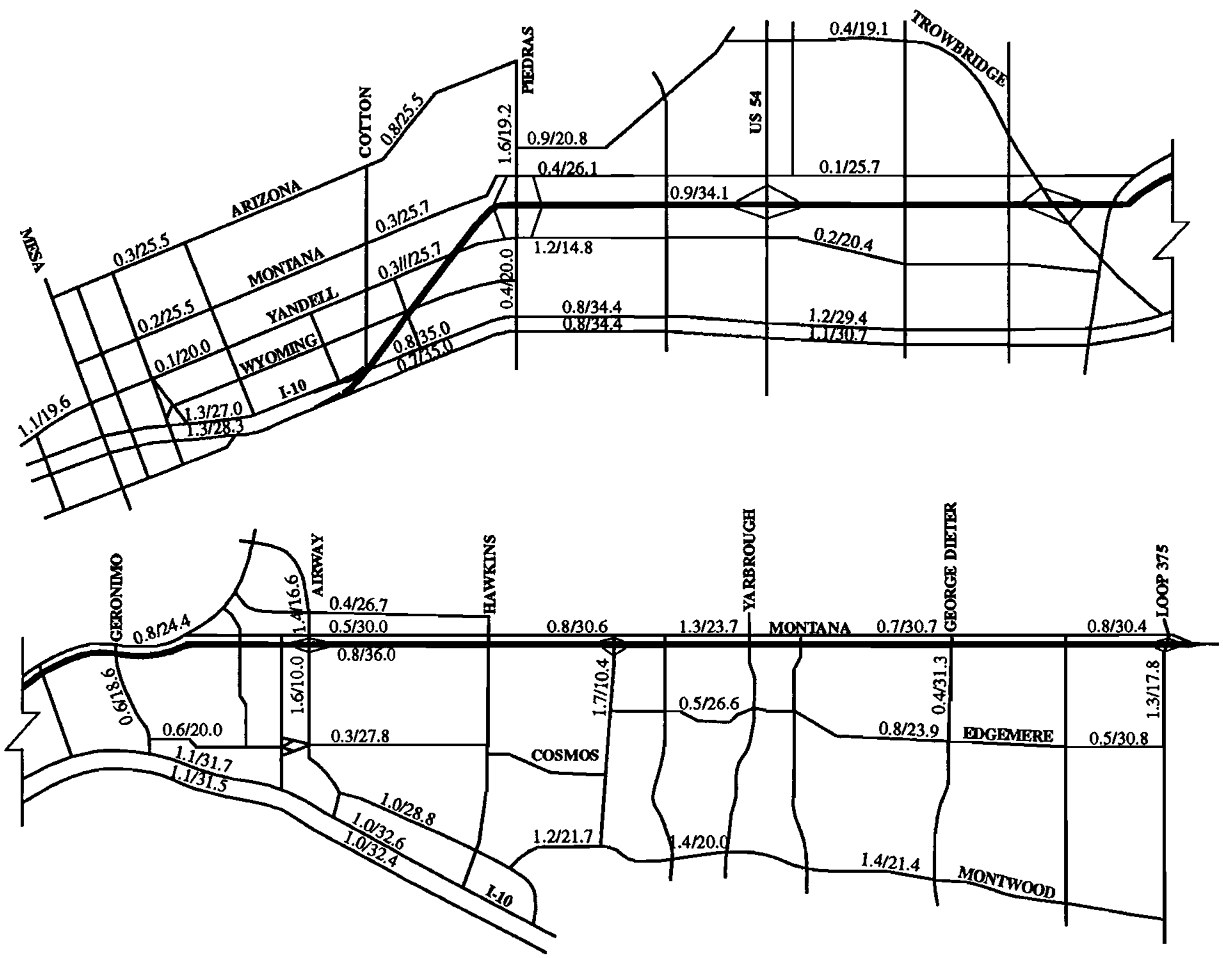

Figure B5b. Alternative 4 - Freeway to I-10 with Six Diamond Connections (V/C Ratios and Speeds)

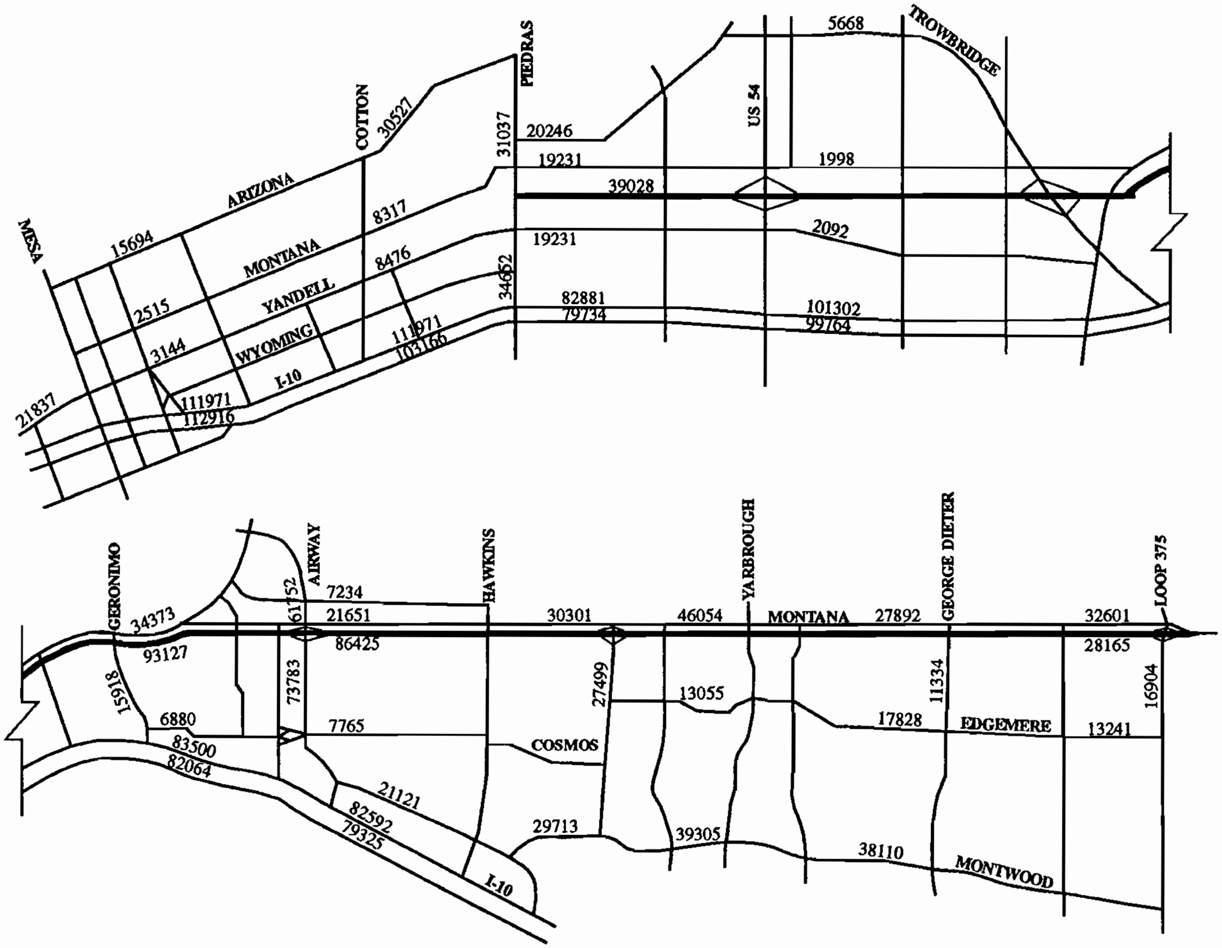

Figure B6a. Alternative 5 - Freeway Ending at Piedras with Five Diamond Connections (Year 2015 Volumes)

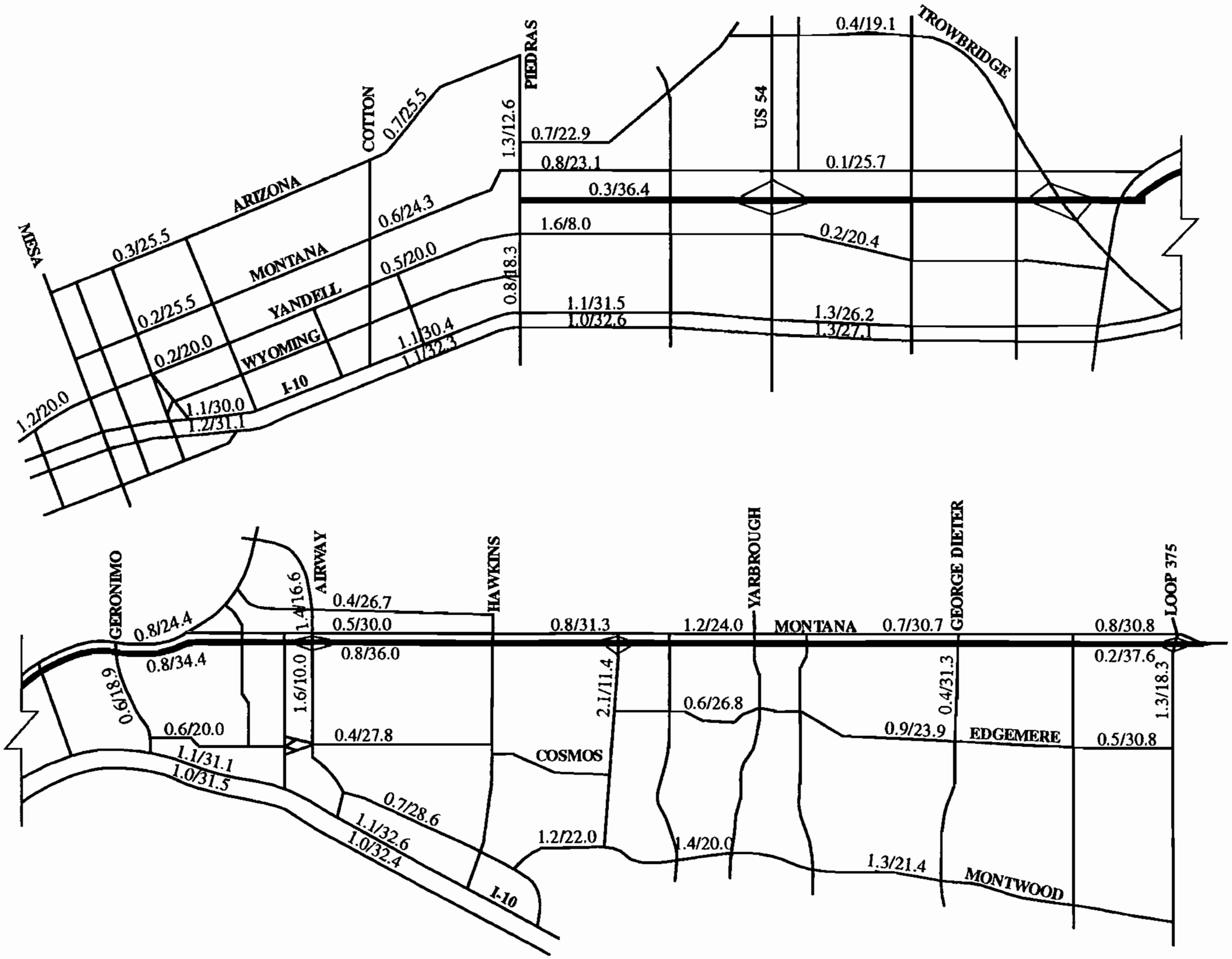

Figure B6b. Alternative 5 - Freeway Ending at Piedras with Five Diamond Connections (V/C Ratios and Speeds)

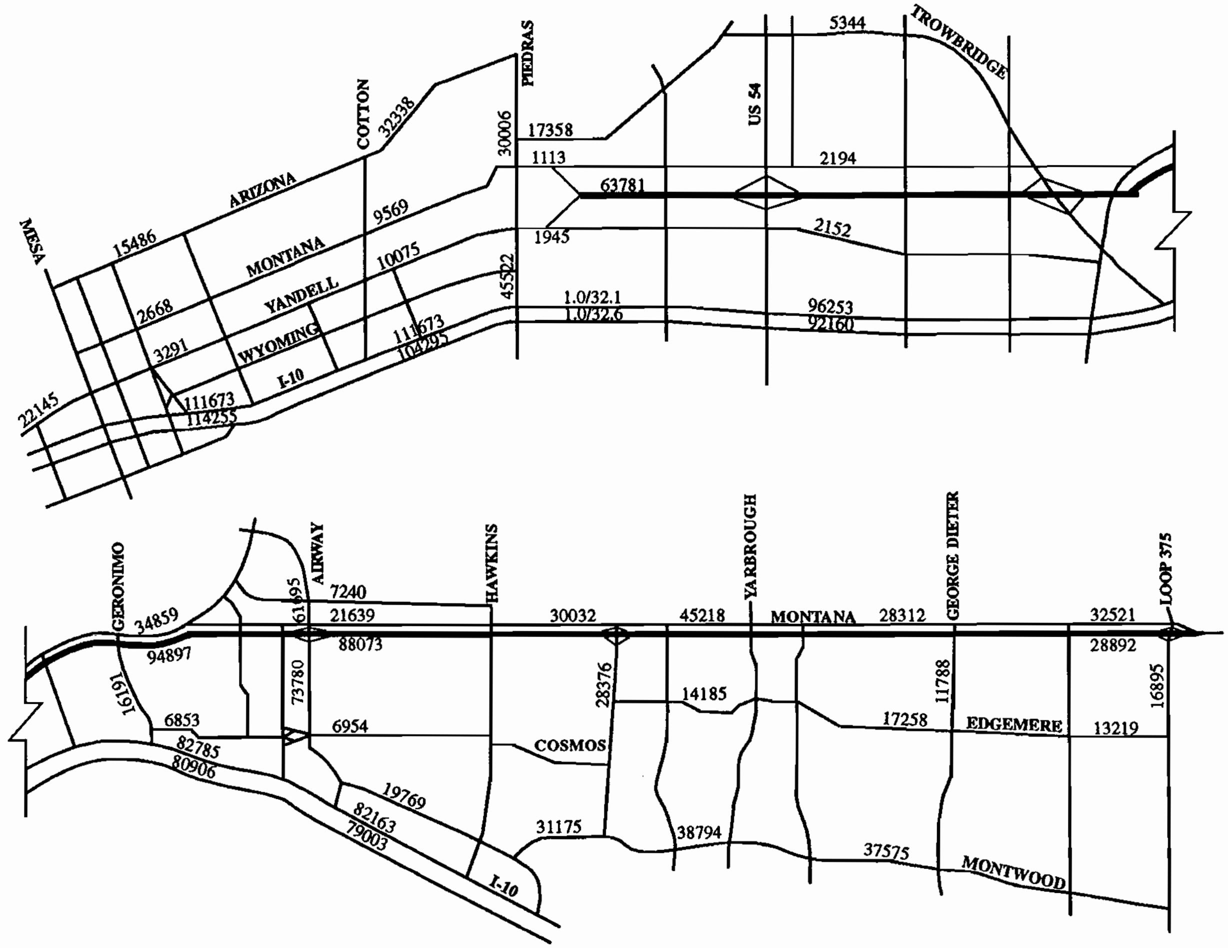

Figure B7a. Alternative 6 - Freeway Ending East of Piedras with Five Diamond Connections (Year 2015 Volumes)

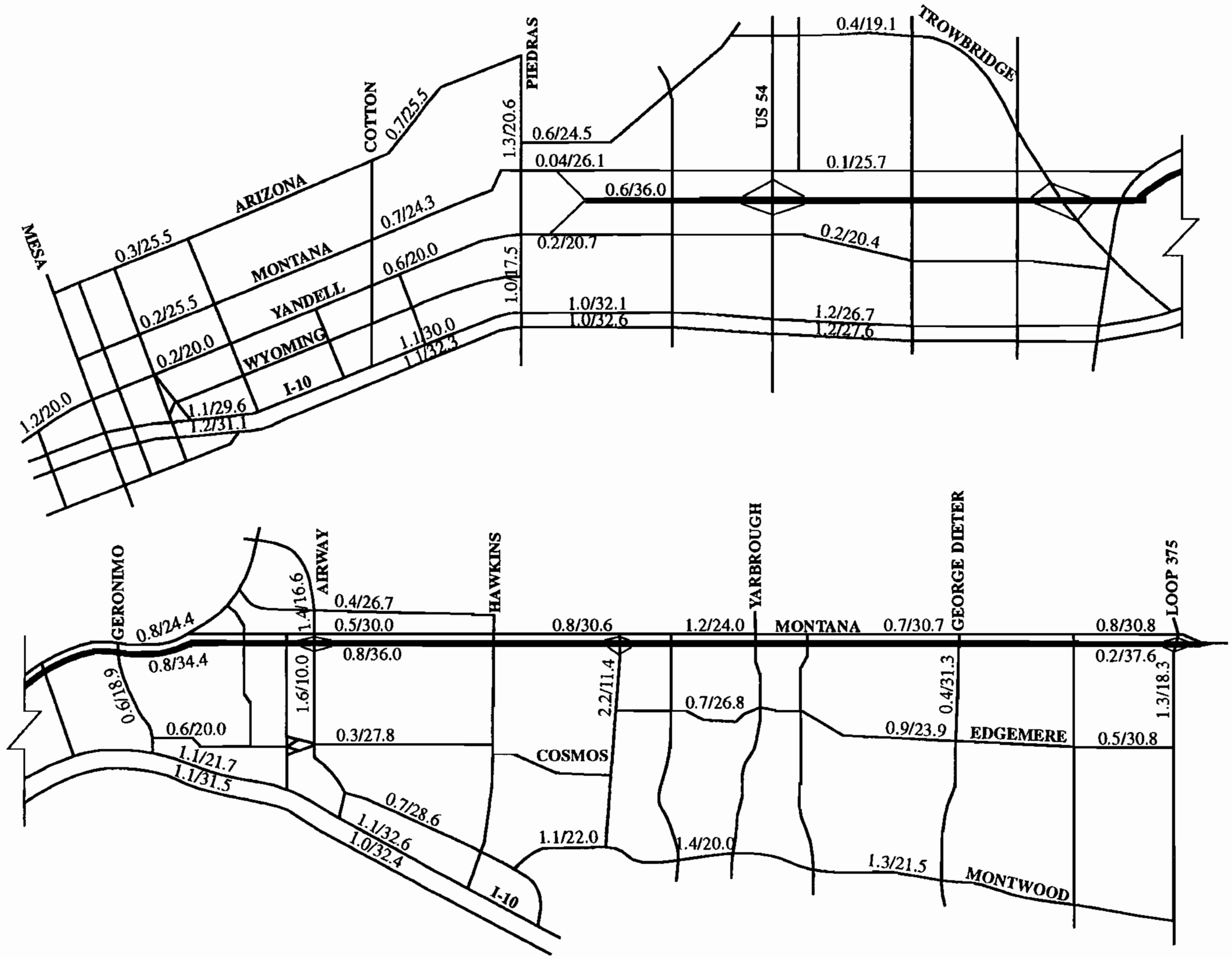

Figure B7b. Alternative 6 - Freeway Ending East of Piedras with Five Diamond Connections (V/C Ratios and Speeds)

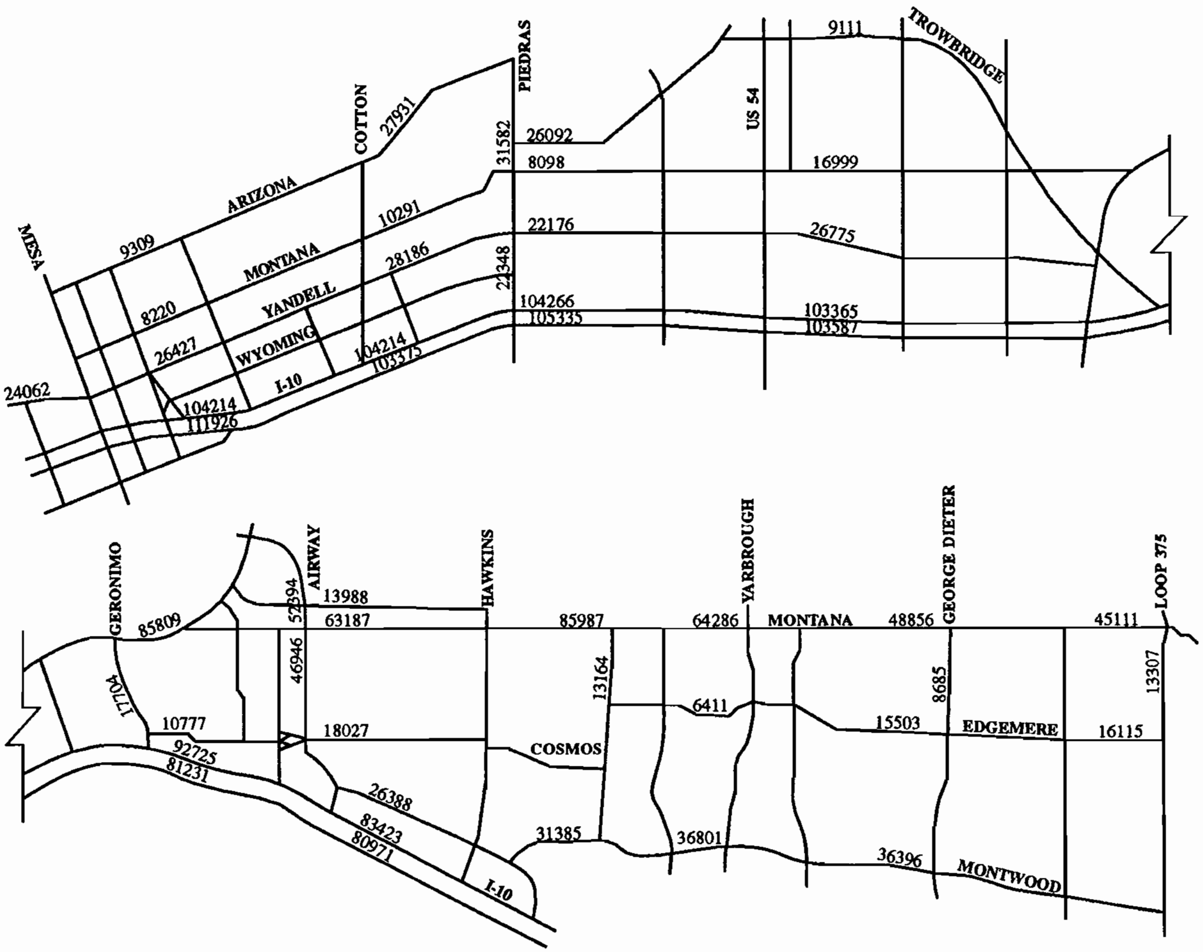

Figure B8a. Alternative 7 - Strategic Arterial with All At-Grade Intersections (Year 2015 Volumes)

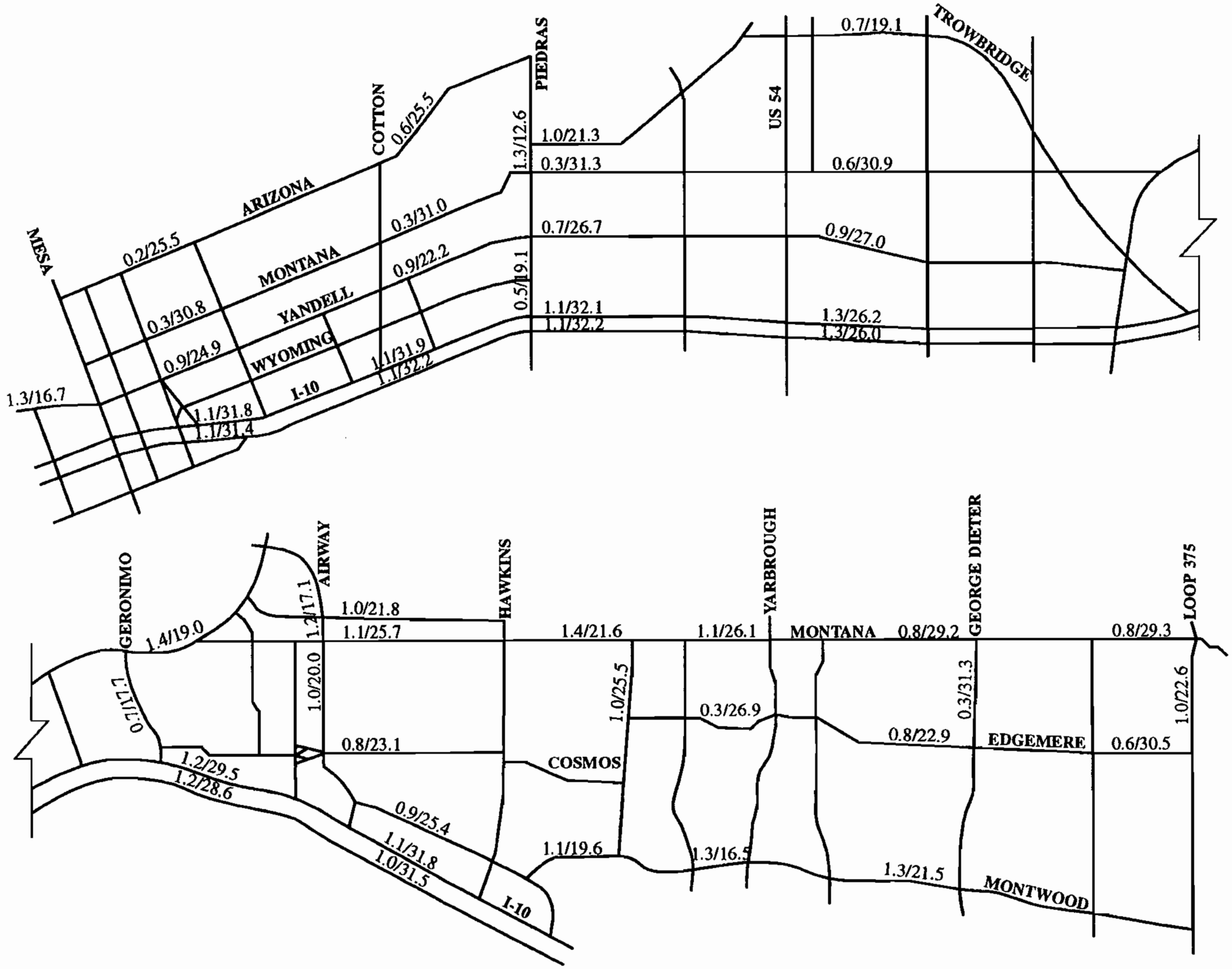

Figure B8b. Alternative 7 - Strategic Arterial with All At-Grade Intersections (V/C Ratios and Speeds)

