TRAVEL TIME AND ACCIDENT BENEFITS DUE TO RECONSTRUCTION OF U.S. 52 BYPASS AT LAFAYETTE, INDIANA

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BY

A. MCNEIL

JHRP

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PURDUE UNIVERSITY AND

INDIANA STATE HIGHWAY COMMISSION

Progress Report

TRAVEL TIME AND ACCIDENT BENEFITS DUE TO RECONSTRUCTION OF U.S. 52 BYPASS AT LAFAYETTE, INDIANA

TO: J. F. McLaughlin, Director
Joint Highway Research Project

July 7, 1971

File No.: 8-7-5

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

Project No.: C-36-66E

The attached research report is a Progress Report on the HPR-1 (8) research project "Traffic Engineering Demonstration on the U.S. 52 Bypass Lafayette, Indiana". It is titled "Travel Time and Accident Benefits Due to Reconstruction of U.S. 52 Bypass at Lafayette, Indiana" and has been authored by A. E. McNeil, Graduate Assistant in Research on our staff. Professor H. L. Michael directed the study. This report is the final report on the phase of the project devoted to evaluation of the benefits of the reconstruction.

Travel time and accident benefits were evaluated for the portion of the Bypass reconstructed during 1968-69 and were found to be substantial. The dollar value of such benefits in fact were estimated to be in excess of the dollar costs of the reconstruction. Other benefits to the community, the land adjacent to the highway and to the highway user resulted in a conclusion that the reconstruction is a good investment.

The research was conducted as part of an HPR Part I research project and as such the report will also be forwarded to the ISHC and the FHWA for review, comment and acceptance as partial fulfillment of the objectives of the project.

Respectfully submitted,

Harold L. Michael

Harold L. Michael
Associate Director

HLM:ms

cc: F. L. Ashbaucher
W. L. Dolch
W. H. Goetz
W. L. Grecco
M. J. Gutzwiller
G. K. Hallock
M. E. Harr
R. H. Harrell
M. L. Hayes
E. M. Mikhail
R. D. Miles
J. W. Miller
C. F. Scholer
M. B. Scott
W. T. Spencer
N. W. Steinkamp
H. R. J. Walsh
K. B. Woods
E. J. Yoder

Progress Report

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by

Alexander E. McNeil
Graduate Assistant in Research

Joint Highway Research Project
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ABSTRACT

McNeil, Alexander Edward. MSCE, Purdue University, June 1971. TRAVEL TIME AND ACCIDENT BENEFITS DUE TO RECONSTRUCTION OF U.S. 52 BYPASS AT LAFAYETTE, INDIANA. Major Professor: Harold L. Michael

The purpose of this study was to determine the benefits that have accrued to both road-users and nonusers due to the reconstruction of the first stage of the U.S. 52 Bypass at Lafayette, Indiana. To determine these benefits, a before and after study was made of the travel times on the facility and the number and severity of the traffic accidents occurring. Some of the effect on the nonuser was evaluated by examining the land-use changes that have occurred along the roadway since the reconstruction.

A two-way analysis of variance performed on those travel time runs collected during the peak hours of the day indicated a significant reduction in travel time after the reconstruction. Additional analysis also indicated travel time savings during the off-peak period. Values of travel time were estimated and the total travel time benefits due to the reconstruction were estimated.

All reported accidents occurring on the reconstructed portion of the facility for a four year period before and one year after the reconstruction were analyzed in depth. The locations of greatest accident concentration were determined and the specific causes of accidents both at and between the intersections were determined. An

CHAPTER I. INTRODUCTION

The U.S. 52 Bypass at Lafayette-West Lafayette, Indiana was originally opened to traffic in 1938 and provided a means whereby motorists could go around these two cities without going through them. This seven-mile long, two-lane undivided facility is on a direct route between Chicago, Illinois and Indianapolis, Indiana and carries traffic that is through, terminal and local in nature. The location of the Bypass in relation to the cities of Lafayette and West Lafayette is shown in Figure 1.

At the time of its construction, the land around this facility was used almost exclusively for farming. The cost of the land, available labor, and the improved transportation offered by the Bypass attracted a variety of establishments to locations along the new facility. Highway-oriented businesses rapidly moved to locations along the roadway to cater to the needs of travelers. The Bypass also proved to be a forceful factor in determining the location of manufacturing, distributing, and servicing industries, both light and heavy.