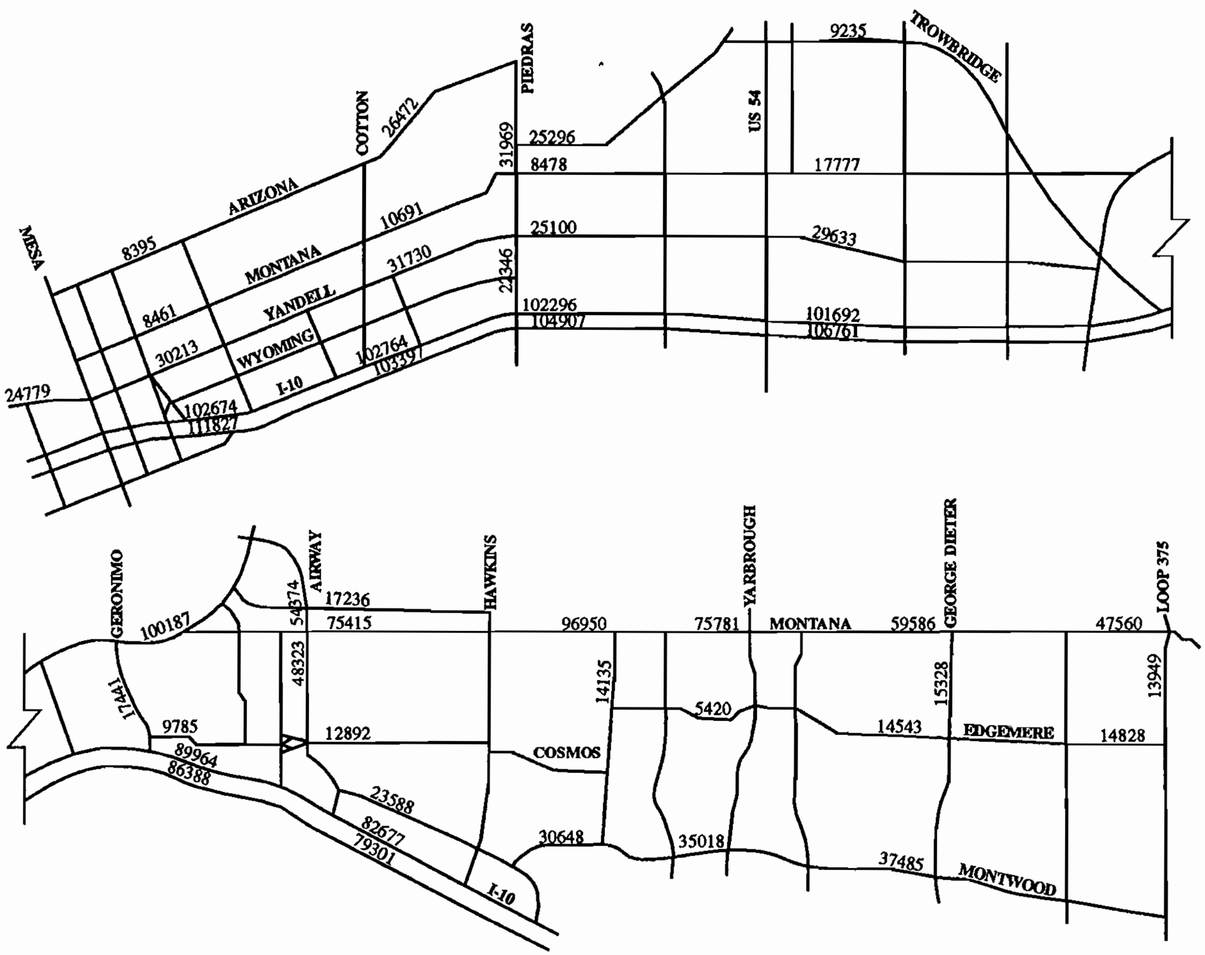

Figure B9a. Alternative 8 - Strategic Arterial with All Grade-Separated Intersections (Year 2015 Volumes)

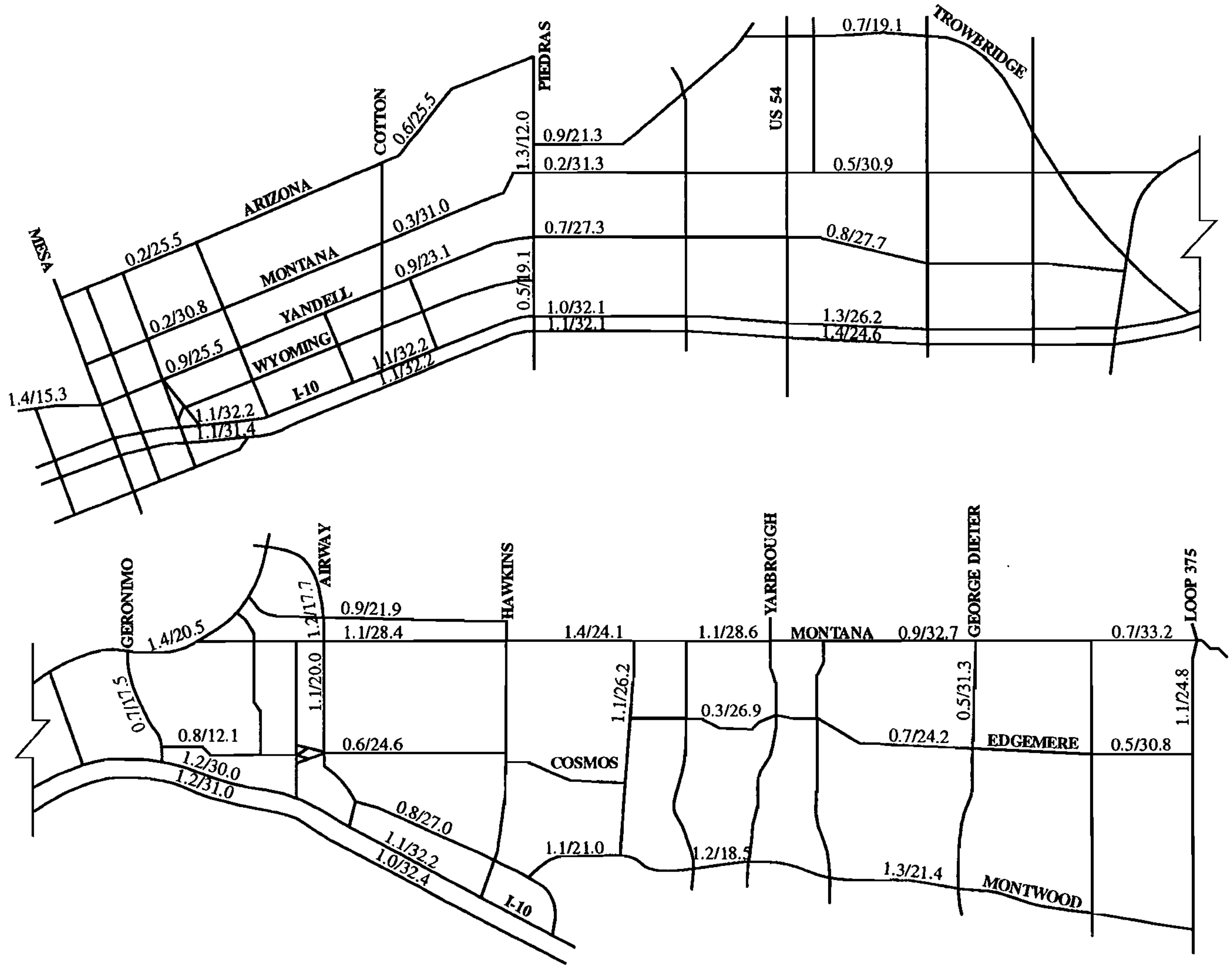

Figure B9b. Alternative 8 - Strategic Arterial with All Grade Separated Intersections (V/C Ratios and Speeds)

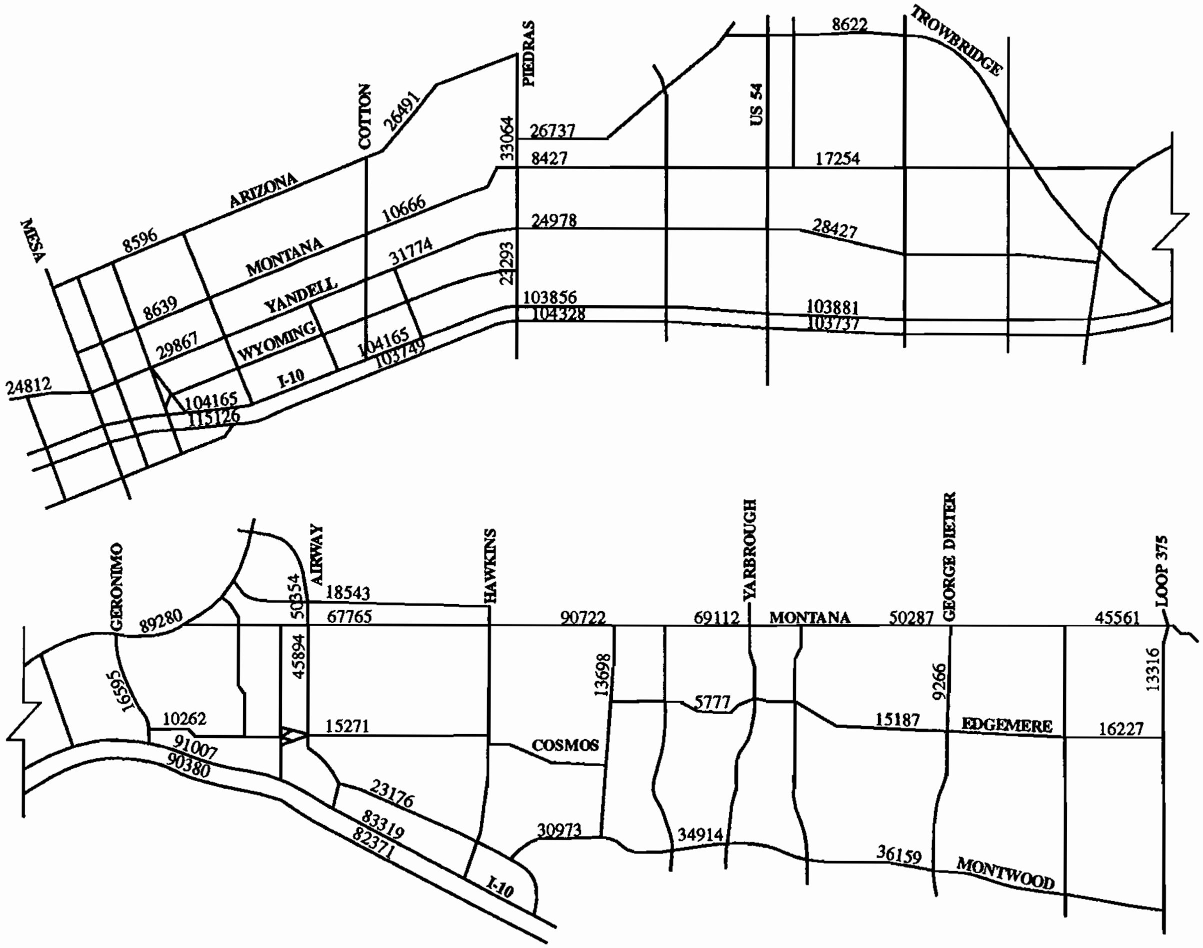

Figure B10a. Alternative 9 - Strategic Arterial with Five Grade-Separated Intersections (Year 2015 Volumes)

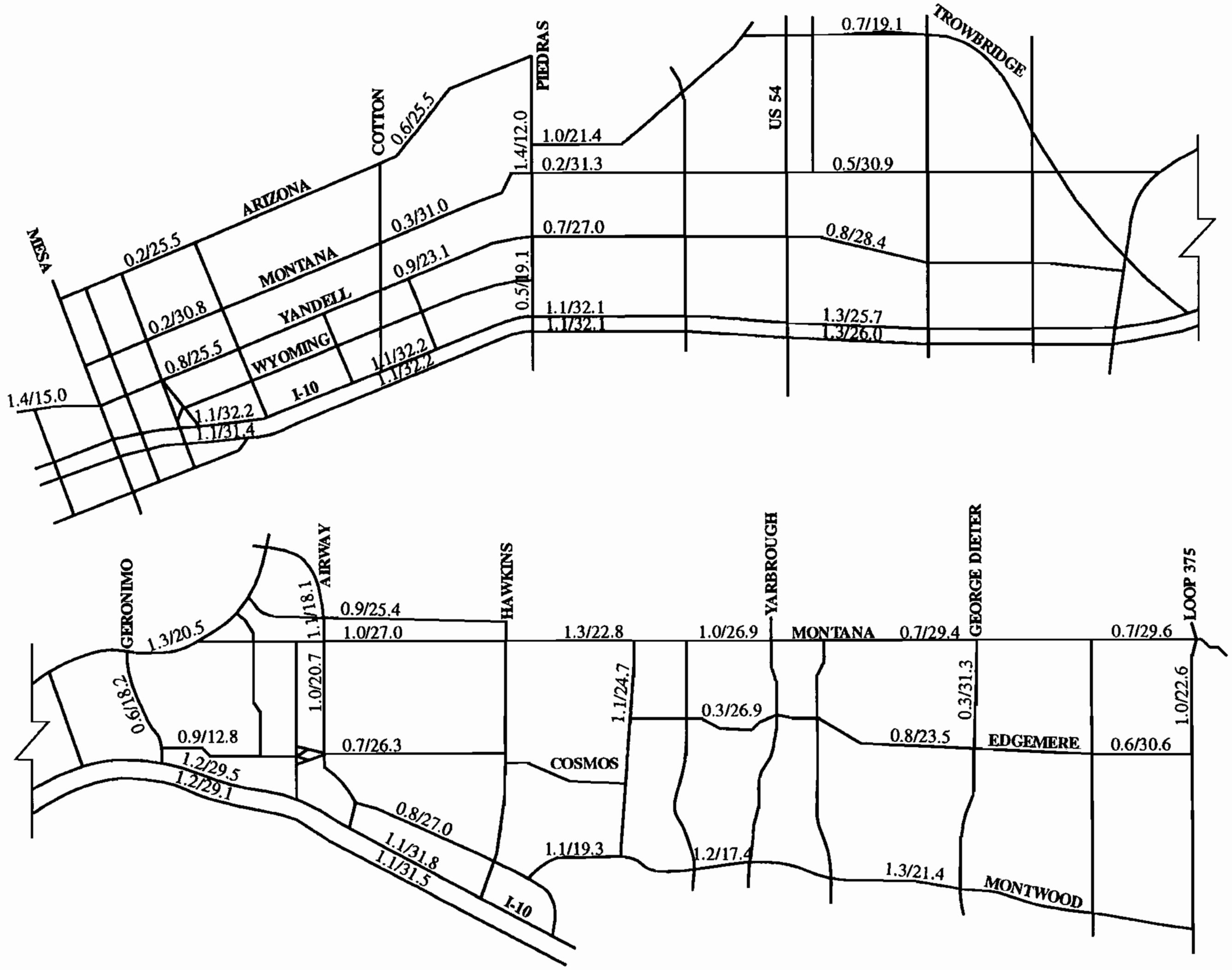

Figure B10b. Alternative 9 - Strategic Arterial with Five Grade Separated Intersections (V/C Ratios and Speeds)

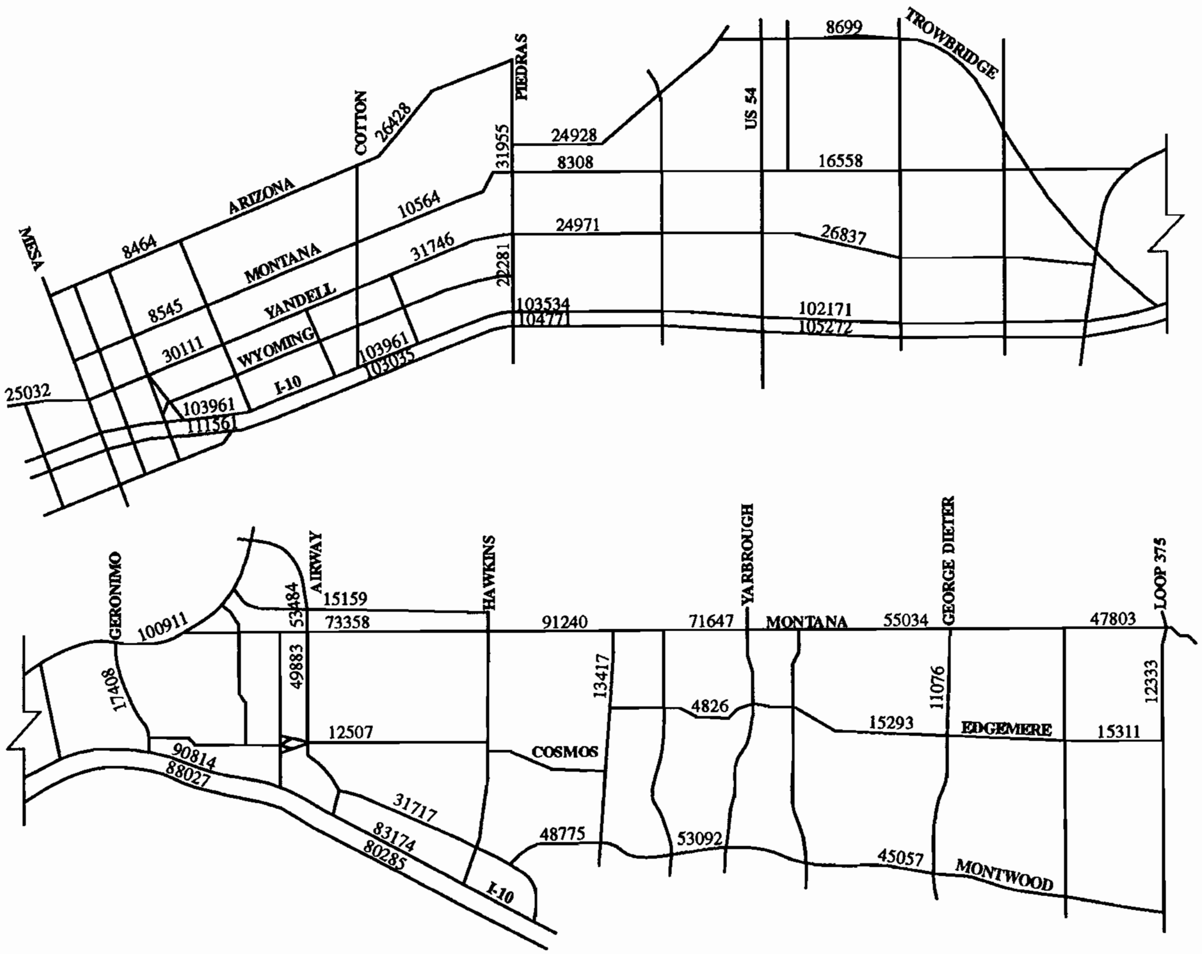

Figure B11a. Alternative 10 - Strategic Arterial Network
(Year 2015 Volumes)

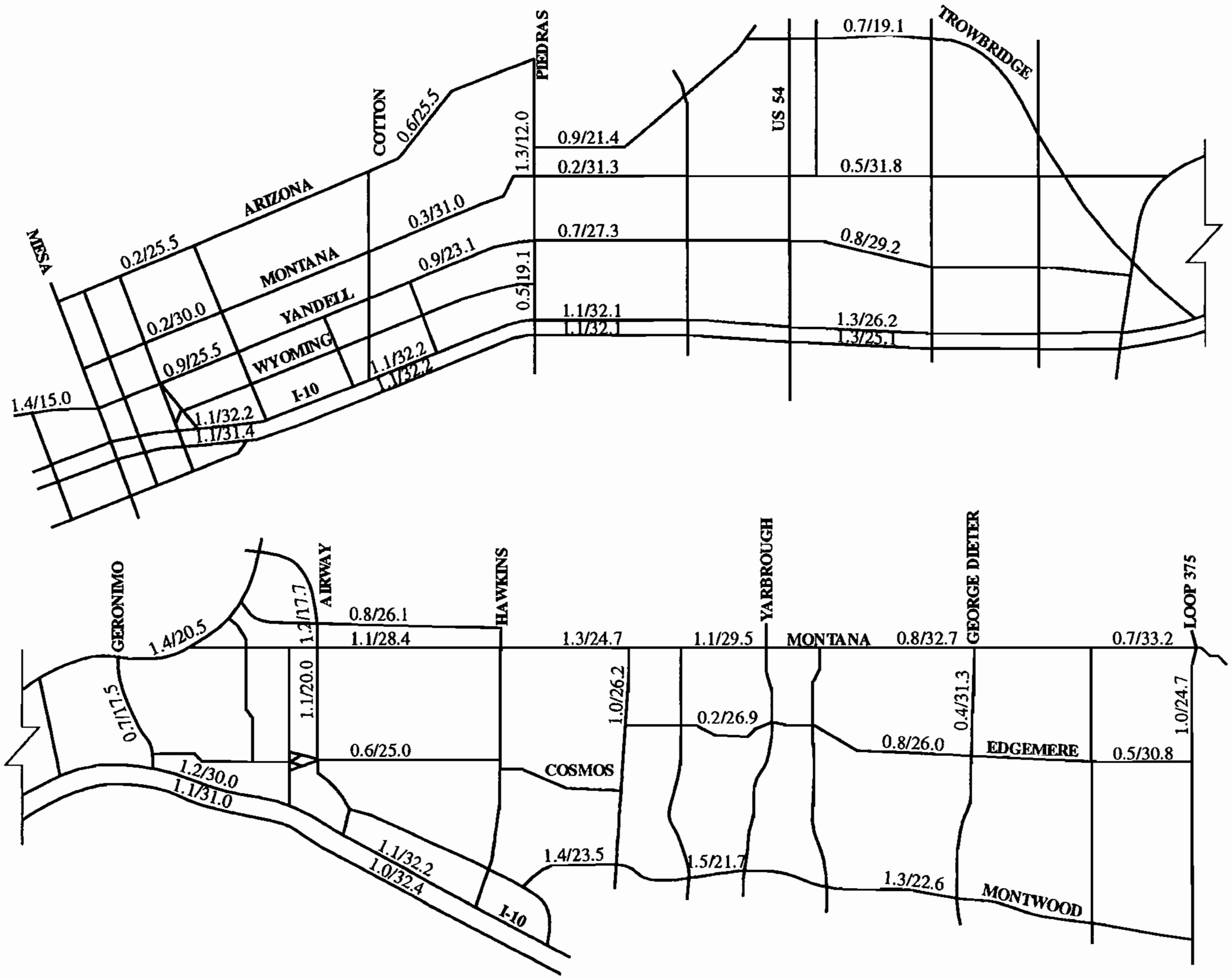

Figure B11b. Alternative 10 - Strategic Arterial Network (V/C Ratios and Speeds)

APPENDIX C

Table C1. Link List - No-Build Alternative

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	20292	1.1	20.5
767-766	Arizona West of Brown	17891	0.4	24.9
759-764	Montana West of Brown	4753	0.3	25.7
760-762	Yandell West of Brown	2036	0.1	20.0
1021-1013	I-10 at Brown	234812	1.2	30.0
780-804	Arizona East of Cotton	29930	0.7	25.0
783-790	Montana East of Cotton	15526	1.1	14.4
4051-787	Yandell East of Cotton	7732	0.4	20.0
1021-1030	I-10 at Cotton	214597	1.1	31.5
798-1287	Pershing East of Piedras	23584	0.9	21.6
796-1288	Montana East of Piedras	18415	0.7	21.9
794-1289	Yandell East of Piedras	1688	0.1	20.4
796-797	Piedras North of Montana	29171	1.2	12.6
794-793	Piedras South of Yandell	27699	0.6	19.7
8011-8019	Montana Freeway East of Piedras	N/A	N/A	N/A
1042-1035	I-10 at Piedras	216287	1.1	31.5
1361-1364	Trowbridge West of Raynolds	9359	0.7	18.7
1375-1376	Montana West of Raynolds	24407	0.9	21.7
1381-1380	Yandell West of Raynolds	4972	0.4	20.3
1002-2352	I-10 at Raynolds	215073	1.4	25.0
1496-4012	Montana East of Geronimo	64987	1.4	19.7
4013-8011	Montana Freeway at Geronimo	N/A	N/A	N/A
915-971	I-10 at Geronimo	187453	1.2	28.4
4021-1497	Geronimo South of Montana	17060	0.7	18.2
1510-3949	Montana East of Airway	54810	1.3	24.5
3948-3951	Montana Freeway at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	18721	0.9	17.0
1513-1515	Viscount East of Airway	29034	1.0	23.8
929-923	I-10 at Airway	170177	1.1	31.4
1478-3610	Boeing East of Airway	11288	0.6	26.2
1478-1510	Airway North of Montana	60347	1.3	17.0
1510-3954	Airway South of Montana	45519	1.0	20.0
2035-3941	Montana West of McRae	69155	1.8	17.7
2045-2046	Cosmos West of McRae	15931	1.9	6.9
2048-2051	Montwood West of McRae	39898	1.4	14.9
2039-3965	McRae South of Montana	11020	0.8	25.5
2081-3937	Montana West of Yarbrough	54540	1.4	23.4
2077-2091	Edgemere West of Yarbrough	10653	0.5	26.2
2071-2103	Montwood West of Yarbrough	41994	1.5	13.5
960-967	I-10 at Yarbrough	164095	1.4	24.3
3921-3923	Montana West of George Dieter	42744	1.0	29.0
2155-2186	Edgemere West of George Dieter	19233	1.0	23.8
3933-3369	George Dieter South of Montana	8339	0.3	31.3
3916-8009	Montana West of Loop 375	43406	1.0	28.3
3935-3910	Montana Freeway at Loop 375	N/A	N/A	N/A
2191-3908	Edgemere West of Loop 375	16135	0.6	30.3
2184-3374	Montwood West of Loop 375	11200	0.4	31.0
873-876	I-10 at Loop 375	92653	0.8	36.0
2199-2628	Loop 375 South of Montana	13618	1.1	22.2

Table C2. Link List - Alternative 1 - Freeway with Direct Connection to I-10 at Piedras

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	18111	1.0	20.5
767-766	Arizona West of Brown	14171	0.3	25.5
759-764	Montana West of Brown	5067	0.4	25.7
760-762	Yandell West of Brown	1655	0.1	20.0
1021-1013	I-10 at Brown	227644	1.3	28.0
780-804	Arizona East of Cotton	28224	0.6	25.0
783-790	Montana East of Cotton	13982	1.0	19.5
4051-787	Yandell East of Cotton	6640	0.4	20.0
1021-1030	I-10 Westbound at Cotton	230764	1.2	29.6
798-1287	Pershing East of Piedras	18951	0.7	24.8
796-1288	Montana East of Piedras	10066	0.5	24.7
794-1289	Yandell East of Piedras	13309	0.7	25.0
796-797	Piedras North of Montana	28760	1.2	14.1
794-793	Piedras South of Yandell	16246	0.4	20.0
8042-8019	Montana Freeway East of Piedras	100021	0.9	34.1
1042-1035	I-10 at Piedras	244202	1.3	27.7
1361-1364	Trowbridge West of Raynolds	3297	0.3	19.1
1375-1376	Montana West of Raynolds	6837	0.3	26.0
1381-1380	Yandell West of Raynolds	4710	0.2	25.4
1002-2352	I-10 at Raynolds	173192	1.2	30.7
1496-4012	Montana East of Geronimo	26367	0.6	25.1
4013-8011	Montana Freeway at Geronimo	97205	0.8	34.1
915-971	I-10 at Geronimo	166525	1.1	31.6
4021-1497	Geronimo South of Montana	13701	0.5	18.9
1510-3949	Montana East of Airway	22305	0.5	30.0
3948-3951	Montana Freeway at Airway	89150	0.8	36.0
1512-1520	Edgemere East of Airway	7119	0.3	27.8
1513-1515	Viscount East of Airway	26422	0.9	28.8
929-923	I-10 at Airway	159496	1.0	32.5
1478-3610	Boeing East of Airway	4756	0.2	26.8
1478-1510	Airway North of Montana	59154	1.3	16.6
1510-3954	Airway South of Montana	71457	1.6	12.0
2035-3941	Montana West of McRae	28357	0.7	30.9
2048-2051	Montwood West of McRae	32746	1.2	22.3
2045-2046	Cosmos West of McRae	6691	0.8	18.1
2039-3965	McRae South of Montana	28477	2.2	11.5
2081-3937	Montana West of Yarbrough	45584	1.2	23.7
2077-2091	Edgemere West of Yarbrough	13690	0.7	26.8
2071-2103	Montwood West of Yarbrough	38634	1.4	20.0
960-967	I-10 West of Yarbrough	166515	1.4	25.4
3921-3923	Montana West of George Dieter	28316	0.7	30.7
2155-2186	Edgemere West of George Dieter	18737	0.9	24.1
3933-3369	George Dieter South of Montana	11875	0.4	31.3
3916-8009	Montana West of Loop 375	32644	0.8	30.4
3917-3919	Montana Freeway at Loop 375	28191	0.2	37.6
2191-3908	Edgemere West of Loop 375	13311	0.5	30.8
2184-3374	Montwood West of Loop 375	12595	0.4	31.1
873-876	I-10 West of Loop 375	94059	0.8	35.8
2199-2628	Loop 375 South of Montana	16886	1.3	18.3

Table C3. Link List - Alternative 2 - Freeway to Piedras Connecting to a One-Way Pair

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
718-1050	Yandell Entrance to I-10	22874	1.3	12.1
767-766	Arizona West of Brown	6408	0.1	25.5
759-764	Montana West of Brown (One Way)	34296	1.0	22.9
760-762	Yandell West of Brown (One Way)	42150	1.2	25.5
1021-1013	I-10 at Brown	197390	1.0	32.3
780-804	Arizona East of Cotton	25500	0.6	25.5
783-790	Montana East of Cotton (One Way)	38590	1.1	21.1
4051-787	Yandell East of Cotton (One Way)	37085	1.1	27.3
8014-1030	I-10 at Cotton	187430	1.0	32.5
798-1287	Pershing East of Piedras	19335	0.7	23.9
796-1288	Montana East of Piedras	2977	0.1	24.7
794-1289	Yandell East of Piedras	3112	0.2	26.1
796-797	Piedras North of Montana	32374	1.4	10.9
794-793	Piedras South of Yandell	32451	0.7	19.1
8042-8019	Montana Freeway East of Piedras	82306	0.7	35.2
1042-1035	I-10 at Piedras	178188	0.9	33.0
1361-1364	Trowbridge West of Raynolds	2889	0.2	19.1
1375-1376	Montana West of Raynolds	5981	0.3	26.0
1381-1380	Yandell West of Raynolds	4225	0.2	25.4
1002-2352	I-10 at Raynolds	180009	1.2	28.5
1496-4012	Montana East of Geronimo	27144	0.6	25.1
4013-4040	Montana Freeway at Geronimo	97001	0.8	34.4
915-971	I-10 at Geronimo	165546	1.1	31.1
4021-1497	Geronimo South of Montana	14418	0.6	18.9
1510-3949	Montana East of Airway	21836	0.5	30.0
3948-8031	Montana Freeway at Airway	88856	0.8	36.0
1512-1520	Edgemere East of Airway	8584	0.4	27.8
1513-1515	Viscount East of Airway	28462	1.0	28.8
929-923	I-10 at Airway	158692	1.0	32.1
1478-3610	Boeing East of Airway	4734	0.2	26.8
1478-1510	Airway North of Montana	59669	1.3	16.6
1509-3954	Airway South of Montana	52738	1.2	20.0
2035-3941	Montana West of McRae	28297	0.7	30.9
2048-2051	Montwood West of McRae	33551	0.7	26.7
2045-2046	Cosmos West of MeRae	7077	0.8	18.3
2039-3965	McRae South of Montana	25615	2.0	11.4
2081-3937	Montana West of Yarbrough	48086	1.3	23.7
2077-2091	Edgemere West of Yarbrough	10369	0.5	26.8
2071-2103	Montwood West of Yarbrough	39791	1.4	20.0
960-967	I-10 West of Yarbrough	164424	1.4	25.2
3921-3923	Montana West of George Dieter	28865	0.7	30.7
2155-2186	Edgemere West of George Dieter	17071	0.8	24.1
3933-3369	George Dieter South of Montana	12609	0.4	31.3
3916-8009	Montana West of Loop 375	32457	0.8	30.4
3917-3919	Montana Freeway Westbound at Loop 375	28468	0.2	37.6
2191-3908	Edgemere West of Loop 375	13315	0.5	30.8
2184-3374	Montwood west of Loop 375	12173	0.4	31.0
873-876	I-10 west of Loop 375	96114	0.8	35.8
2199-2628	Loop 375 South of Montana	17118	1.3	18.0

Table C4. Link List - Alternative 3 - Strategic Arterial with Montana/Yandell One-Way Pair

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	22807	1.3	12.9
767-766	Arizona West of Brown	5032	0.1	25.5
759-764	Montana West of Brown (One-Way)	32501	0.9	28.2
760-762	Yandell West of Brown (One-Way)	28789	0.8	23.2
1021-1013	I-10 at Brown	212529	1.1	32.0
780-804	Arizona East of Cotton	23718	0.5	25.5
783-790	Montana East of Cotton (One Way)	33733	1.0	26.9
4051-787	Yandell East of Cotton (One Way)	34031	1.0	19.4
1021-1030	I-10 at Cotton	196825	1.0	33.1
798-1287	Pershing East of Piedras	22968	0.8	20.8
796-1288	Montana East of Piedras (One Way)	30446	0.9	29.1
794-1289	Yandell East of Piedras (One Way)	28155	0.8	22.7
796-797	Piedras North of Montana	32933	1.4	10.0
794-793	Piedras South of Yandell	19776	0.4	20.0
8011-8019	Montana Freeway East of Piedras	N/A	N/A	N/A
1042-1035	I-10 at Piedras	199935	1.0	32.6
1361-1364	Trowbridge West of Raynolds	4648	0.4	19.1
1375-1376	Montana West of Raynolds (One Way)	33920	1.0	26.9
1381-1380	Yandell West of Raynolds (One Way)	29371	0.8	23.2
1002-2352	I-10 at Raynolds	202150	1.3	26.4
1496-4012	Montana East of Geronimo	92981	1.3	21.9
4013-8011	Montana Freeway at Geronimo	N/A	N/A	N/A
915-971	I-10 at Geronimo	179392	1.2	30.0
4021-1497	Geronimo South of Montana	16805	0.6	18.0
1510-3949	Montana East of Airway	74647	1.1	27.0
3948-3951	Montana Freeway at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	13768	0.6	22.0
1513-1515	Viscount East of Airway	23108	0.8	27.3
929-923	I-10 at Airway	165675	1.1	31.9
1478-3610	Boeing East of Airway	11676	0.6	26.6
1478-1510	Airway North of Montana	54278	1.2	18.1
1510-3954	Airway South of Montana	44517	1.0	21.4
2035-3941	Montana West of McRae	95200	1.4	24.3
2048-2051	Montwood West of McRae	31007	1.1	21.0
2045-2046	Cosmos West of McRae	9639	1.1	9.9
2039-3965	McRae South of Montana	13710	1.1	26.0
2081-3937	Montana West of Yarbrough	74627	1.1	29.0
2077-2091	Edgemere West of Yarbrough	5550	0.3	26.9
2071-2103	Montwood West of Yarbrough	38917	1.4	19.2
960-967	I-10 West of Yarbrough	166326	1.4	25.0
3921-3923	Montana West of George Dieter	58824	0.9	32.5
3933-3369	George Dieter South of Montana	15318	0.5	31.3
2155-2186	Edgemere West of George Dieter	14310	0.7	24.4
2196-2195	Montwood West of George Dieter	39591	1.4	21.2
3916-8009	Montana West of Loop 375	47686	0.7	33.2
3935-3910	Montana Freeway at Loop 375	N/A	N/A	N/A
2191-3908	Edgemere West of Loop 375	14832	0.5	30.8
2184-3374	Montwood West of Loop 375	11963	0.4	31.0
873-876	I-10 West of Loop 375	90250	0.8	35.8
2199-2628	Loop 375 South of Montana	14071	1.1	25.0

Table C5. Link List - Alternative 4 - Strategic Arterial with Wyoming/Yandell One-Way Pair

(Year 2015 Traffic)

NODES	LINK	VOLUME	V/C	SPEED
712-1050	Yandell Entrance to I-10	22526	1.3	15.8
767-766	Arizona West of Brown	8743	0.2	25.5
761-4043	Wyoming West of Brown (One Way)	21972	0.6	30.0
760-762	Yandell West of Brown (One Way)	28570	0.8	24.9
1021-1013	I-10 at Brown	213606	1.1	32.0
780-804	Arizona East of Cotton	23520	0.5	25.5
786-4045	Wyoming East of Cotton (One Way)	30255	0.9	26.0
4051-787	Yandell East of Cotton (One Way)	32910	0.9	22.2
1021-1030	I-10 at Cotton	193705	1.0	33.3
798-1287	Pershing East of Piedras	21673	0.8	22.1
796-1288	Montana East of Piedras (One Way)	28580	0.8	27.9
794-1289	Yandell East of Piedras (One Way)	27694	0.8	27.4
796-797	Piedras North of Montana	30614	1.3	11.4
794-793	Piedras South of Yandell	26133	0.6	19.1
8042-8019	Montana Freeway East of Piedras	N/A	N/A	N/A
1042-1035	I-10 at Piedras	196975	1.0	32.9
1361-1364	Trowbridge West of Raynolds	5147	0.4	19.1
1375-1376	Montana West of Raynolds (One Way)	31045	0.9	26.0
1381-1380	Yandell West of Raynolds (One Way)	30328	0.9	27.5
1002-2352	I-10 at Raynolds	203429	1.3	26.4
1496-4012	Montana East of Geronimo	91757	1.3	21.9
4013-8011	Montana Freeway at Geronimo	N/A	N/A	N/A
915-971	I-10 at Geronimo	178865	1.2	30.3
4021-1497	Geronimo South of Montana	18727	0.7	16.0
1510-3949	Montana East of Airway	74538	1.1	27.0
3948-3951	Montana Freeway at Airway	N/A	N/A	N/A
1512-1520	Edgemere East of Airway	13656	0.6	22.8
1513-1515	Viscount East of Airway	22940	0.8	27.3
929-923	I-10 at Airway	165413	1.1	31.9
1478-3610	Boeing East of Airway	11892	0.6	26.6
1478-1510	Airway North of Montana	54208	1.2	17.7
1510-3954	Airway South of Montana	43844	1.0	21.4
2035-3941	Montana West of McRae	95029	1.4	24.3
2048-2051	Montwood West of McRae	30543	1.1	21.0
2045-2046	Cosmos West of McRae	9706	1.1	9.9
2039-3965	McRae South of Montana	13502	1.0	26.2
2081-3937	Montana West of Yarbrough	74269	1.1	29.0
2077-2091	Edgemere West of Yarbrough	5729	0.3	26.9
2071-2103	Montwood West of Yarbrough	34639	1.2	18.8
960-967	I-10 West of Yarbrough	169627	1.4	25.0
3921-3923	Montana West of George Dieter	58944	0.9	32.5
3933-3369	George Dieter South of Montana	15409	0.5	31.3
2155-2186	Edgemere West of George Dieter	14325	0.7	24.6
2196-2195	Montwood West of George Dieter	38420	1.4	21.4
3916-8009	Montana West of Loop 375	47687	0.7	33.2
3917-3919	Montana Freeway at Loop 375	N/A	N/A	N/A
2191-3908	Edgemere West of Loop 375	14847	0.5	30.8
2184-3374	Montwood West of Loop 375	10938	0.4	31.0
873-876	I-10 West of Loop 375	88267	0.8	36.0
2199-2628	Loop 375 South of Montana	13919	1.1	25.0

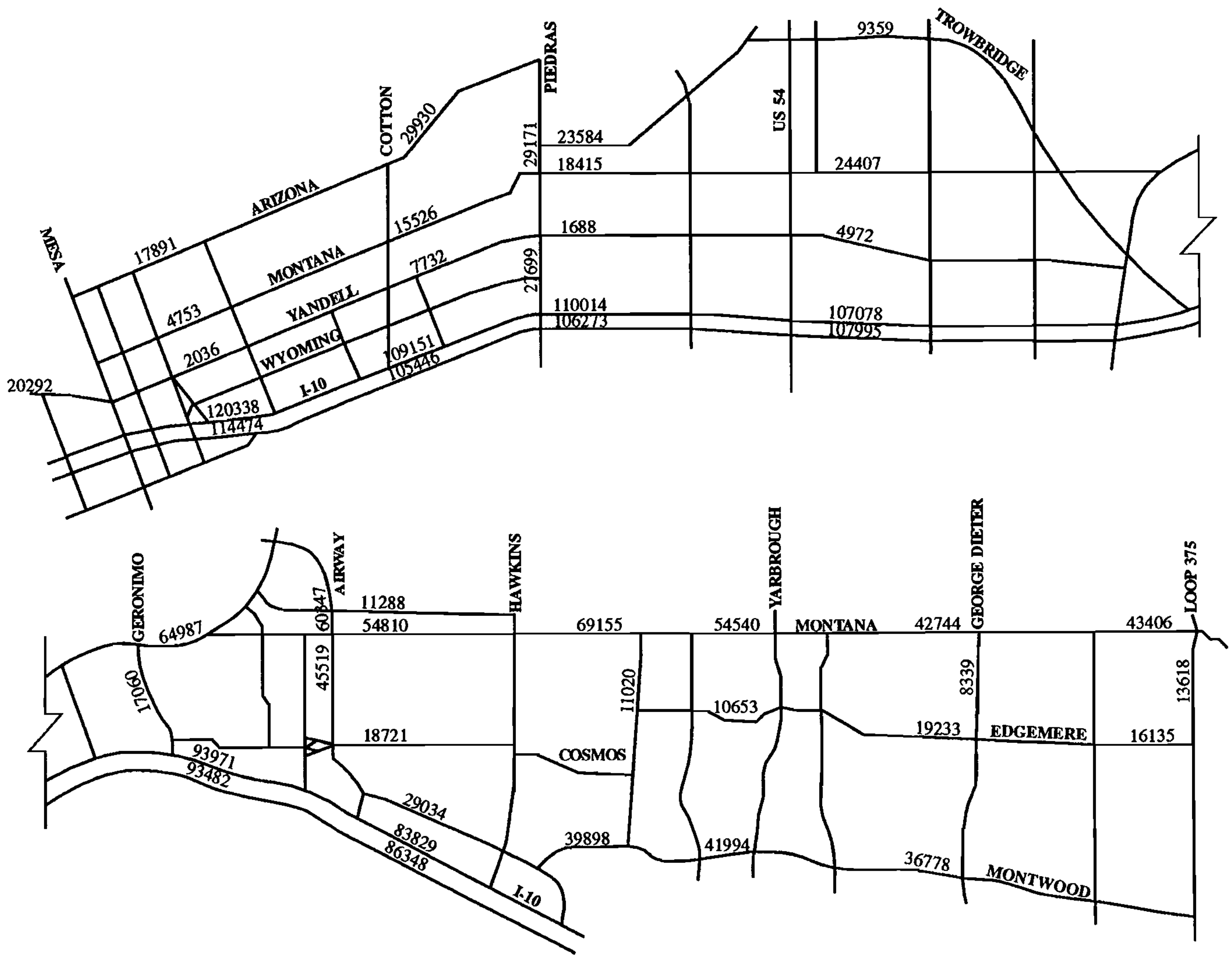

Figure C1a. No-Build Alternative (Year 2015 Volumes)

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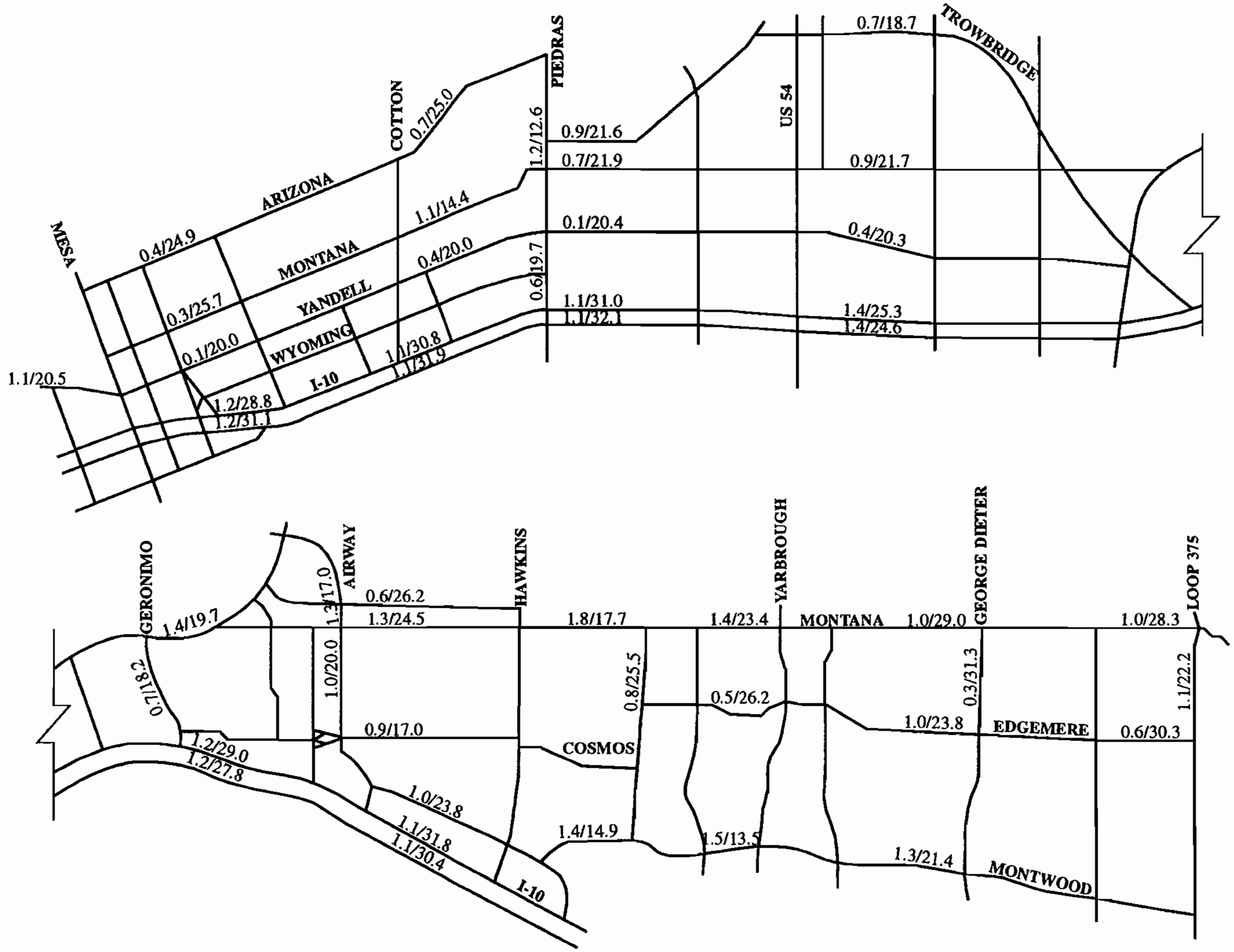

Figure C1b. No-Build Alternative
(V/C Ratios and Speeds)

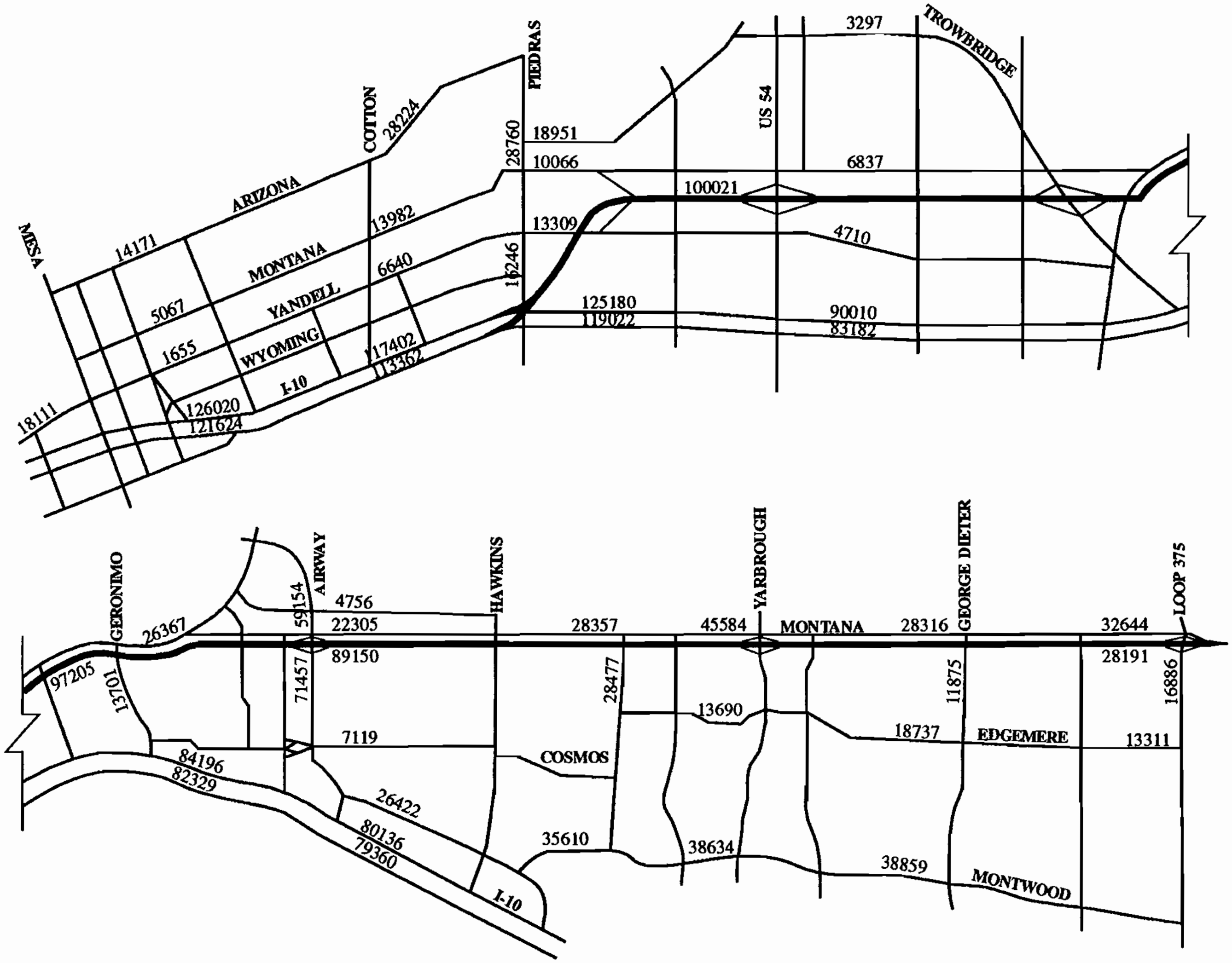

Figure C2a. Alternative 1 - Freeway with Direct Connection to I-10 at Piedras (Year 2015 Volumes)

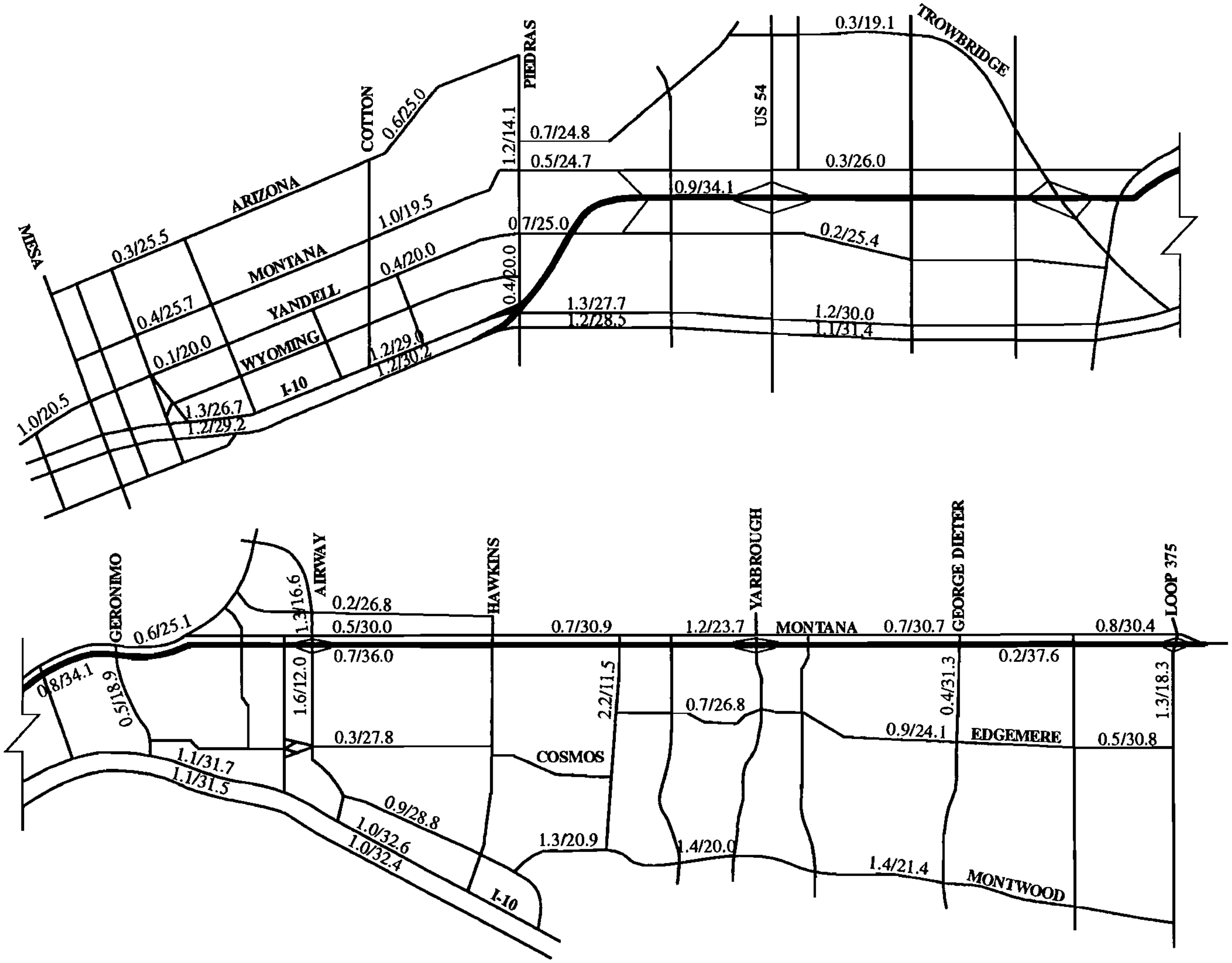

Figure C2b. Alternative 1 - Freeway with Direct Connection to I-10 at Piedras (V/C Ratios and Speeds)

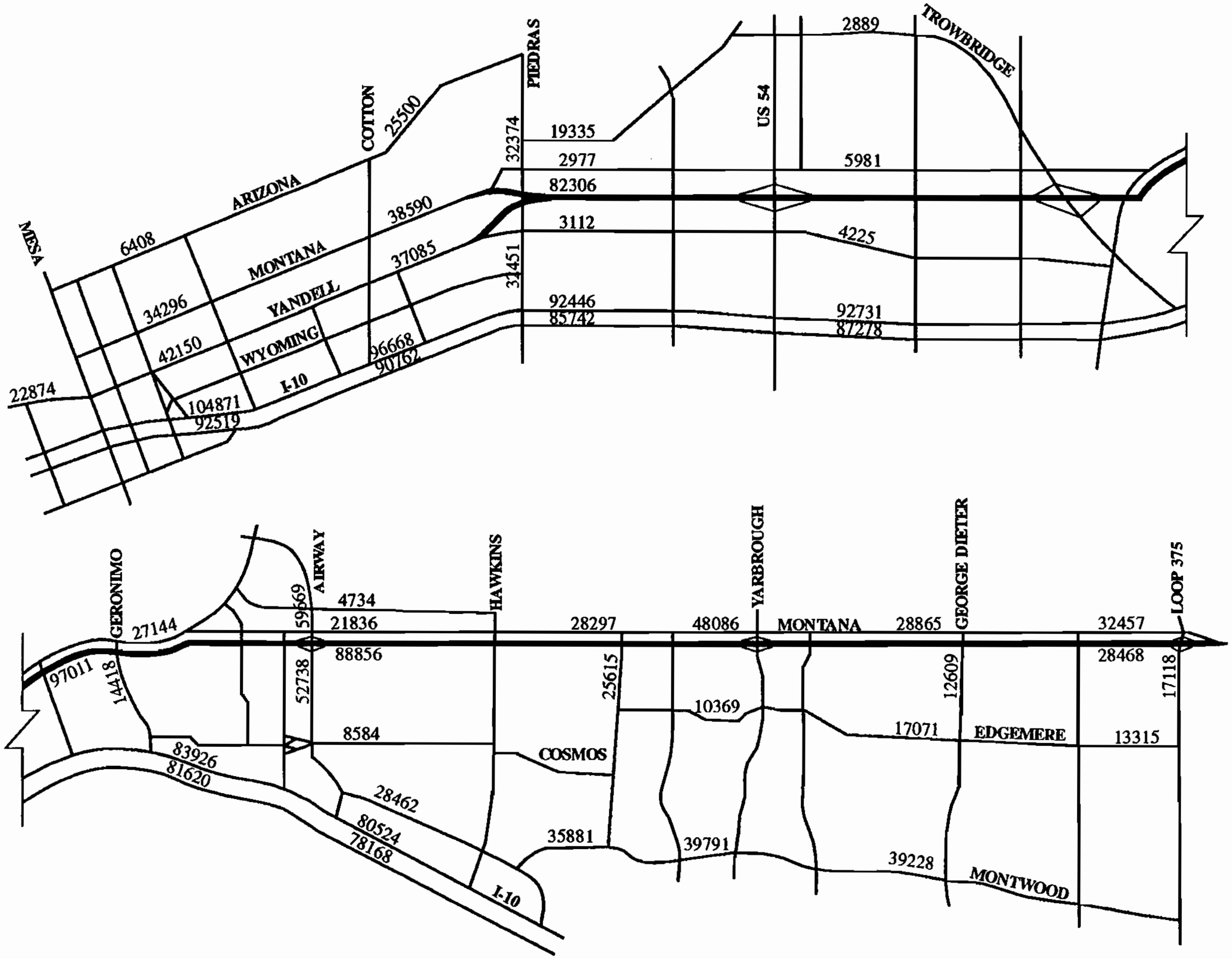

Figure C3a. Alternative 2 - Freeway to Piedras Connecting to a One-Way Pair (Year 2015 Volumes)

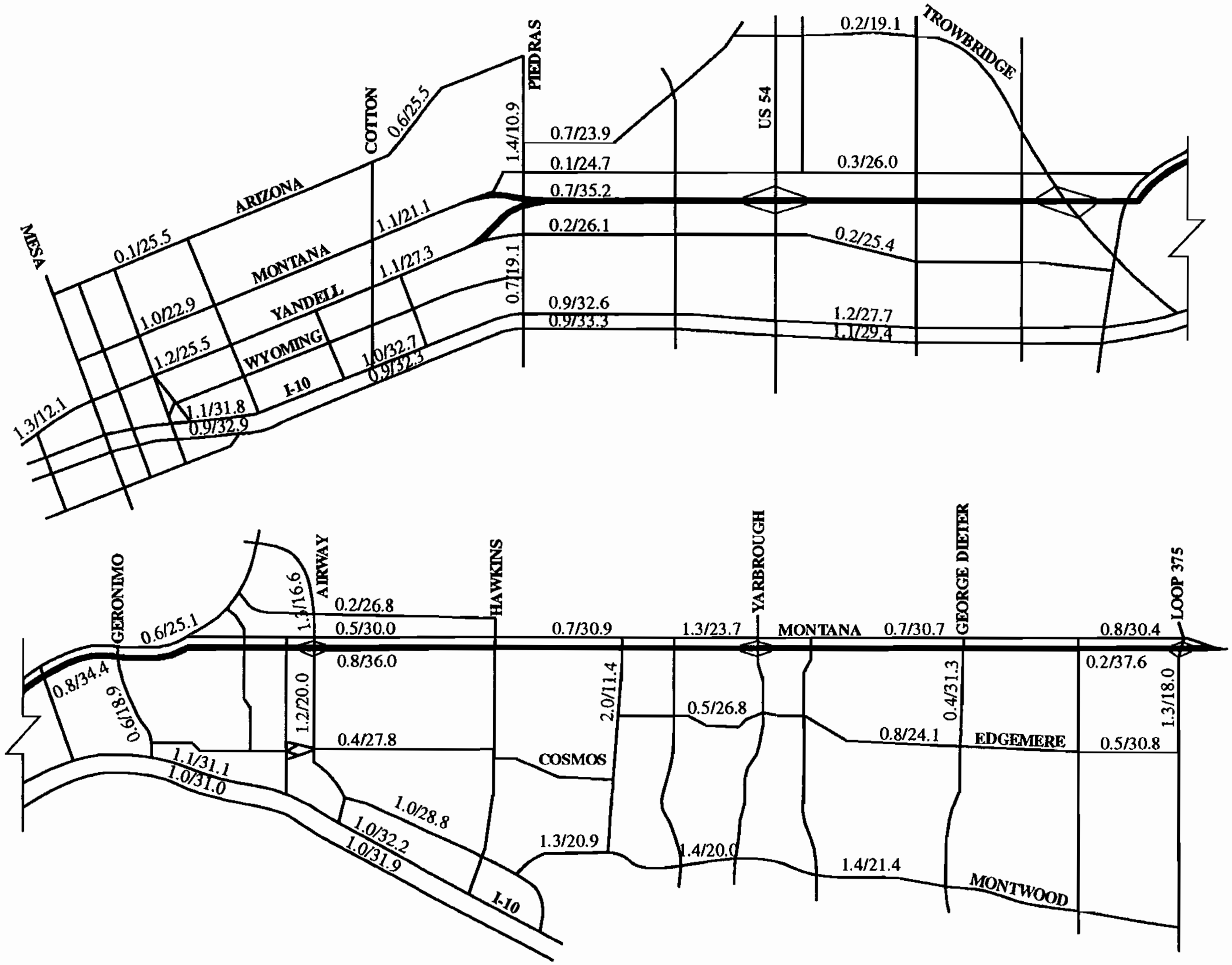

Figure C3b. Alternative 2 - Freeway to Piedras Connecting to a One-Way Pair (V/C Ratios and Speeds)

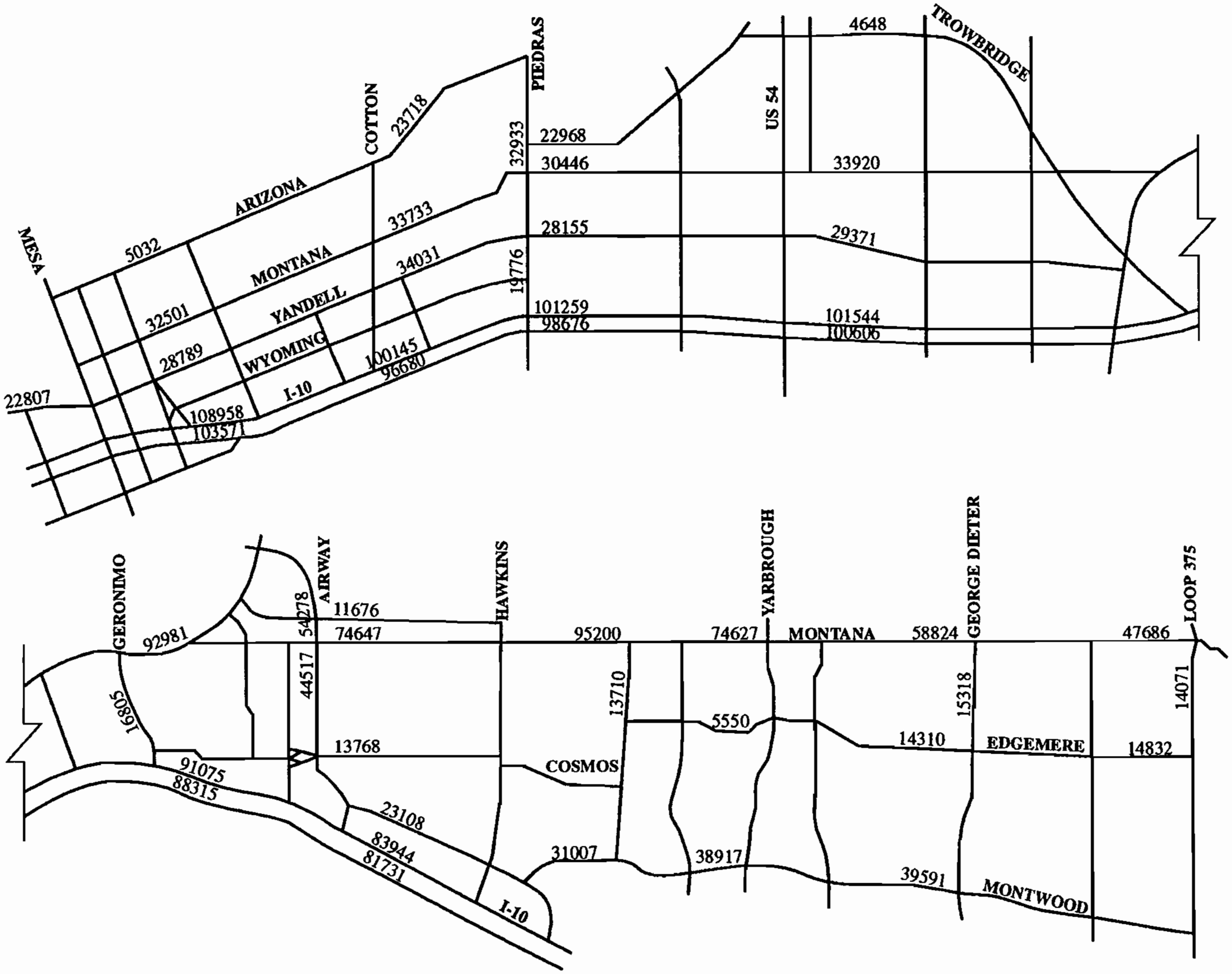

Figure C4a. Alternative 3 - Strategic Arterial with Montana/Yandell One-Way Pair (Year 2015 Volumes)

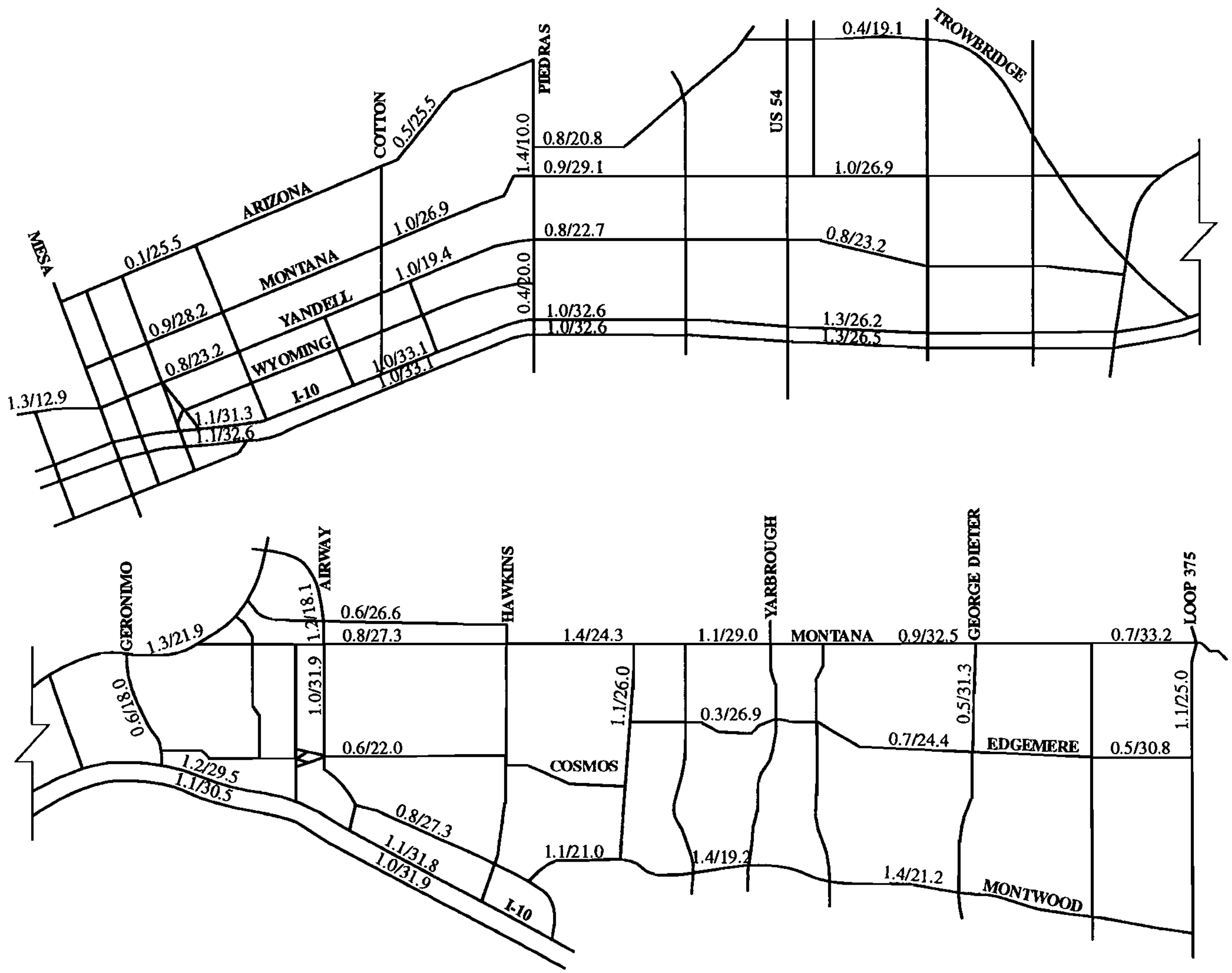

Figure C4b. Alternative 3 - Strategic Arterial with Montana/Yandell One-Way Pair (V/C Ratios and Speeds)

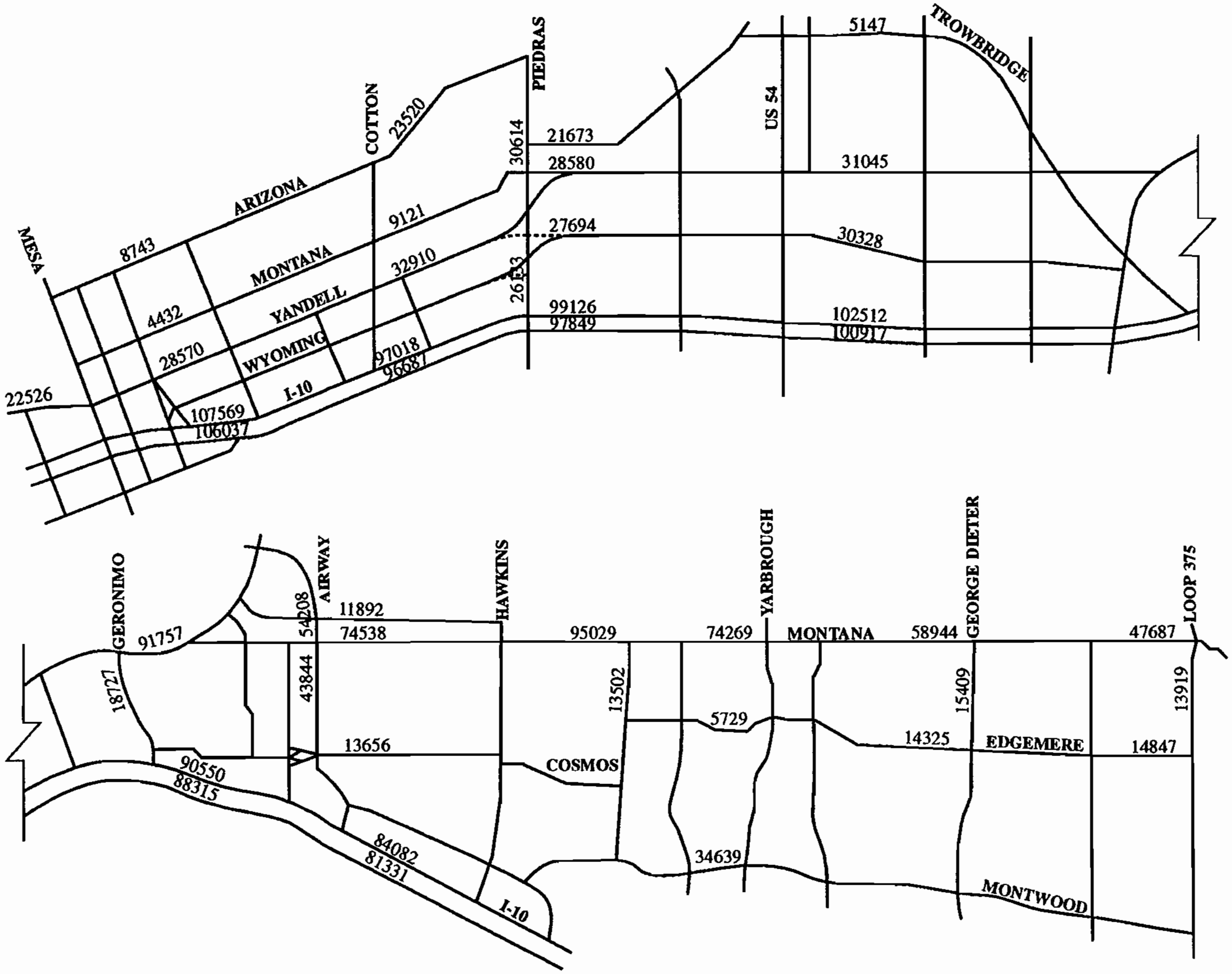

Figure C5a. Alternative 4 - Strategic Arterial with Wyoming/Yandell One-Way Pair (Year 2015 Volumes)

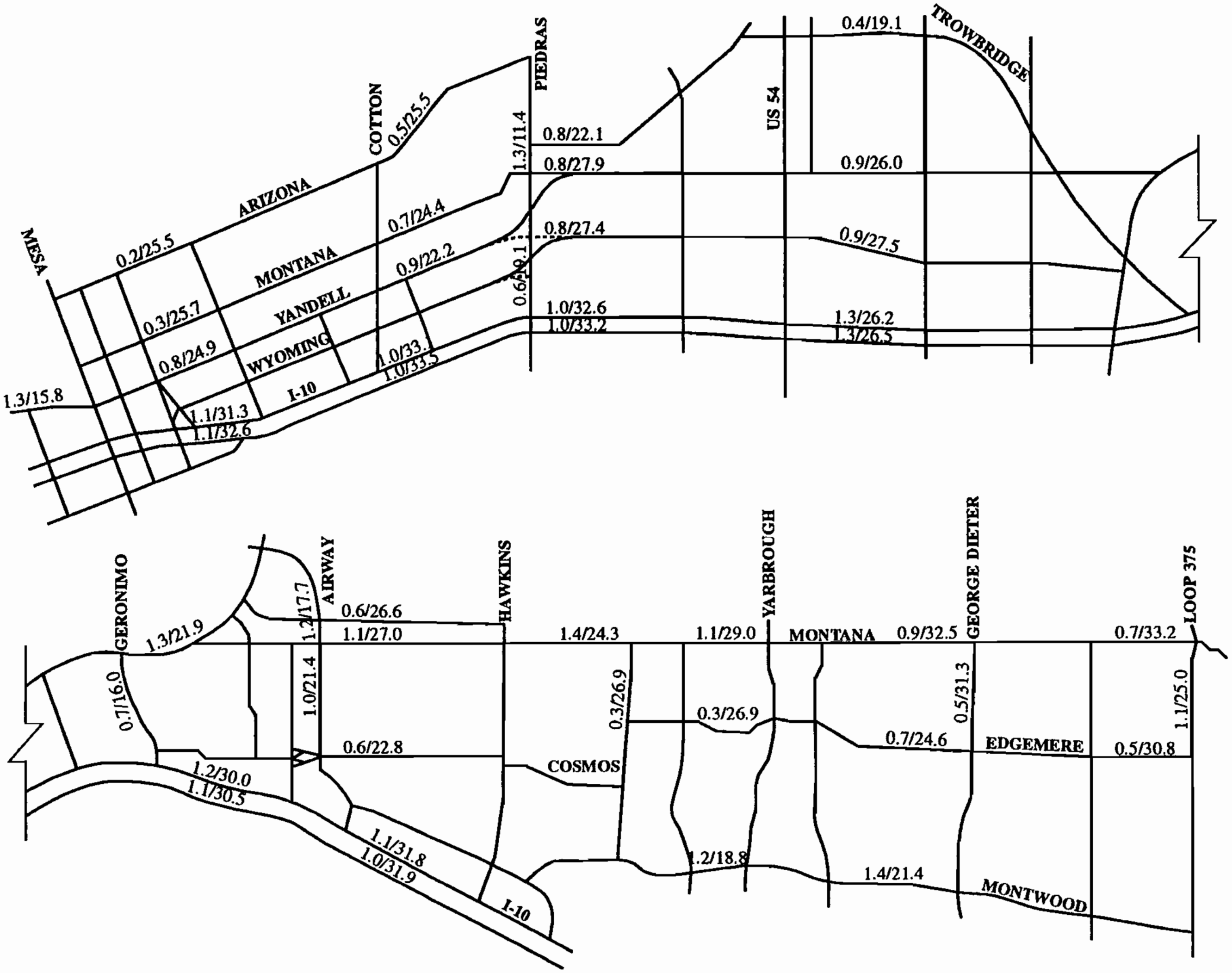

Figure C5b. Alternative 4 - Strategic Arterial with Wyoming/Yandell One-Way Pair (V/C Ratios and Speeds)

APPENDIX D

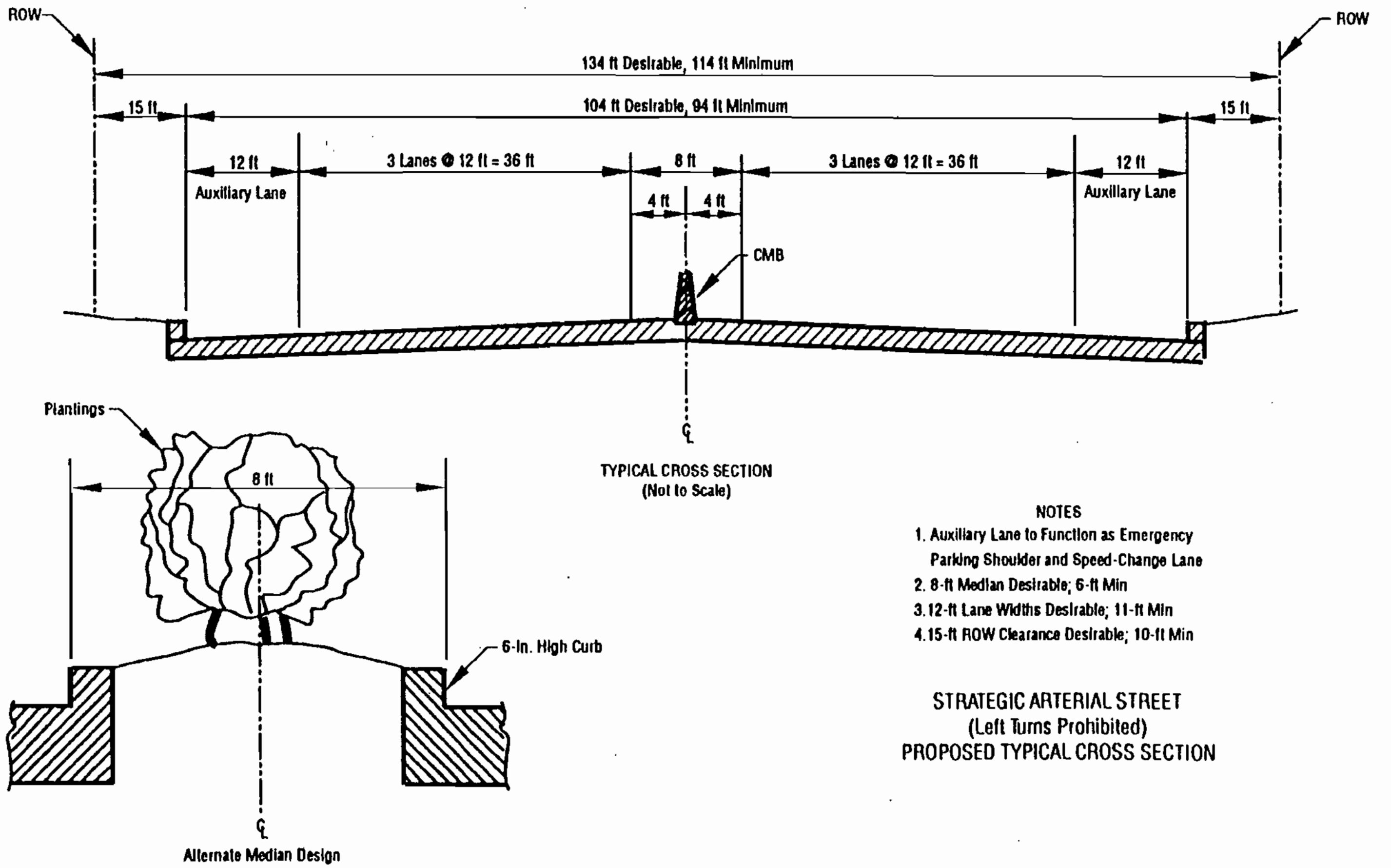

Figure D1. Minimum and Desirable Strategic Arterial Cross Section

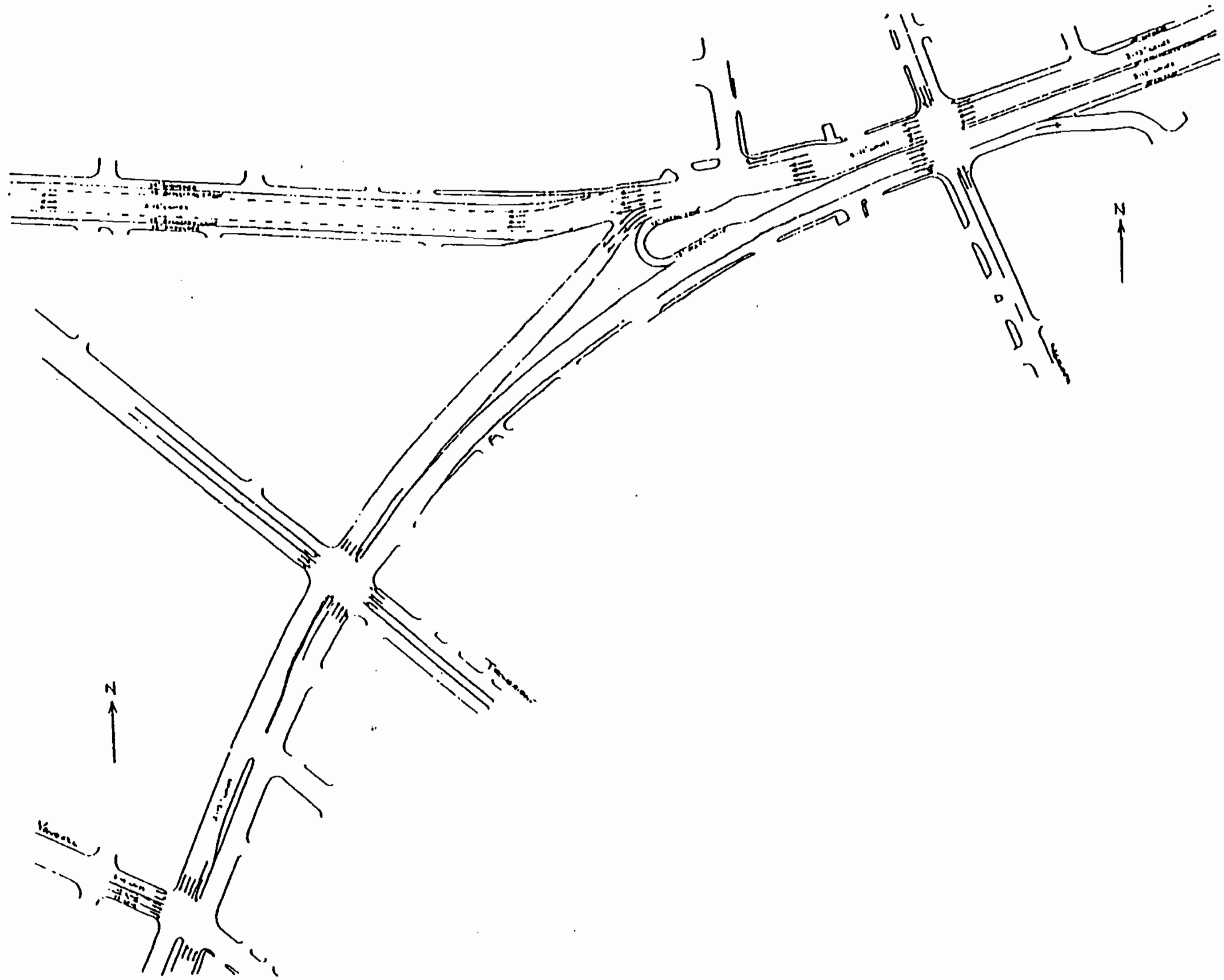

Figure D2. Minimum Paisano Right of Way from Yandell to Magruder

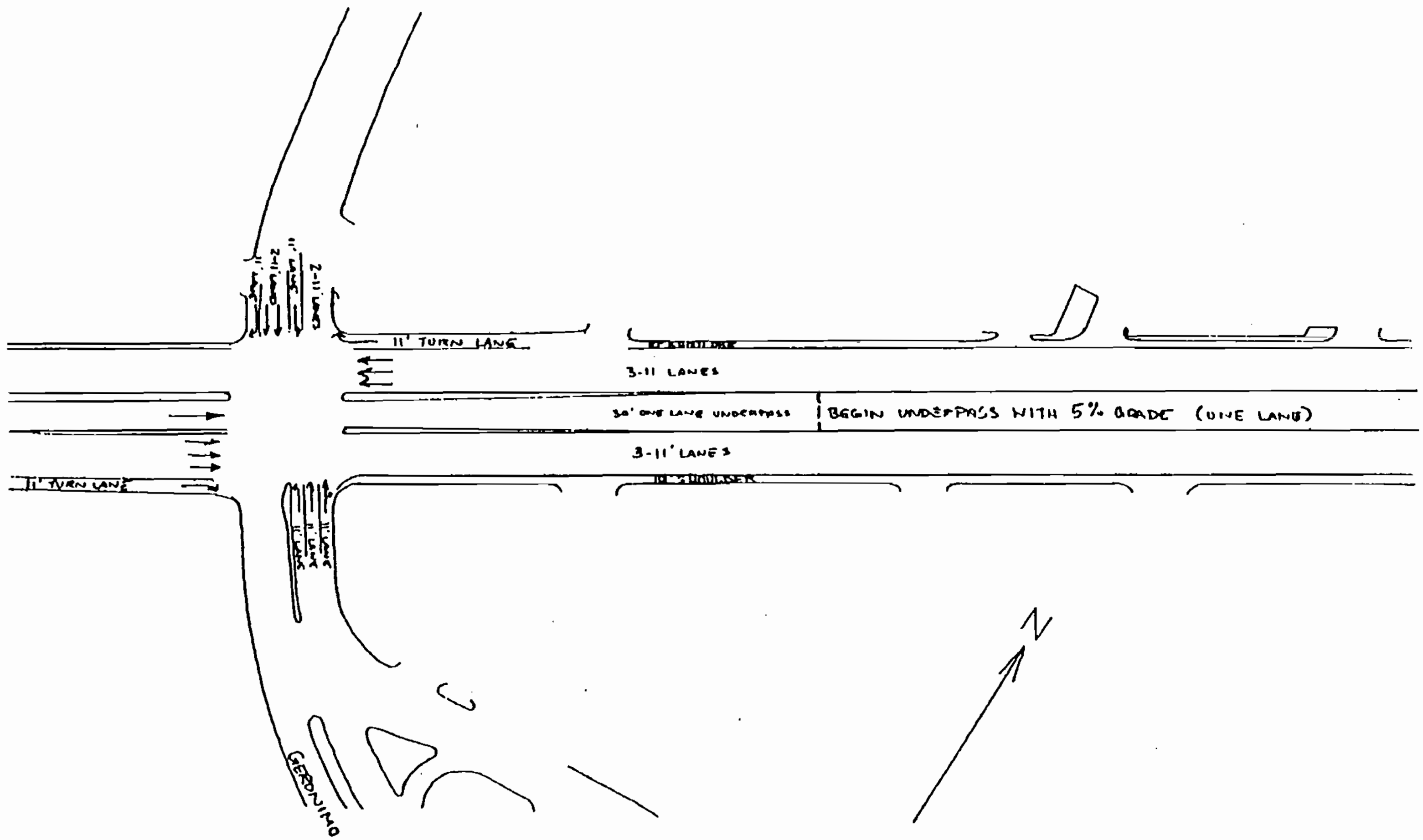

Figure D3. Minimum Right of Way at Geronimo Drive

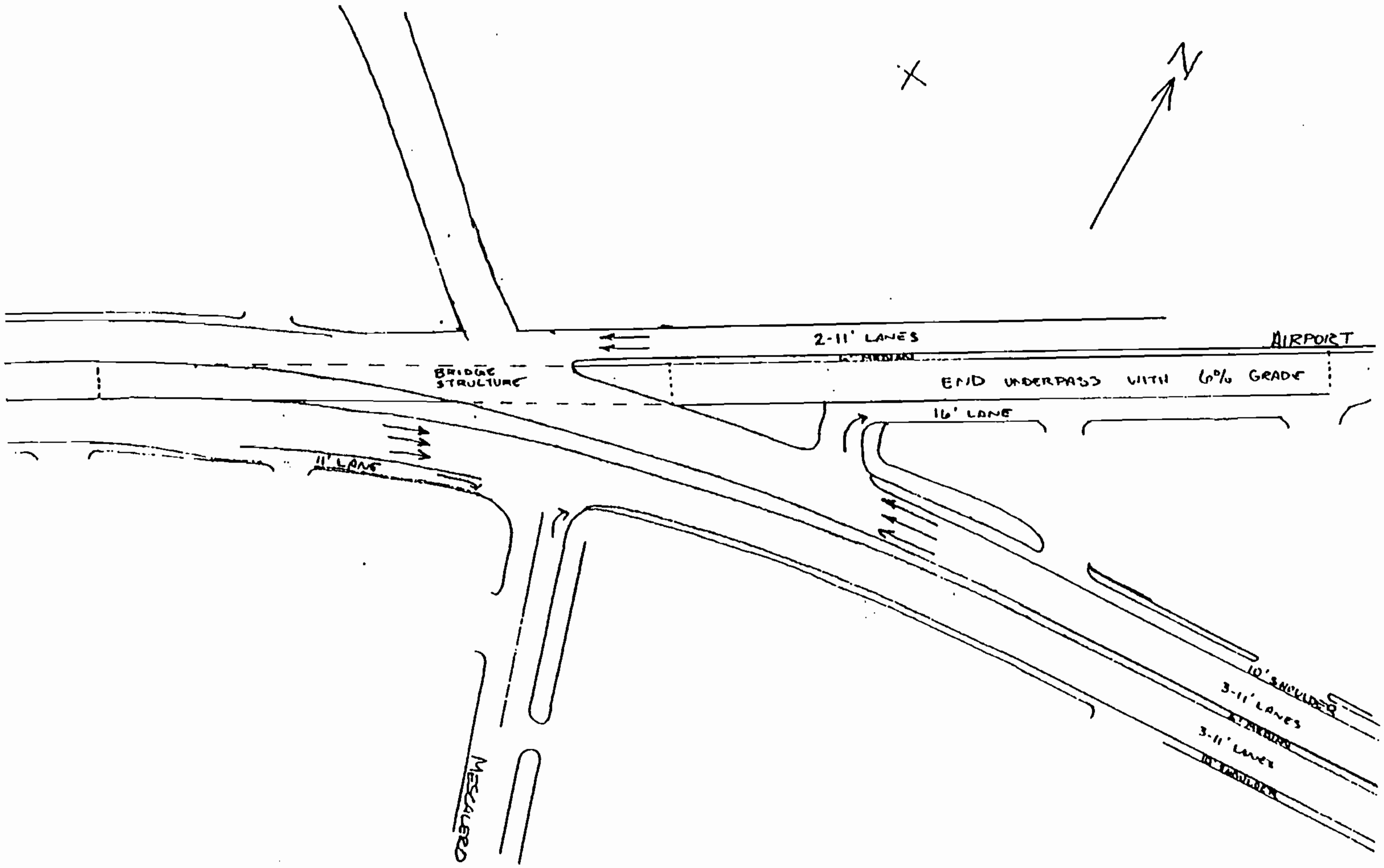

Figure D4. Minimum Right of Way at Mescalero/Airport

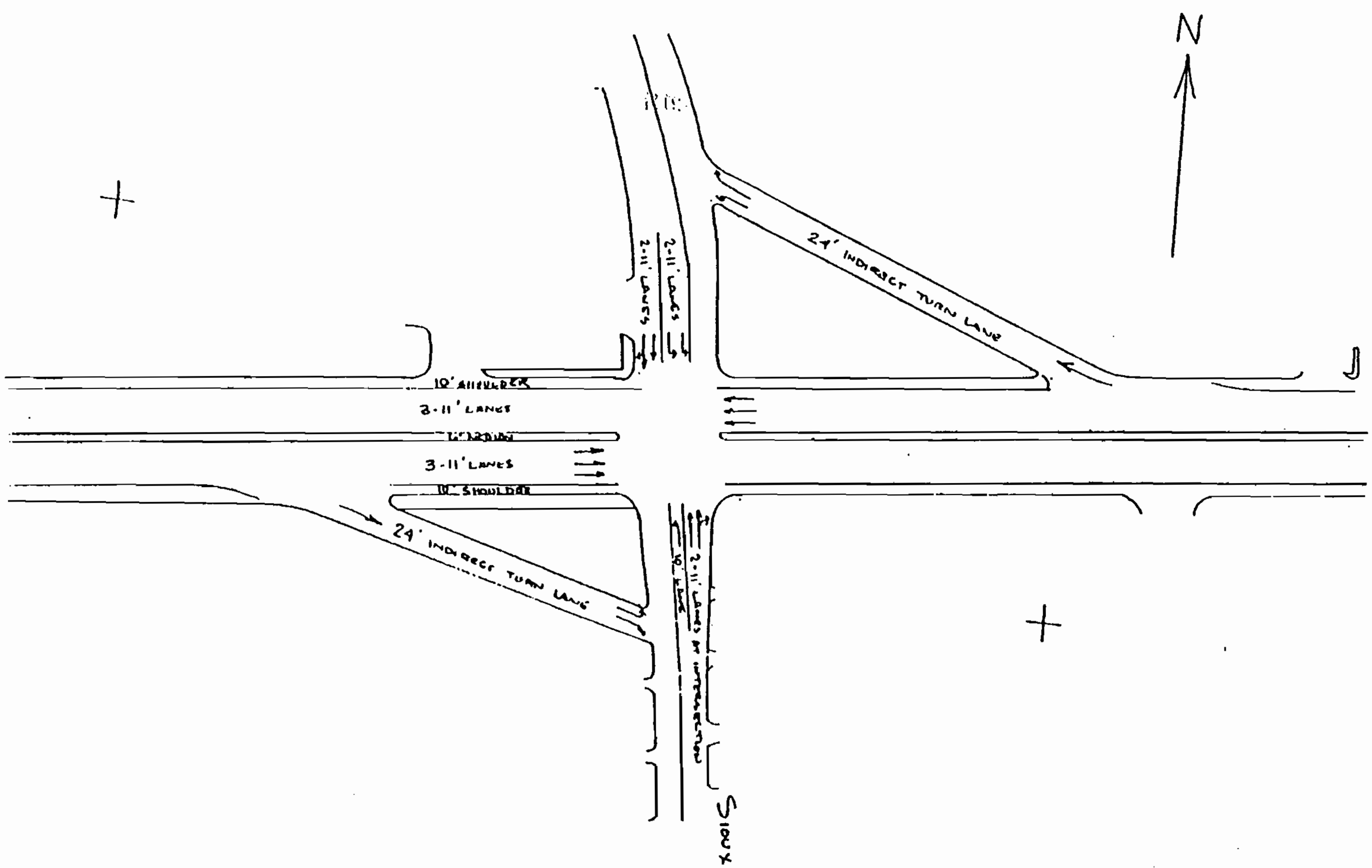

Figure D5. Minimum Right of Way at Sioux Drive

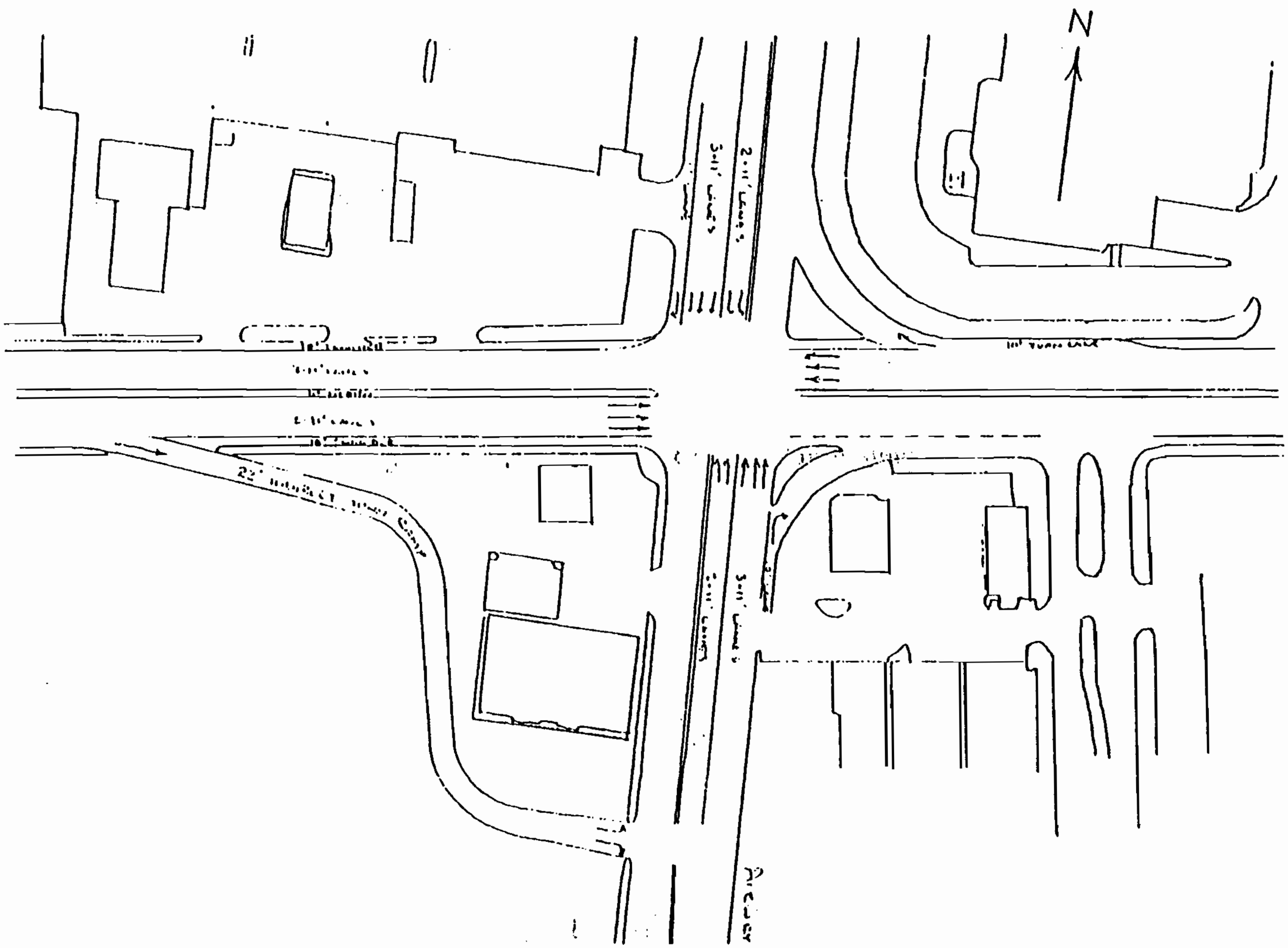

Figure D6. Minimum Right of Way at Airway Boulevard

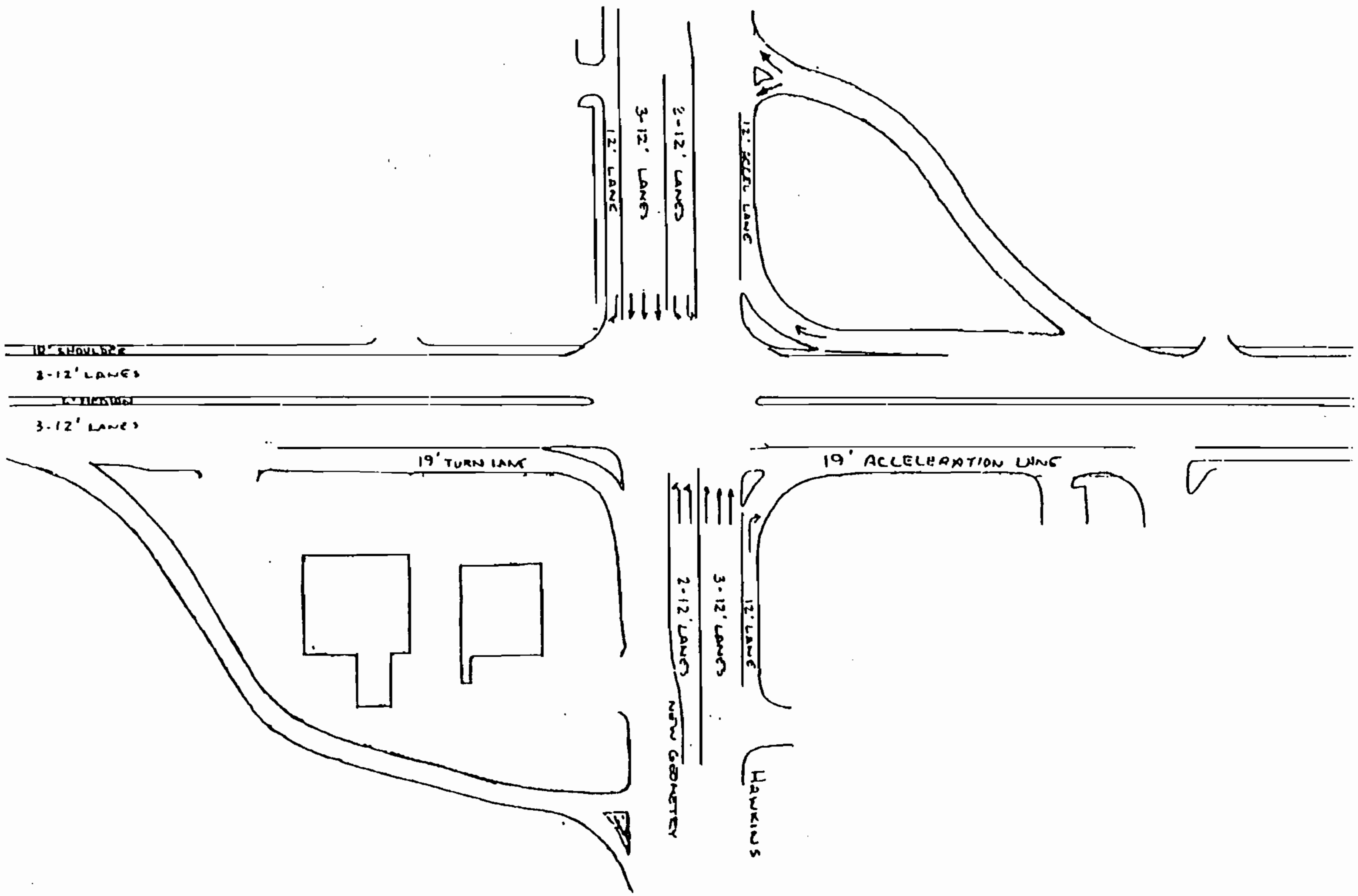

Figure D7. Minimum Right of Way at Hawkins Boulevard

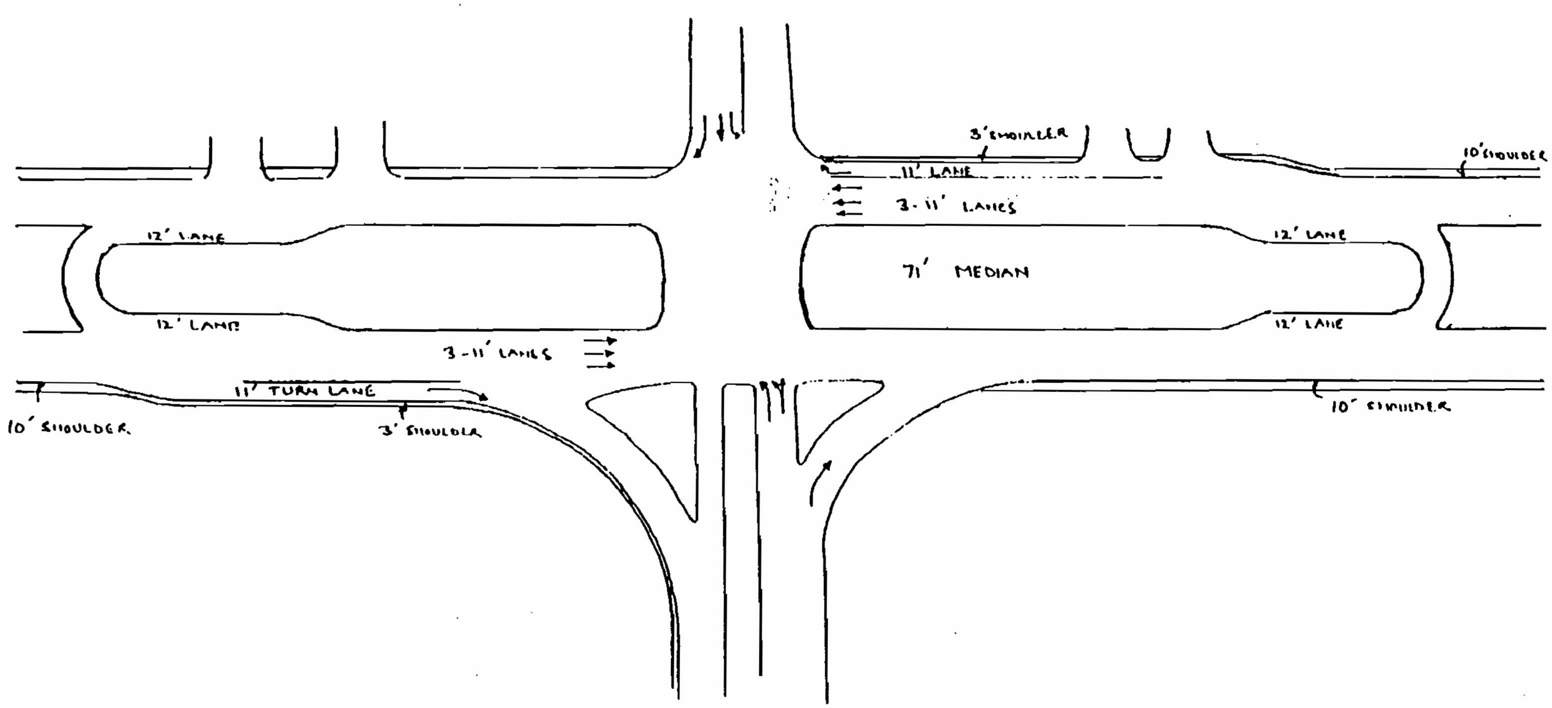

Figure D8. Minimum Right of Way at McRae Boulevard

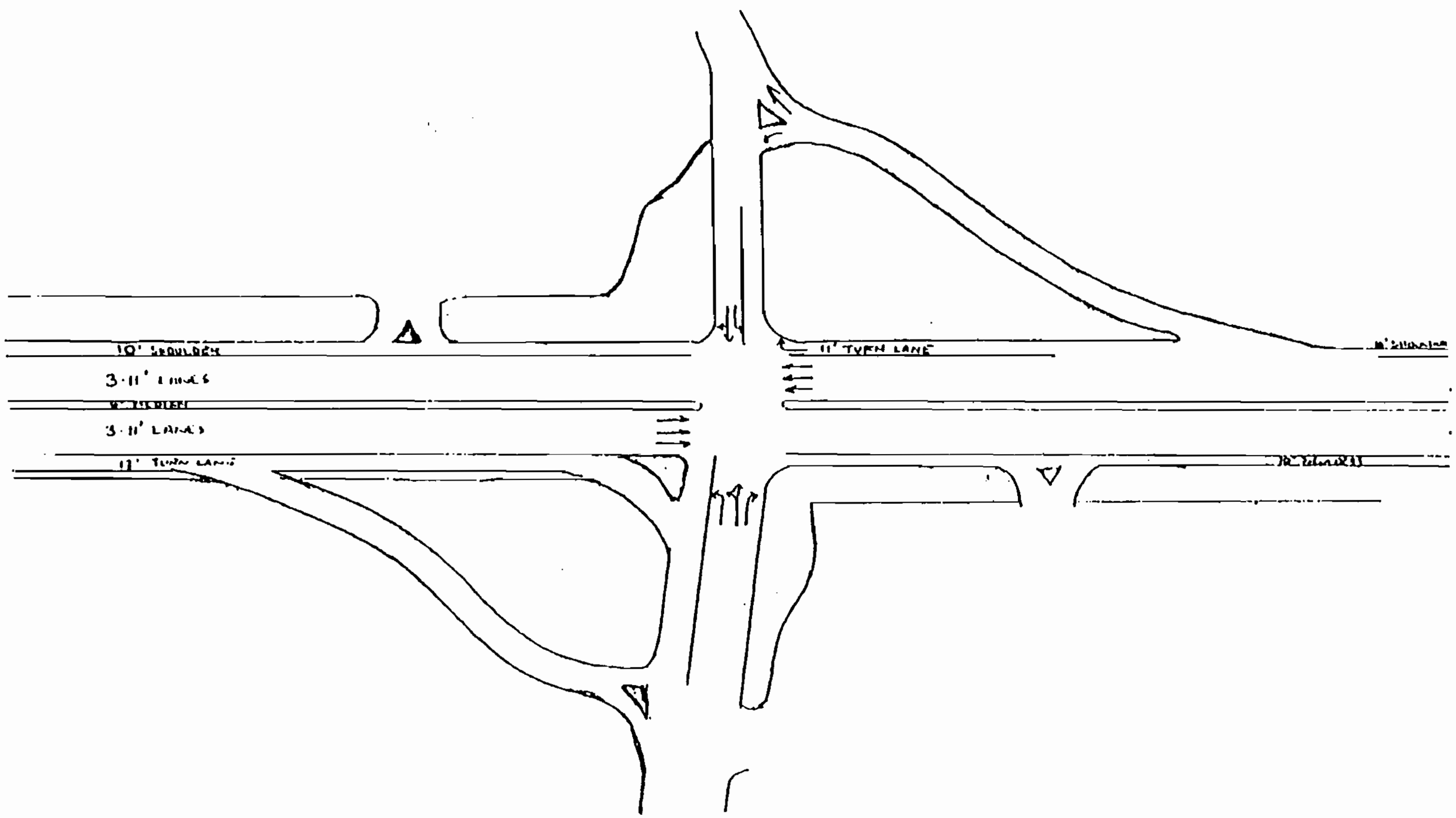

Figure D9. Minimum Right of Way at Wedgewood Drive

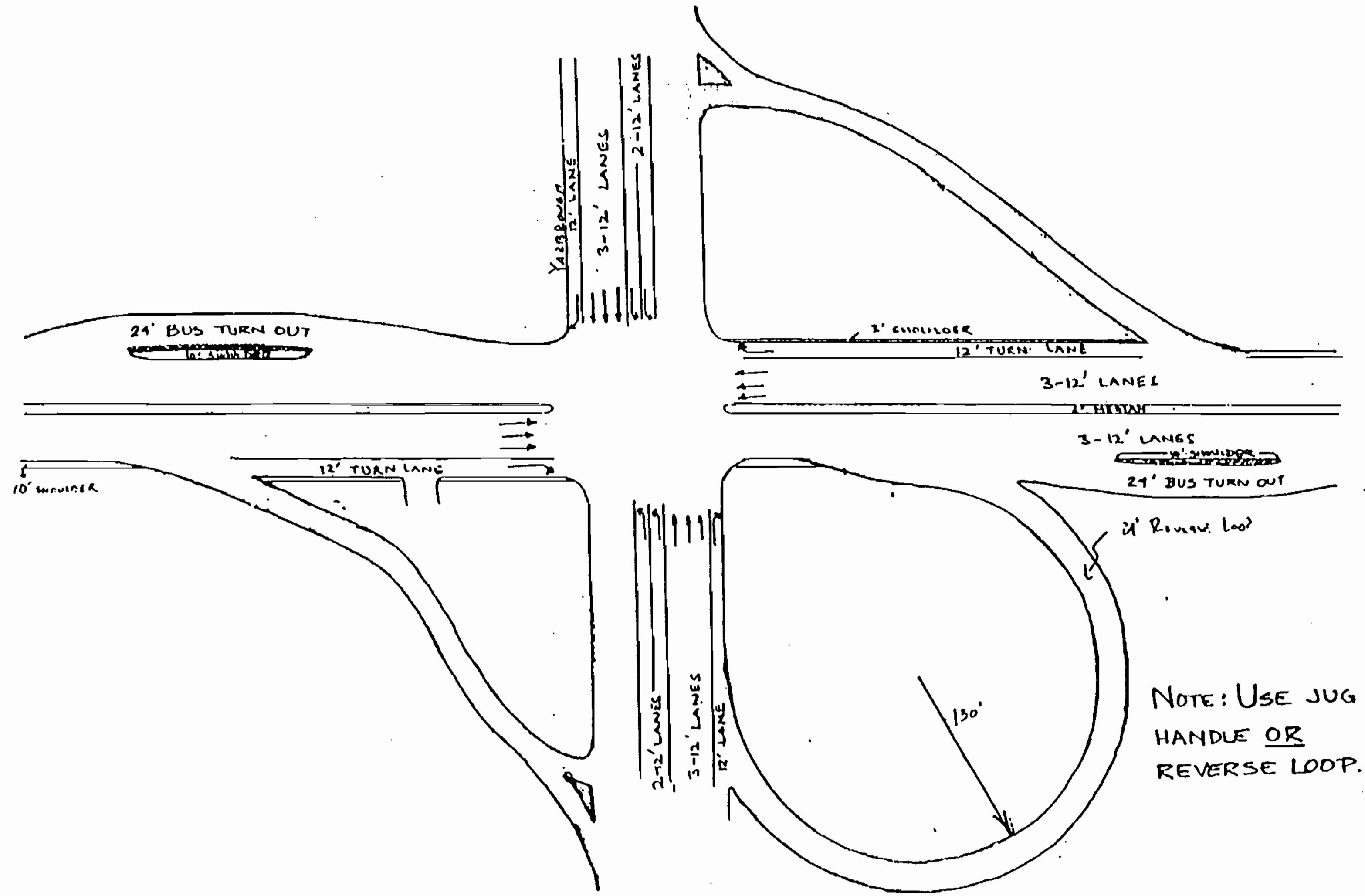

Figure D10. Minimum Right of Way at Yarbrough Drive

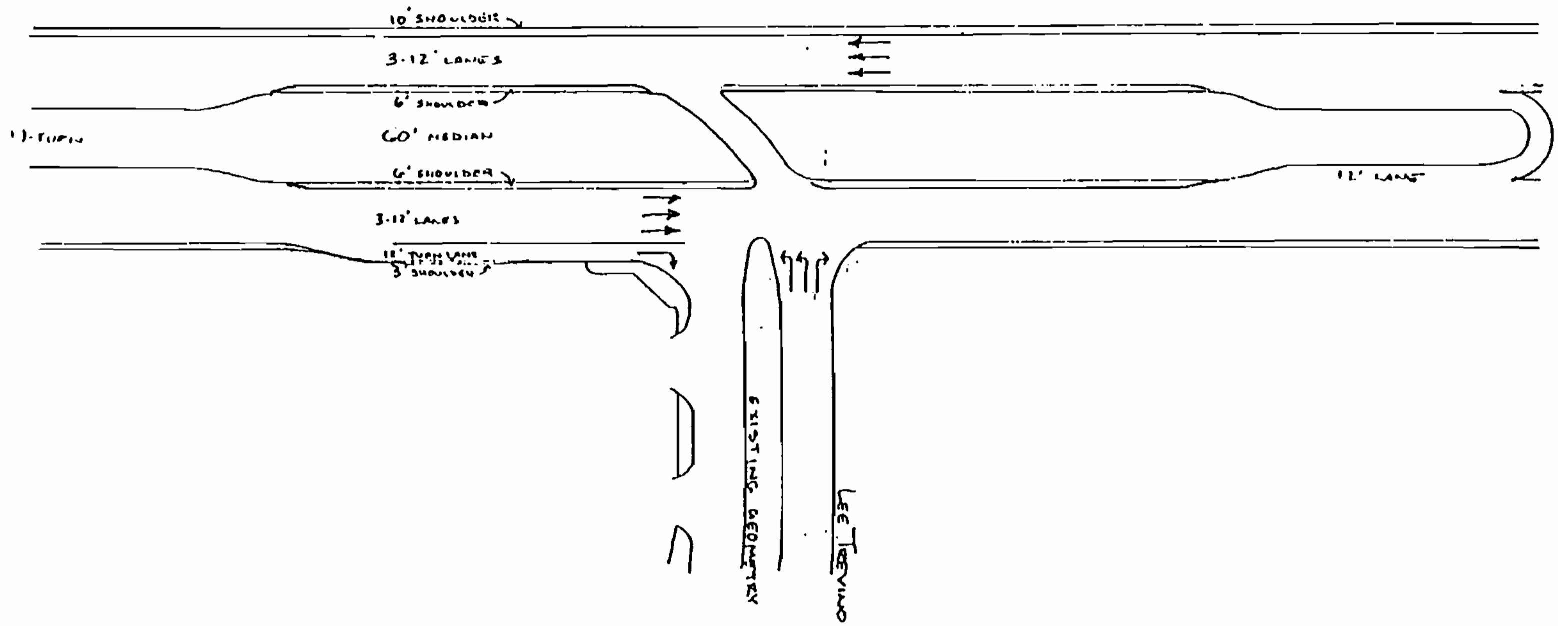

Figure D11. Minimum Right of Way at Lee Trevino Drive

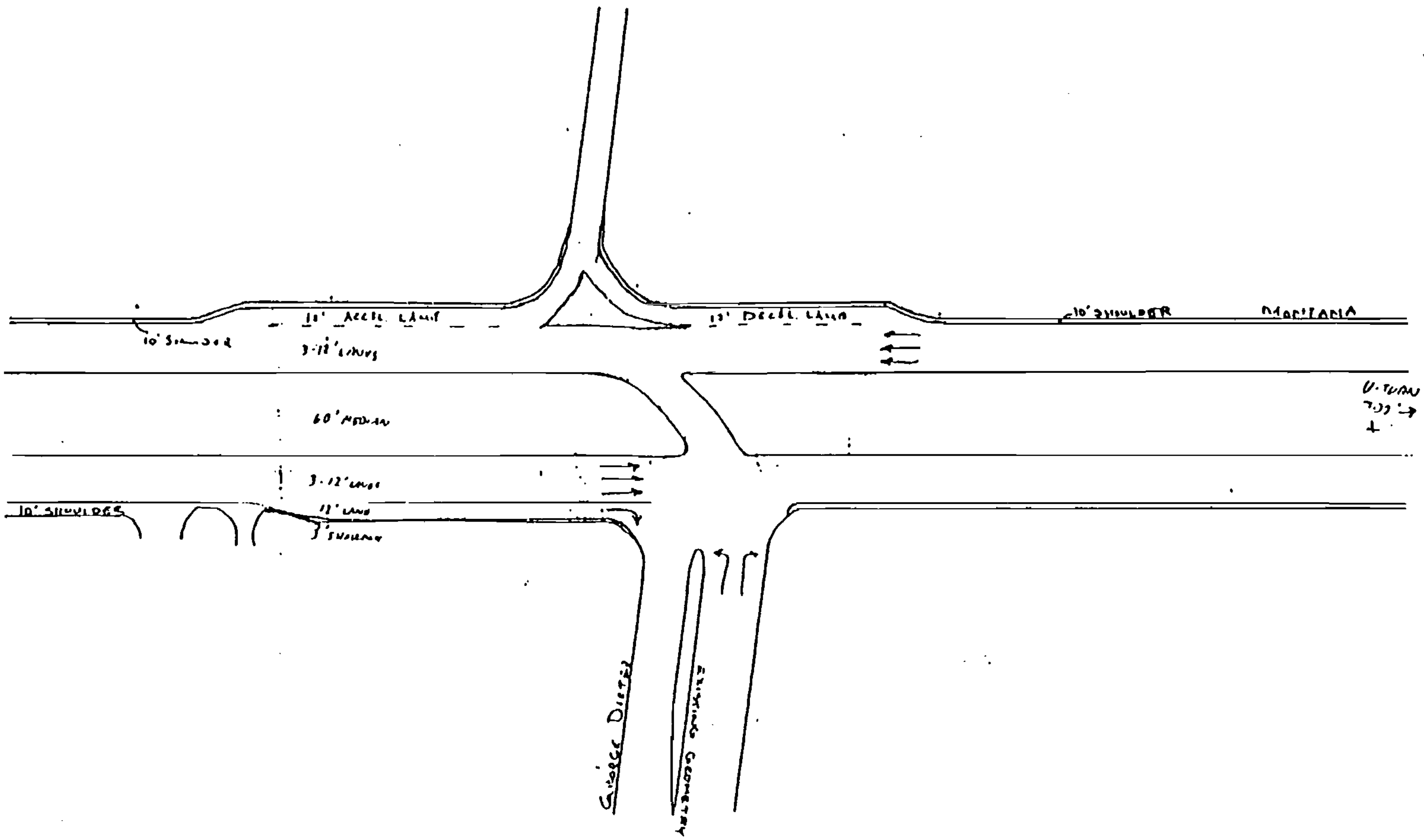

Figure D12. Minimum Right of Way at George Dieter Drive

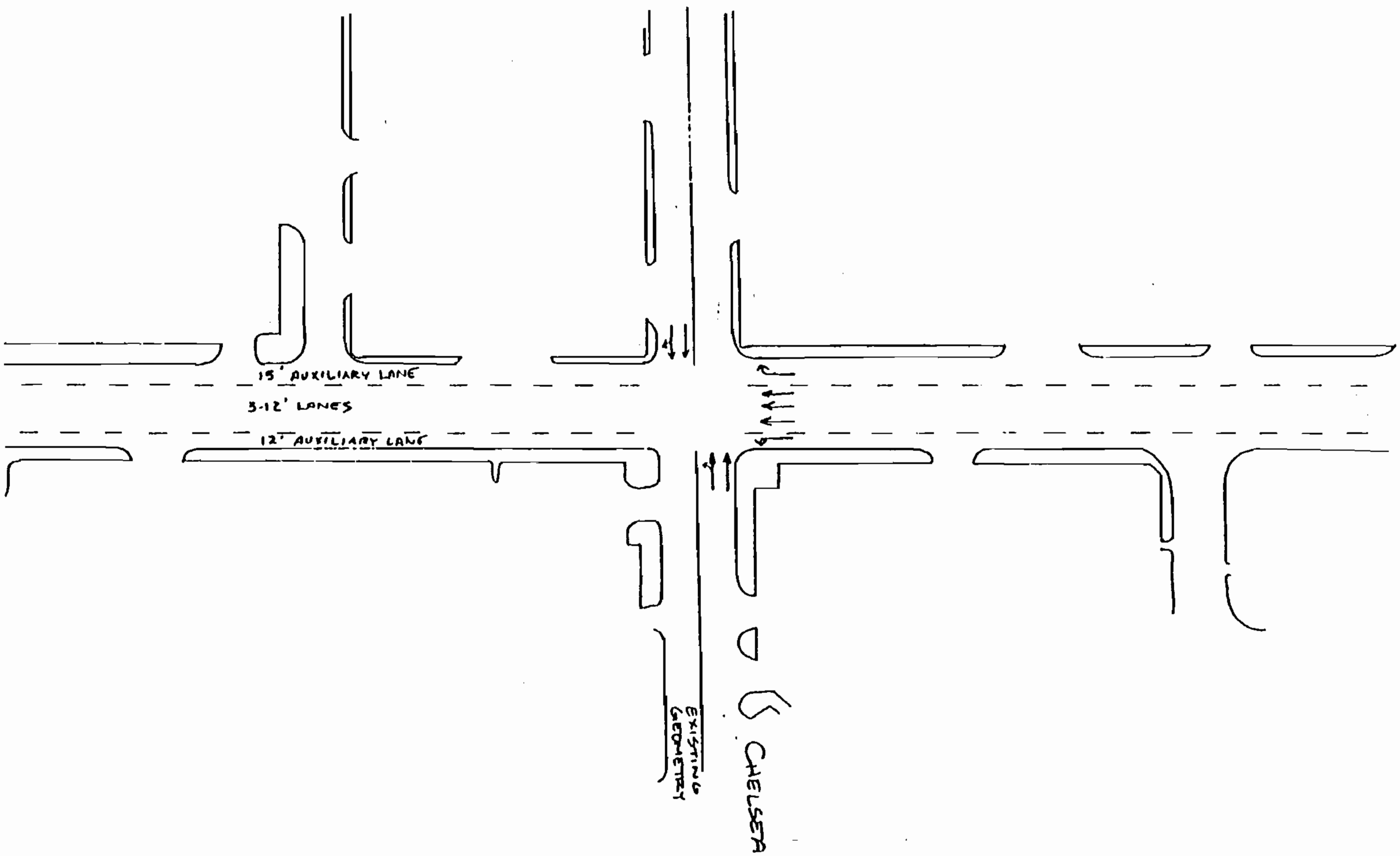

Figure D13. Desirable Right of Way at Chelsea Street

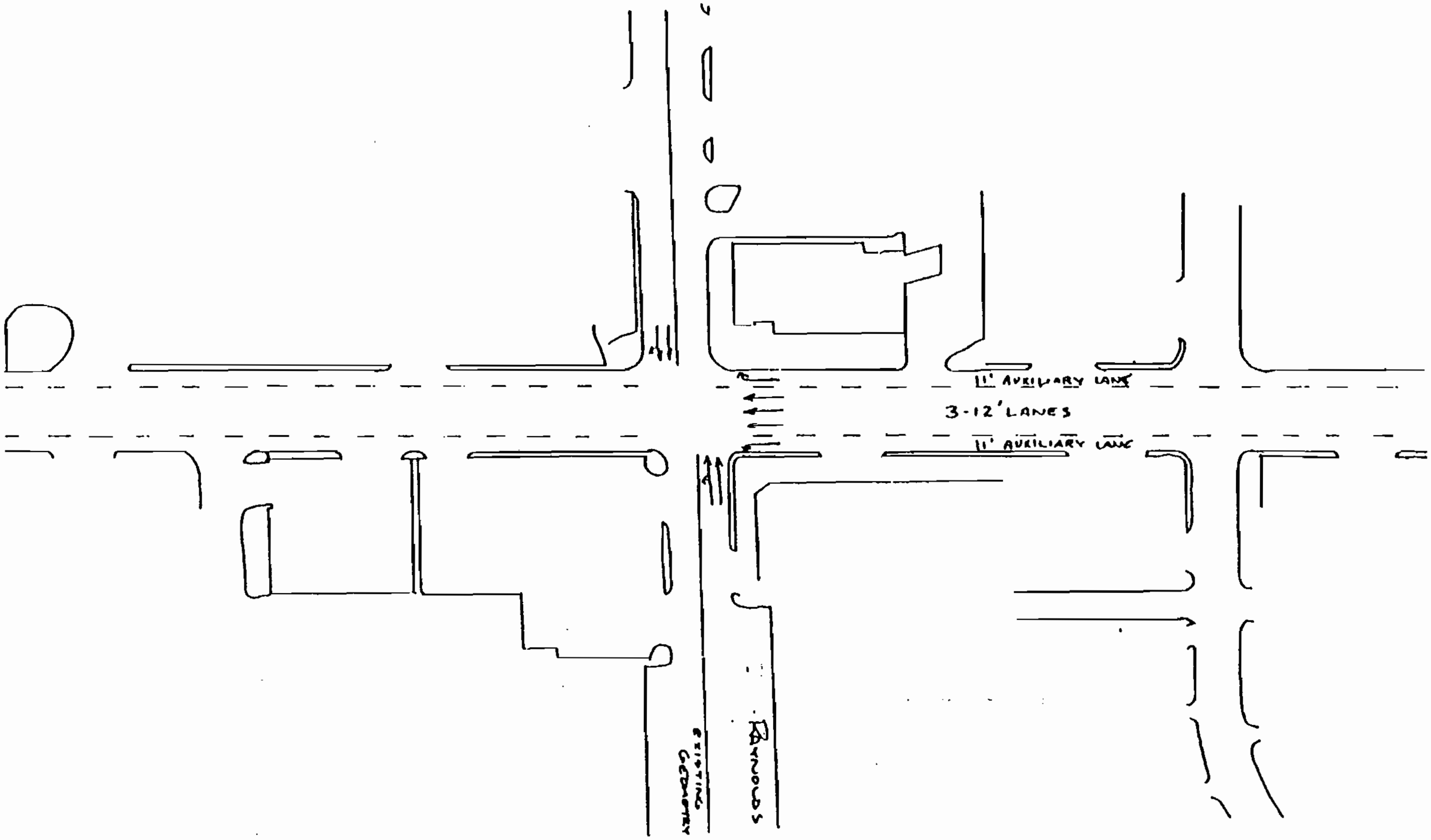

Figure D14. Desirable Right of Way at Raynolds Street (General Cross Section)

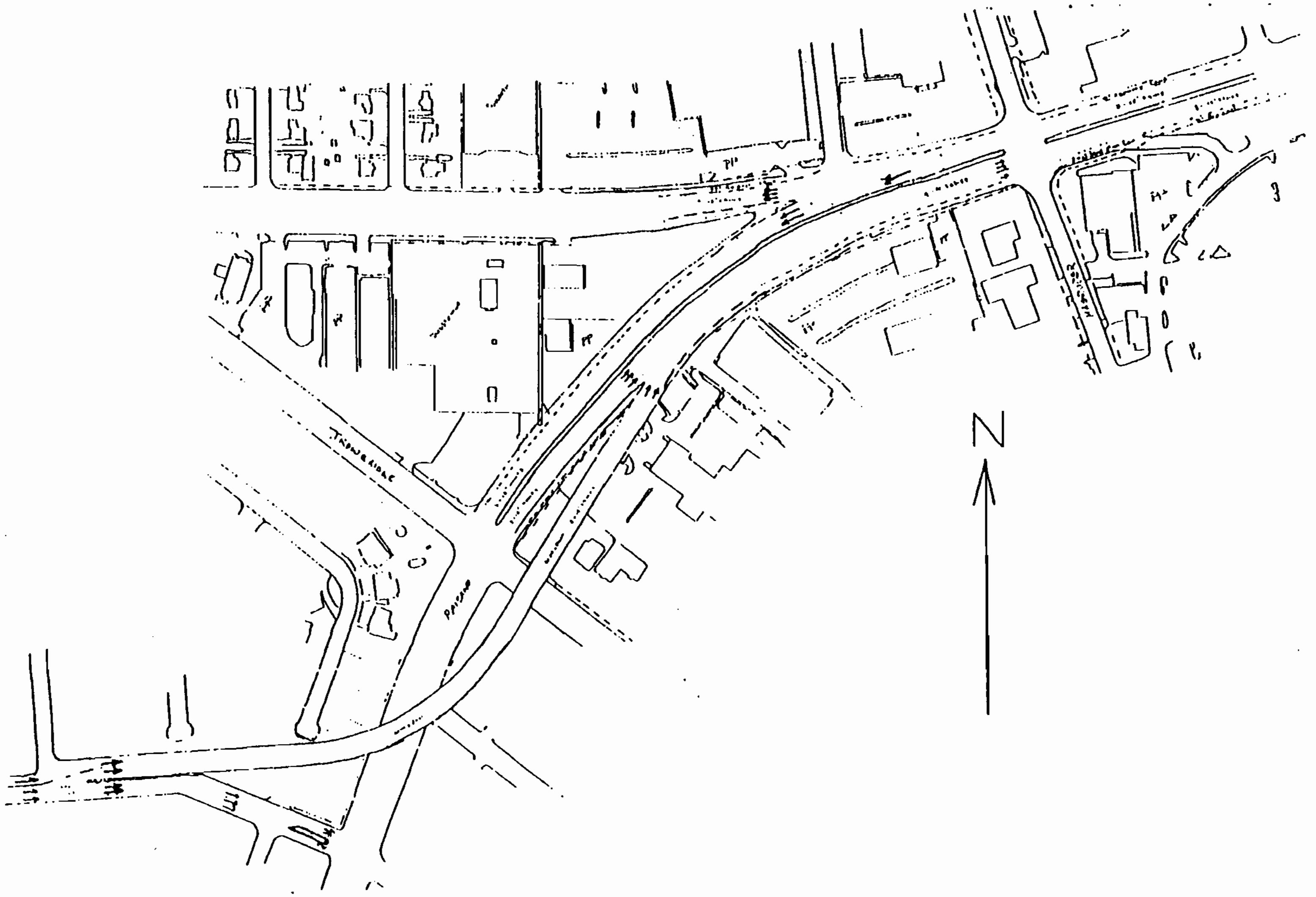

Figure D15. Desirable Paisano Right of Way from Yandell to Magruder

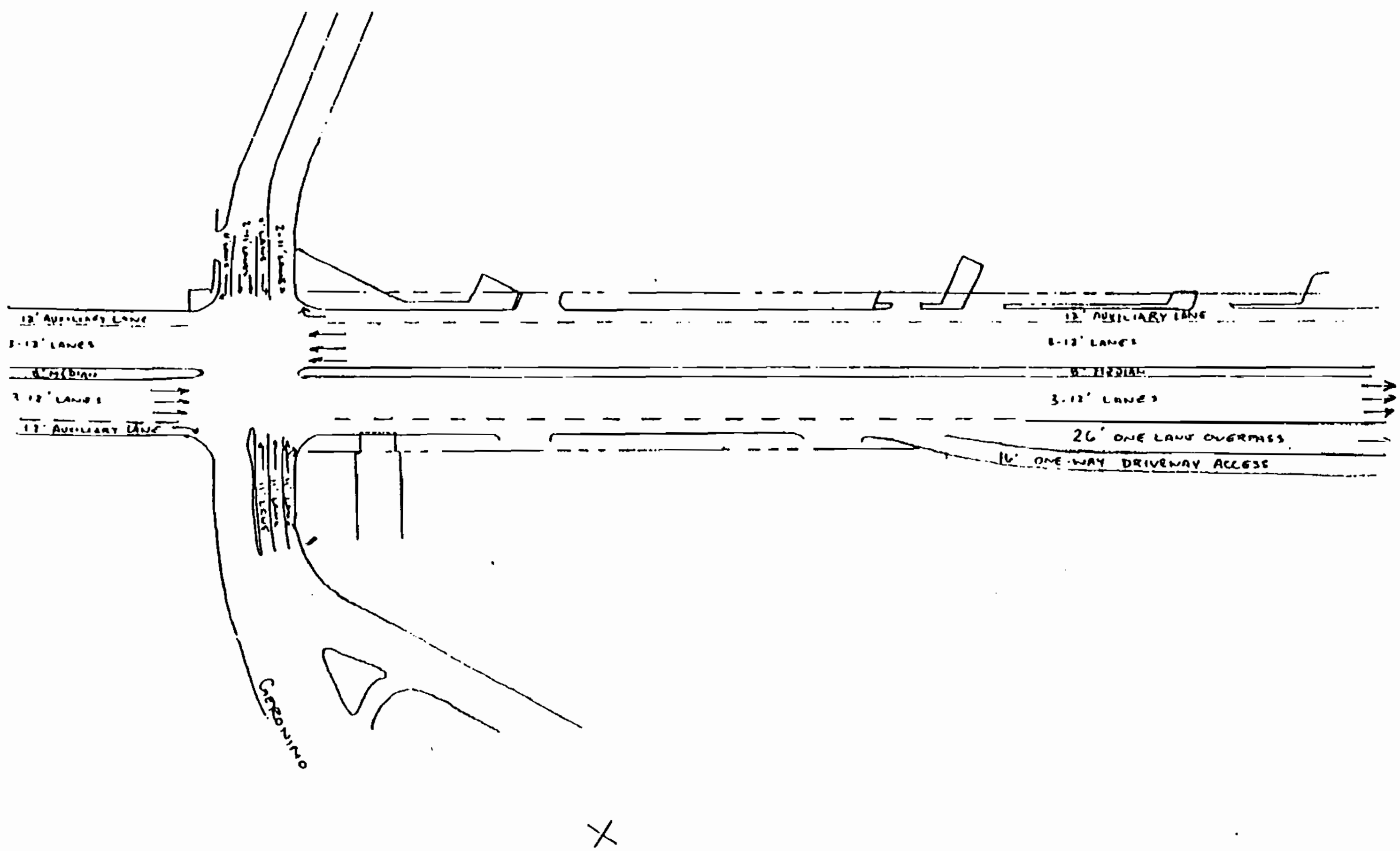

Figure D16. Desirable Right of Way at Geronimo Drive

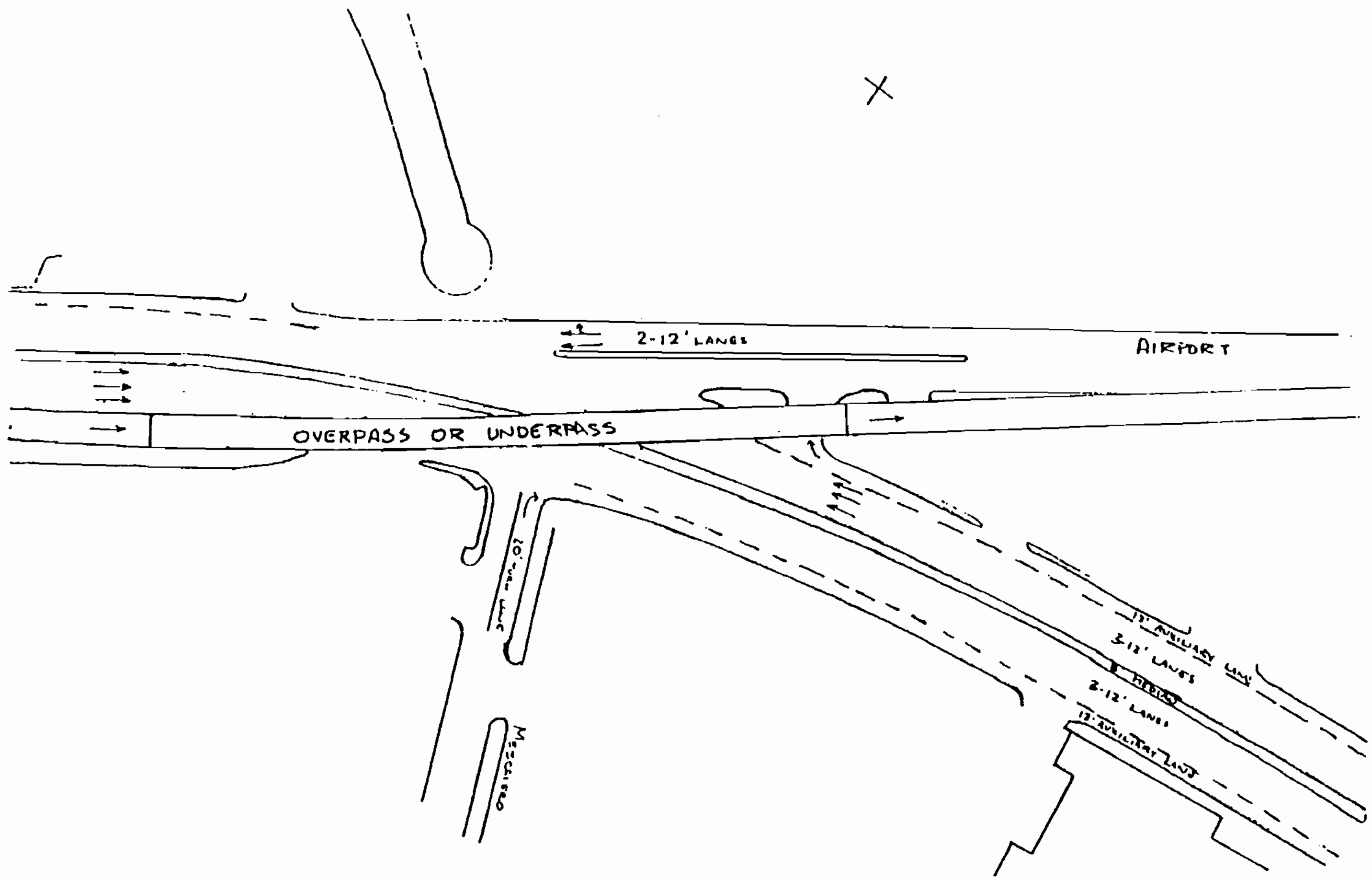

Figure D17. Desirable Right of Way at Mescalero/Airport

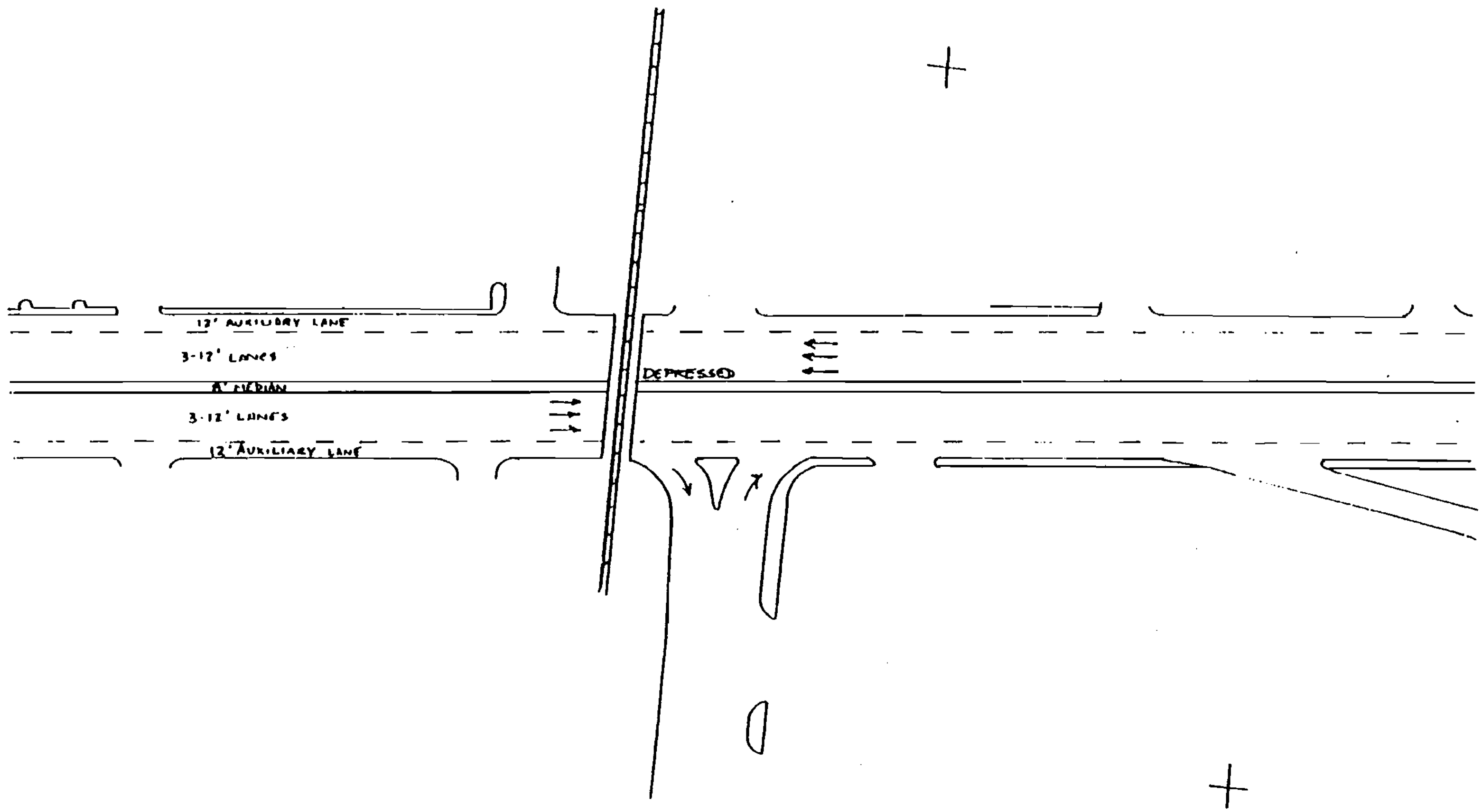

Figure D18. Desirable Right of Way at Robert E. Lee Road

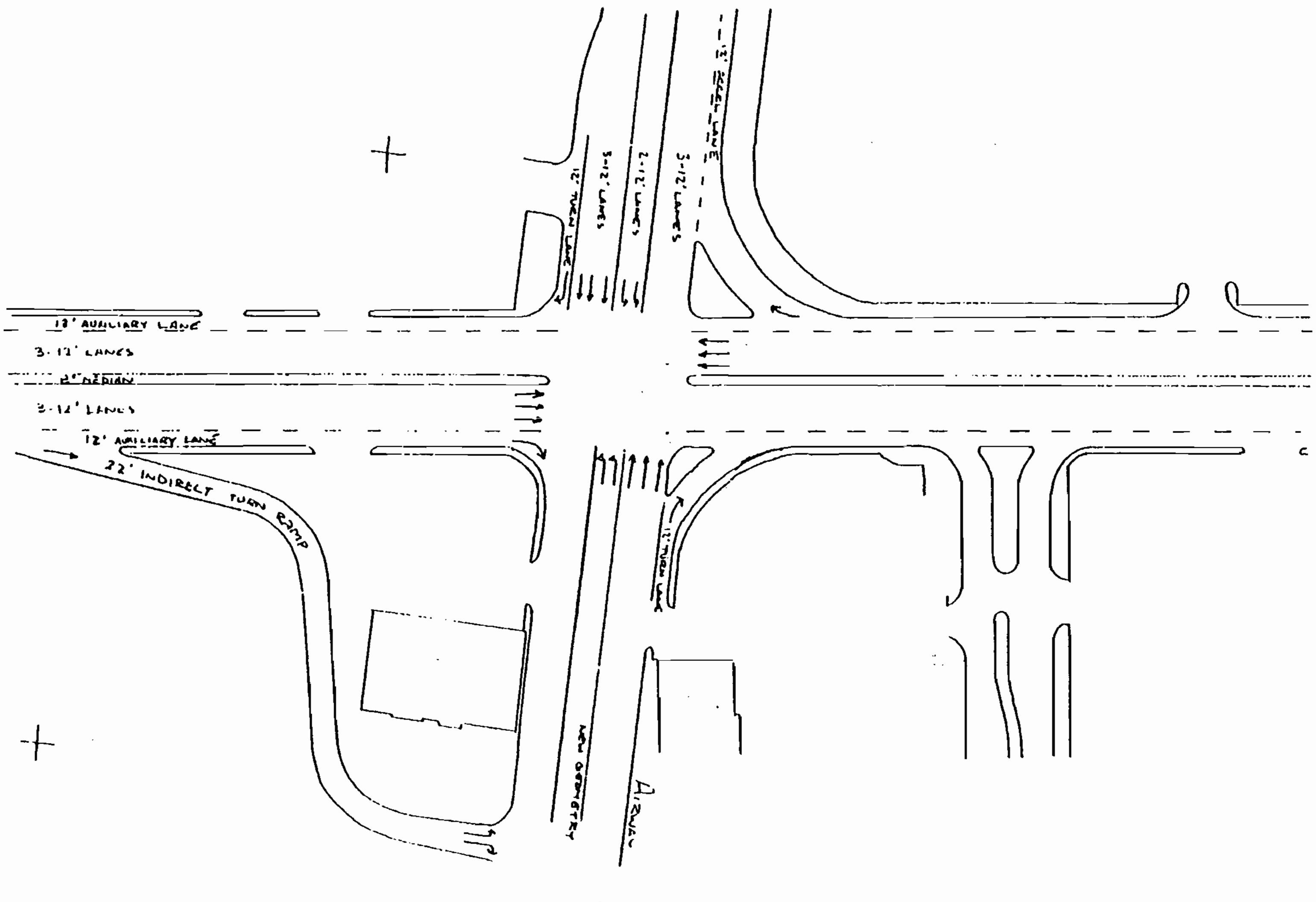

Figure D19. Desirable Right of Way at Airway Boulevard

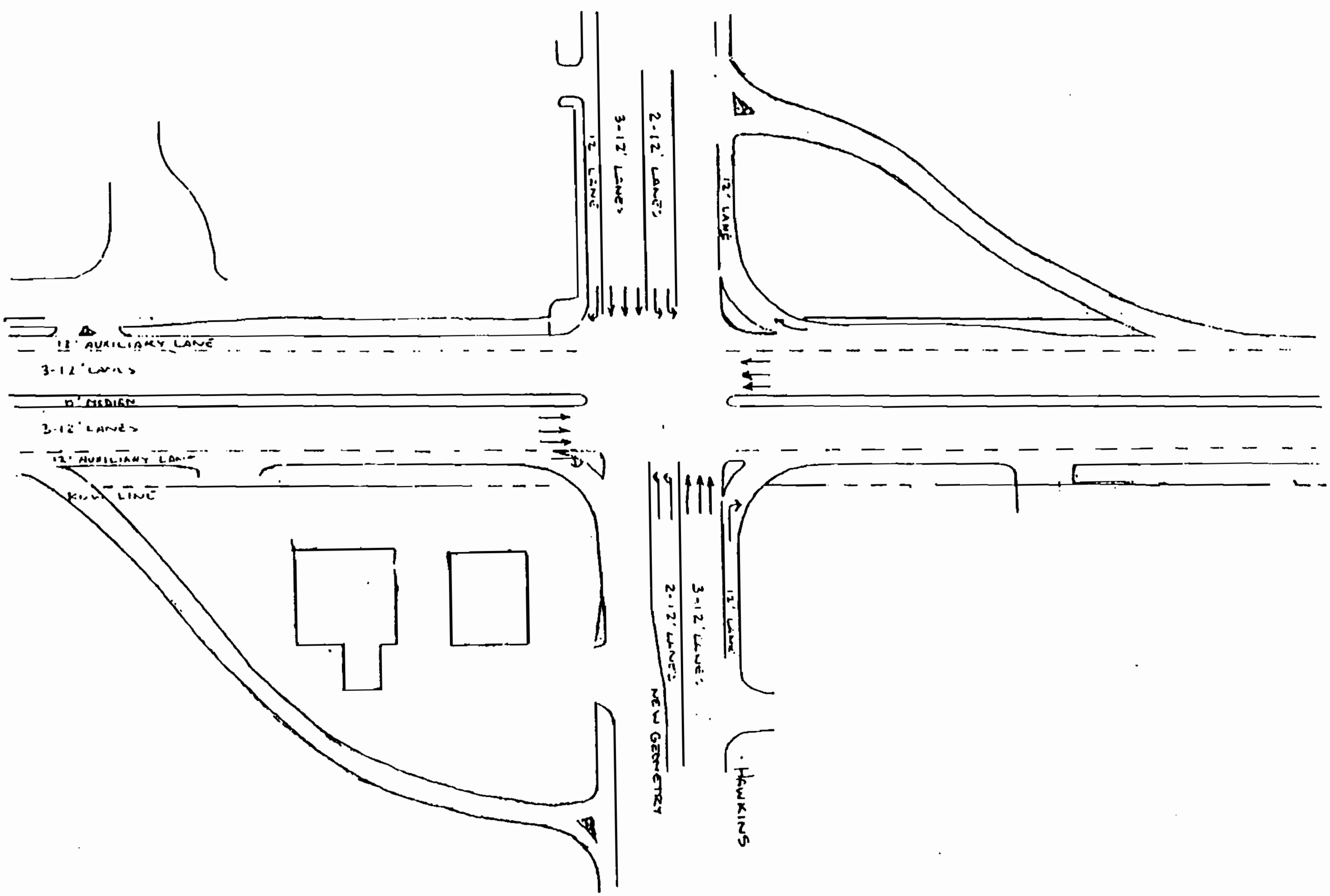

Figure D20. Desirable Right of Way at Hawkins Boulevard

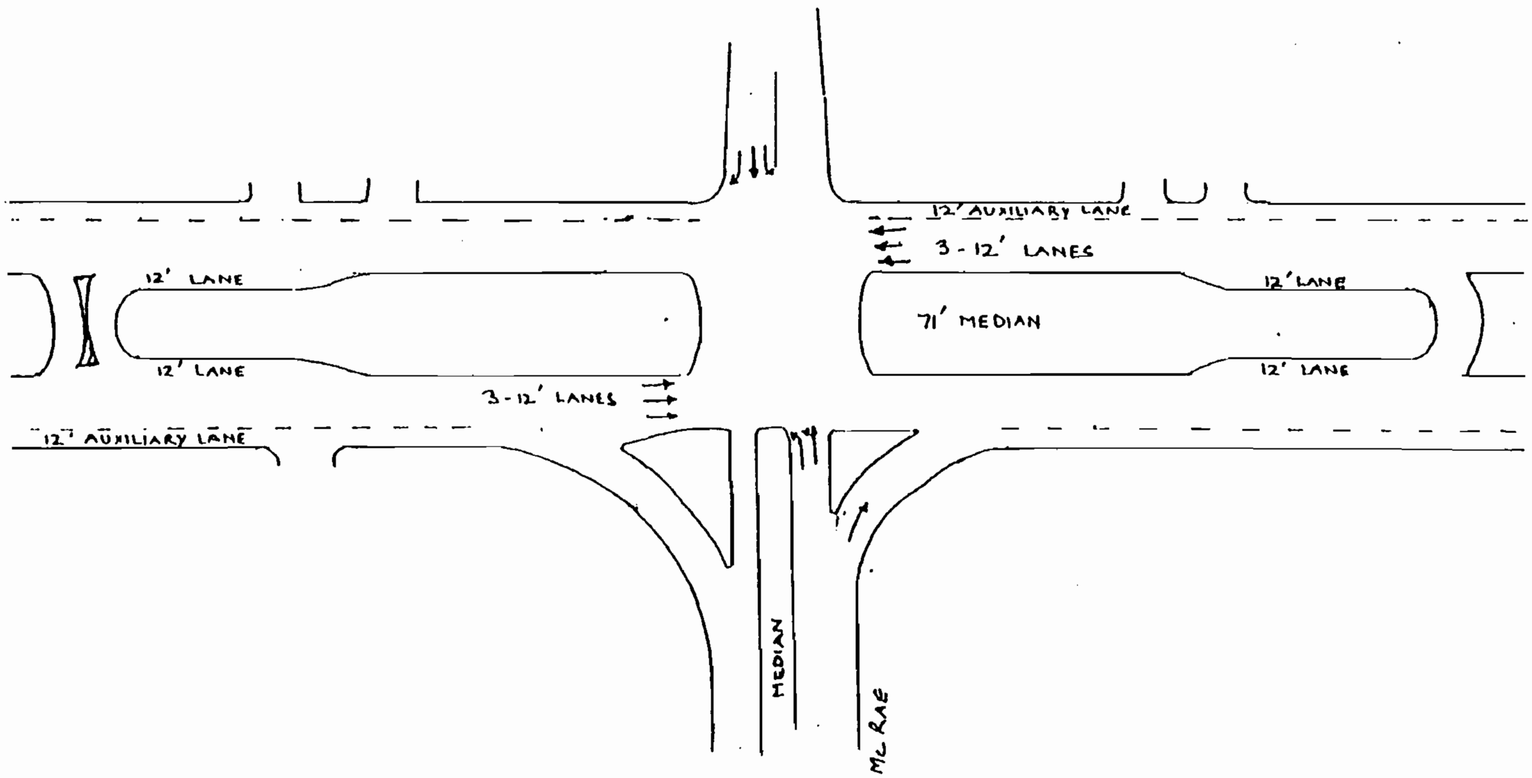

Figure D21. Desirable Right of Way at McRae Boulevard

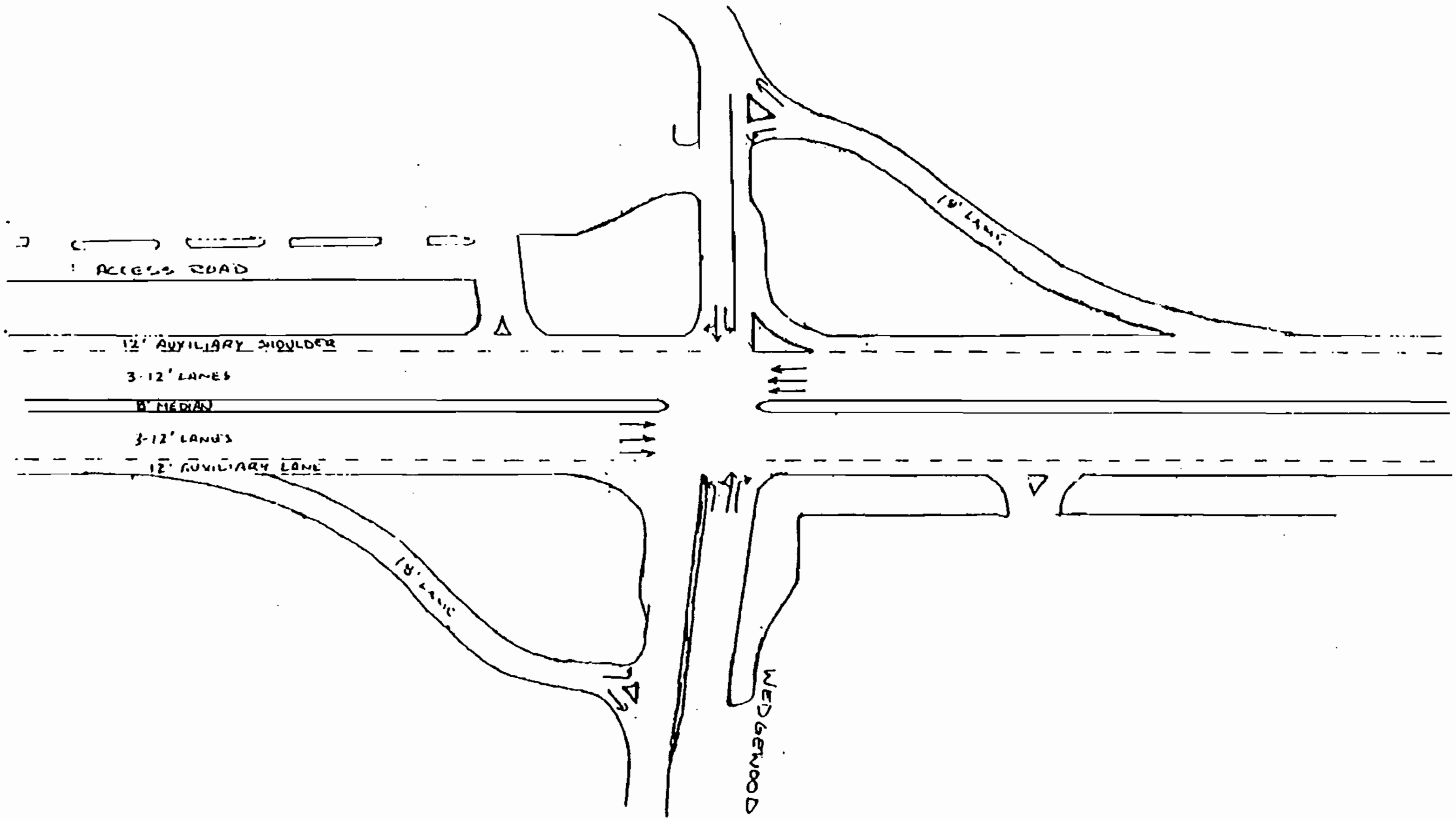

Figure D22. Desirable Right of Way at Wedgewood Drive

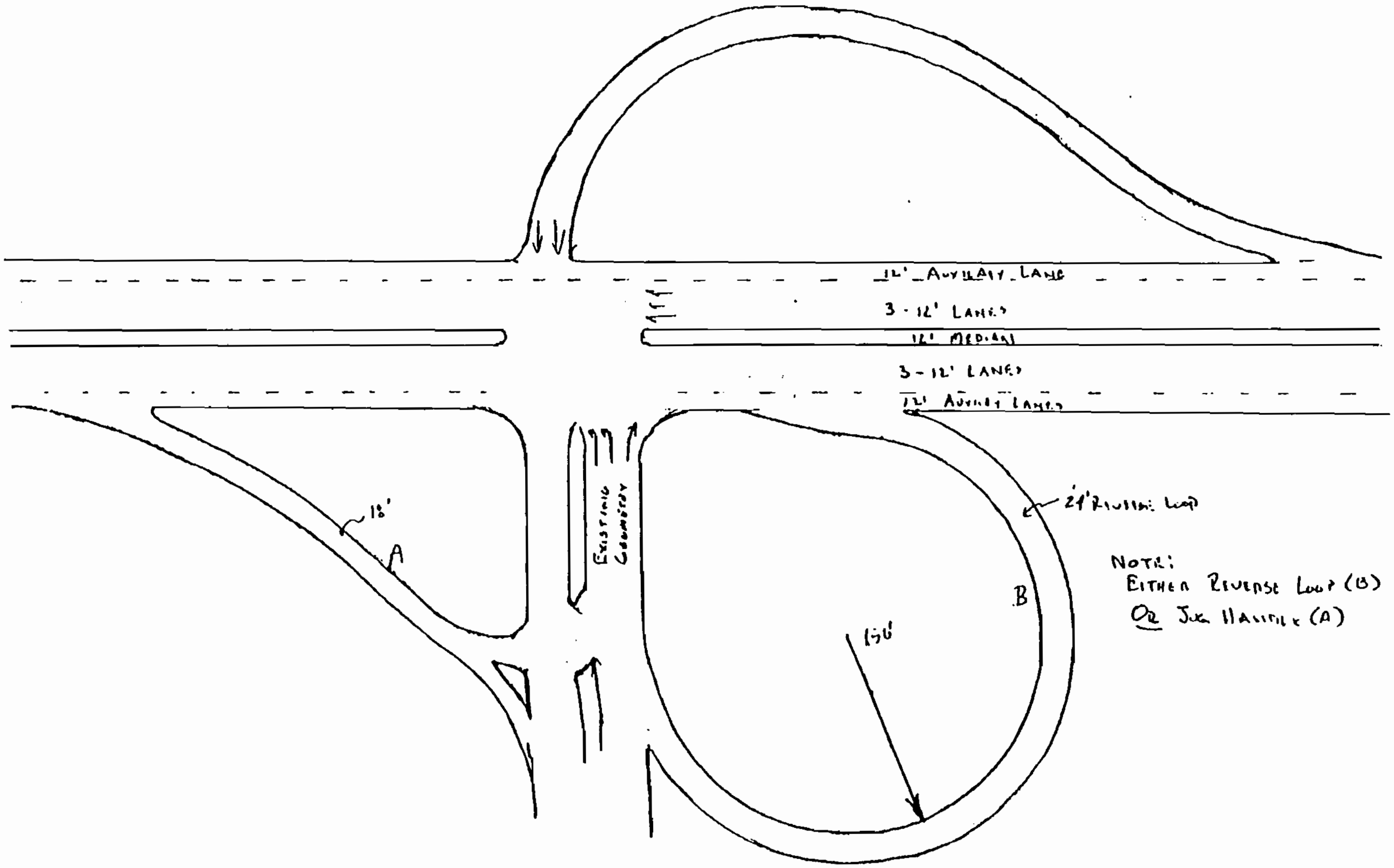

Figure D23. Desirable Right of Way at Yarbrough Drive Before Inner Loop

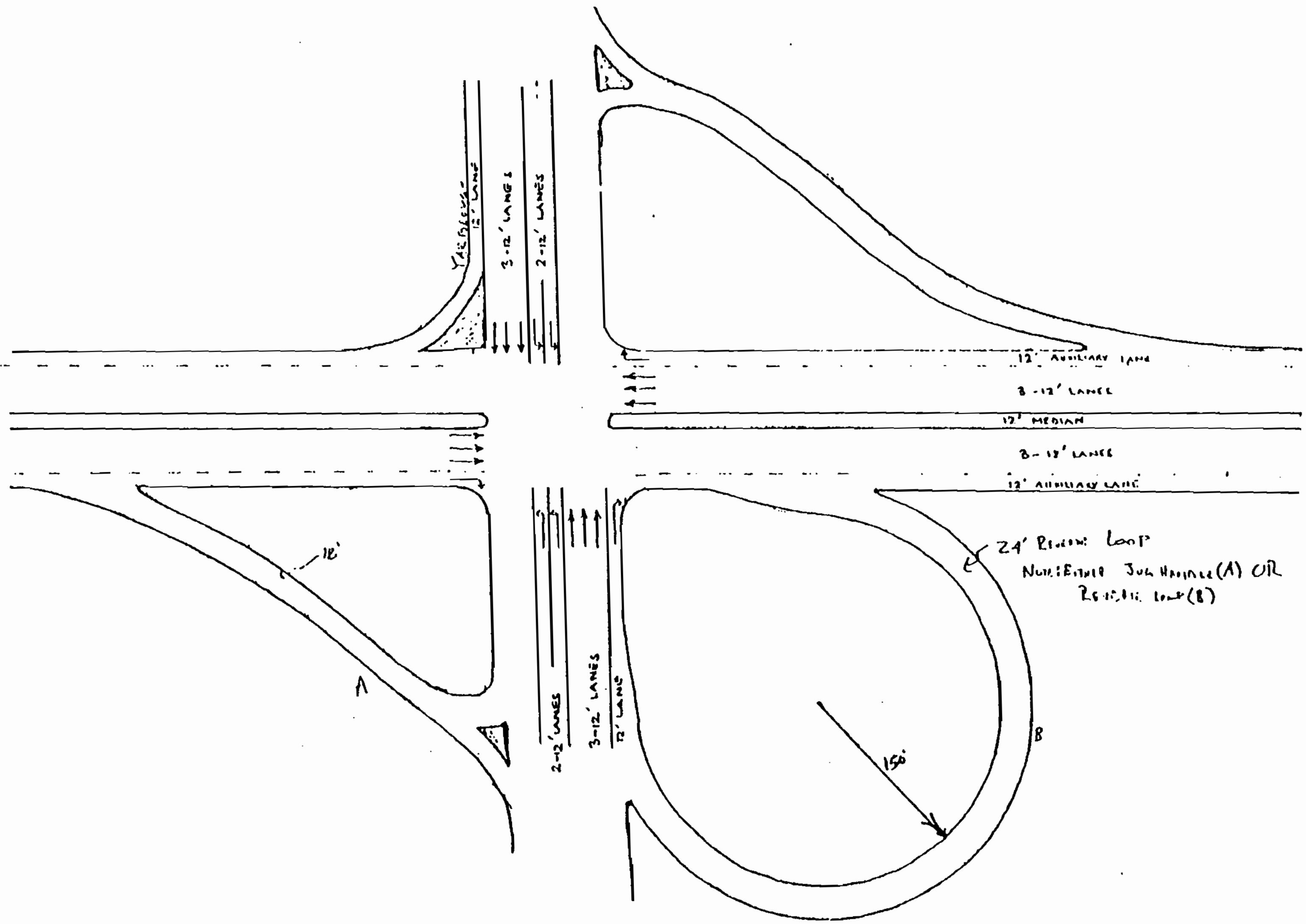

Figure D24. Desirable Right of Way at Yarbrough Drive After Inner Loop

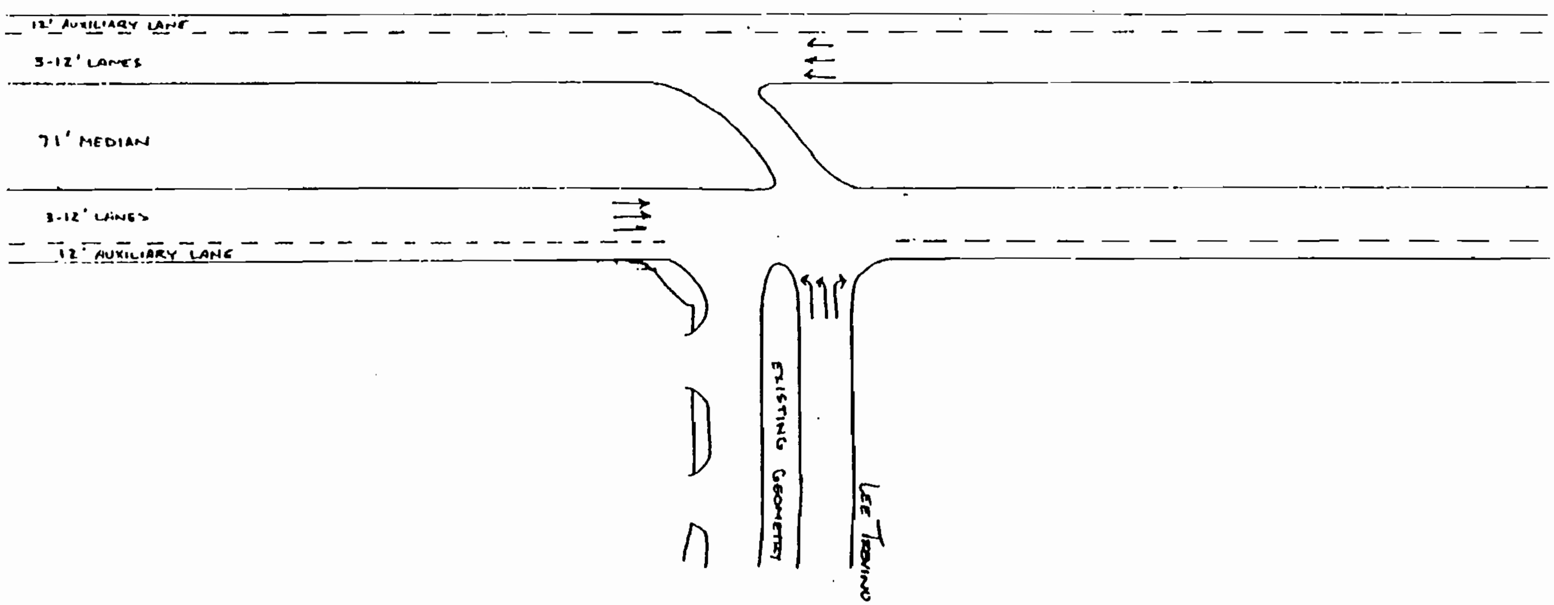

Figure D25. Desirable Right of Way at Lee Trevino Drive

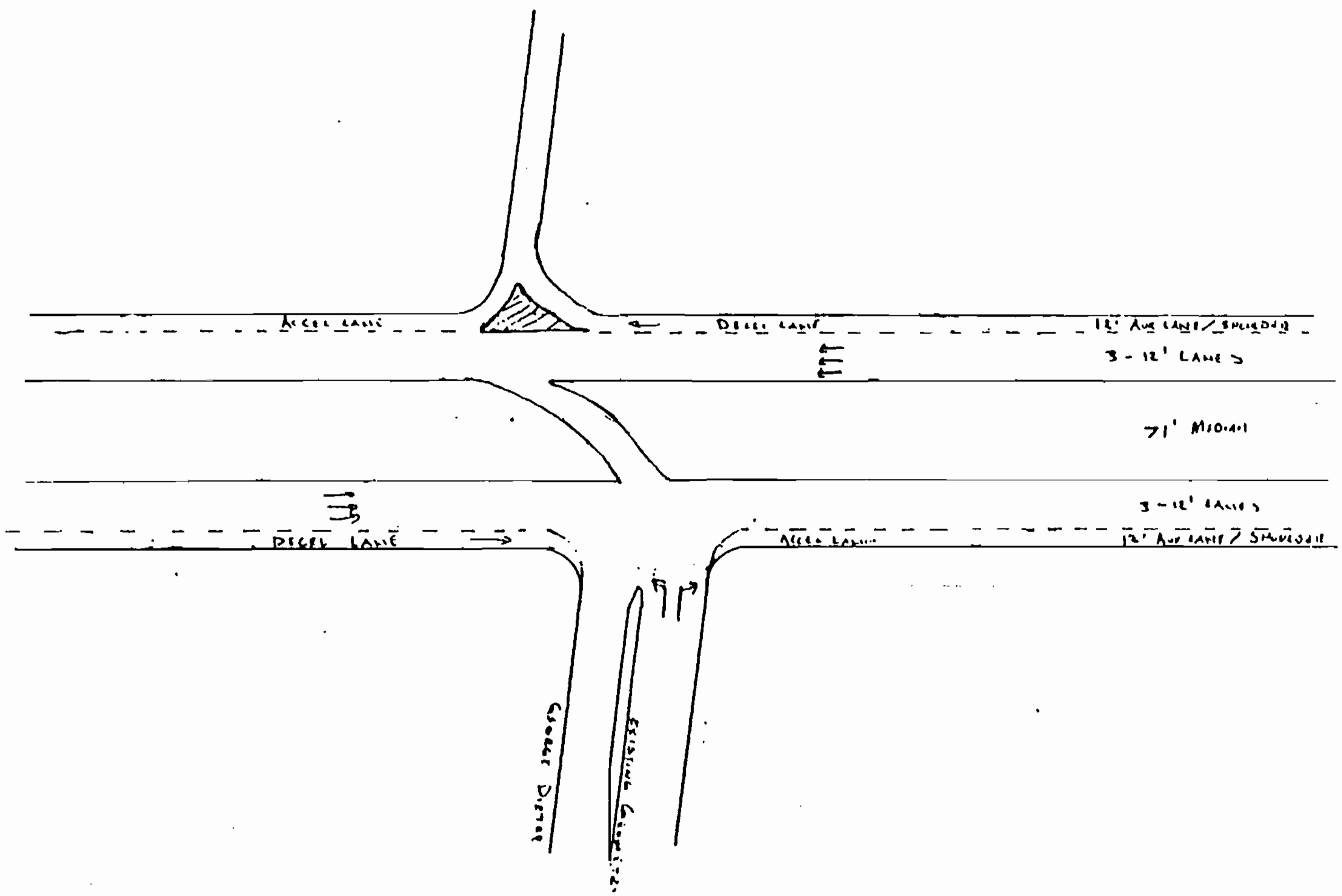

Figure D26. Desirable Right of Way at George Dieter Road

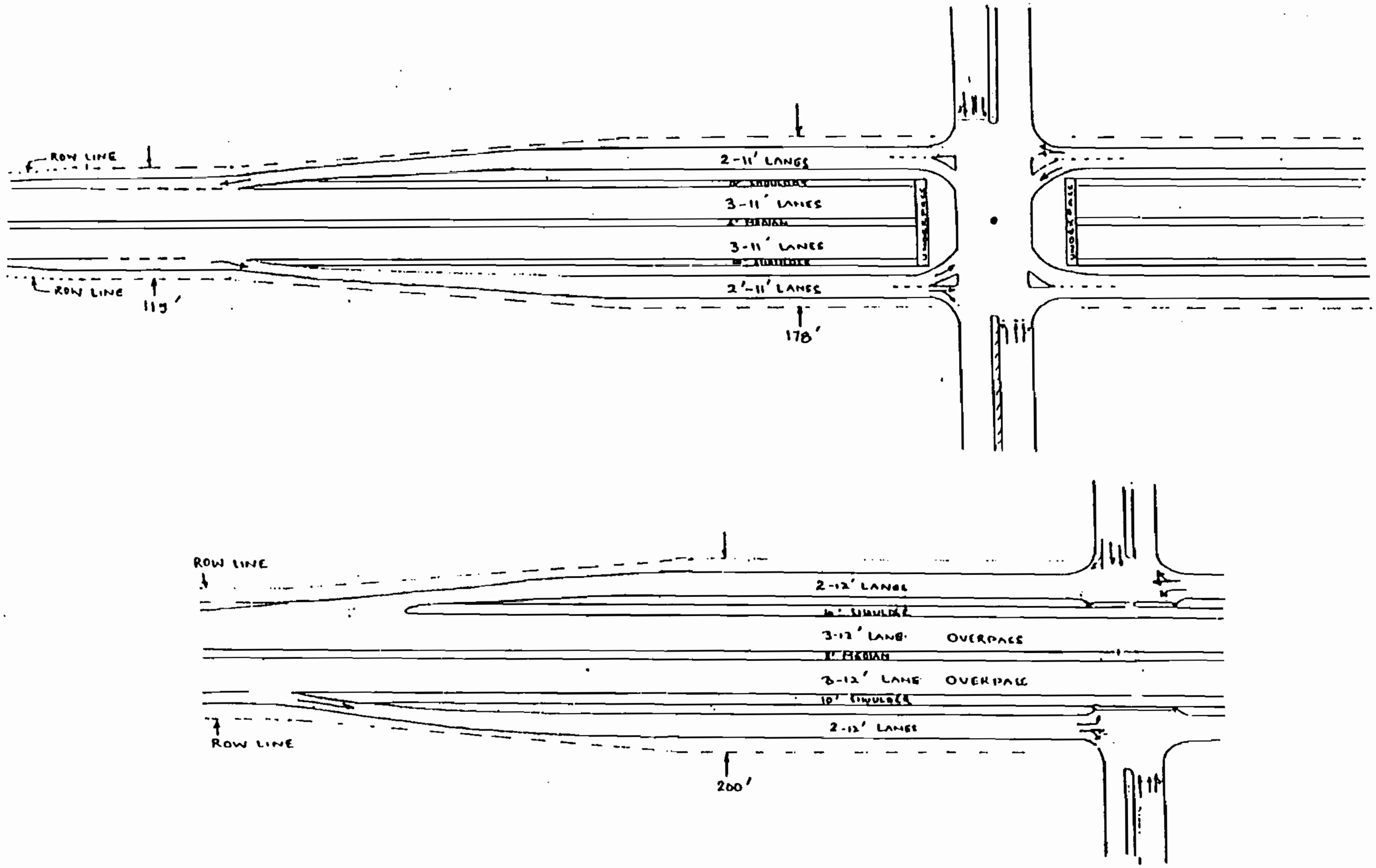

Figure D27. Minimum and Desirable Grade Separation Right of Way