A section of the facility at its southern end is shown in Figure 2. It can be seen that by 1952 the amount of development along this section was quite extensive. Moreover the absence of effective community or state control on the number and location of access points

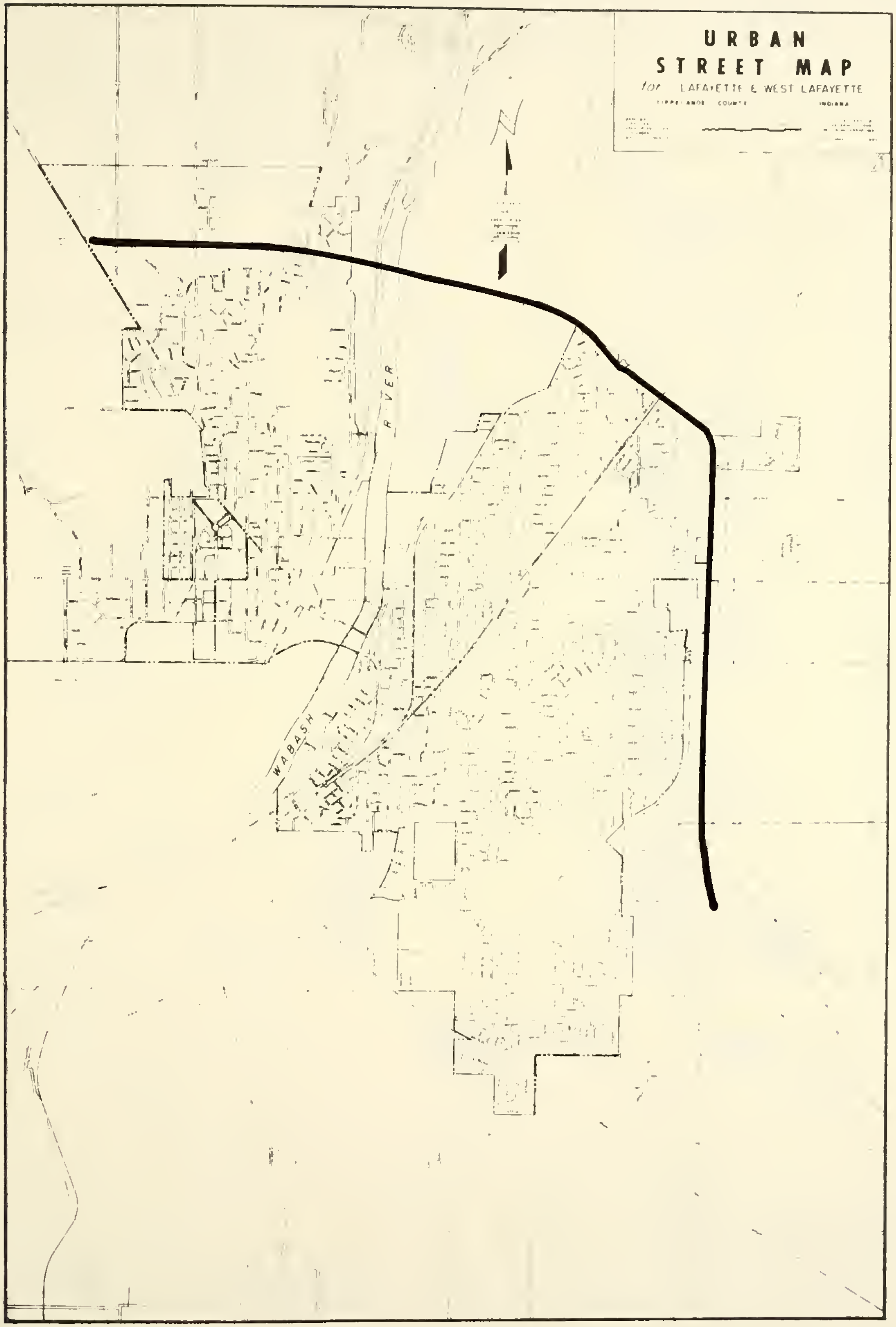

FIGURE 1. AREA MAP OF LAFAYETTE & WEST LAFAYETTE

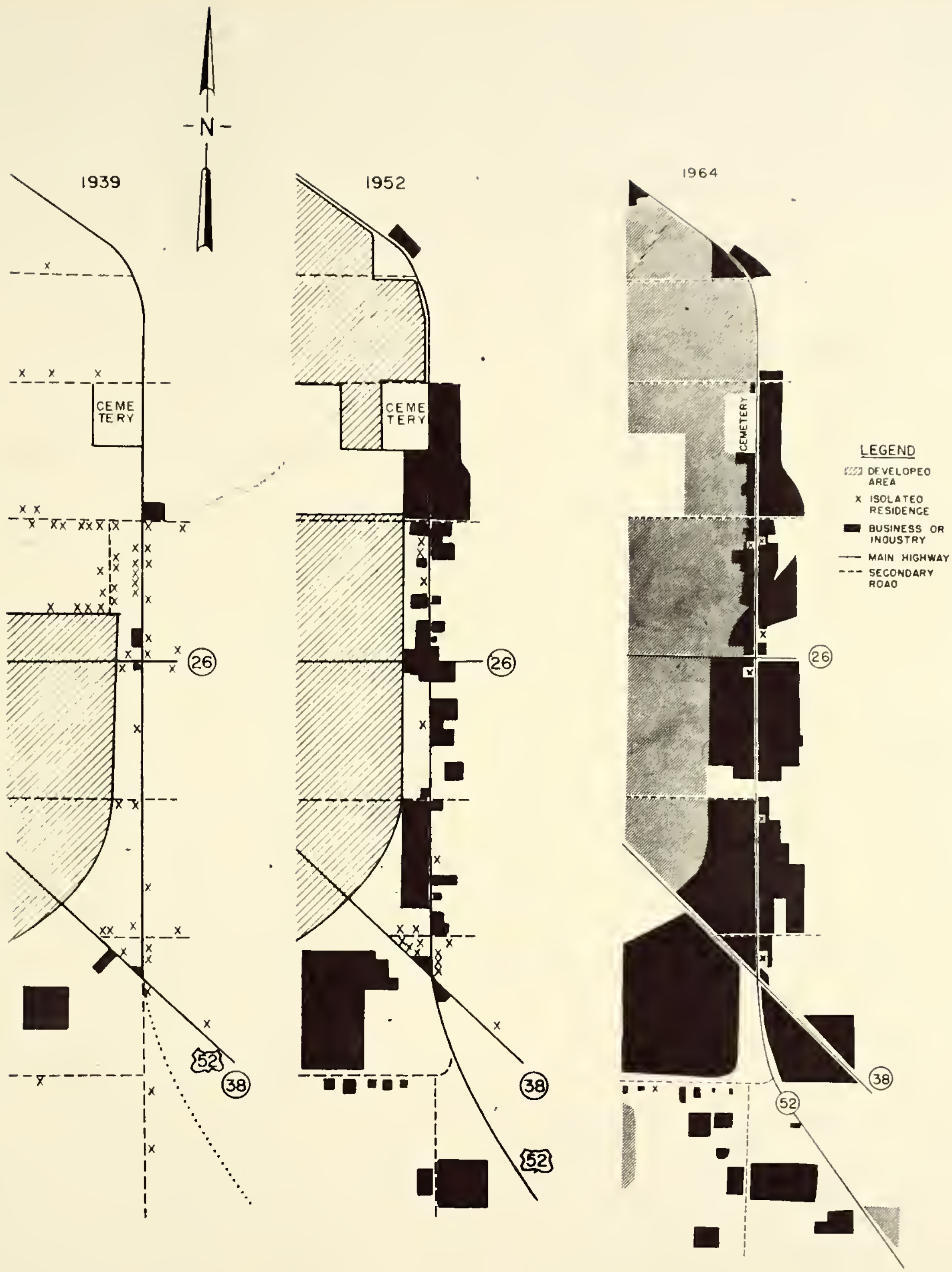

FIGURE 2. DEVELOPMENT ALONG PORTION OF THE U.S. 52 BY-PASS FOR 1939, 1952 AND 1964.

to development on the Bypass resulted in considerable areas of continuous access or in frequent access drives on both sides of the facility. The vehicular traffic using the facility was in the range of 8000 vehicles per day. The resultant delay and congestion experienced in 1952 gave notice that additional traffic capacity would soon be required.

By 1964 this section of the U.S. 52 Bypass resembled an urban arterial, the roadside filled with business establishments. The volume of traffic using the facility had risen to 18,500 vehicles per day, much of this being attracted by these businesses. The through traffic on the Bypass constituted less than fifty percent of this total volume (28). Commercial vehicles in the traffic stream represented approximately fourteen percent of the total traffic volume. The high volume and lack of access control, together with the physical limitations of the facility itself, resulted in severe traffic congestion and delay, and in a high accident frequency, characteristics that the Bypass was originally built to minimize. Another factor contributing to the confusion for the through traveler was the presence of high-speed, four-lane divided facilities at both the north and south ends of the Bypass.

In December of 1965 a public hearing was held to discuss the necessity of increasing the traffic carrying capacity of this facility through engineering improvements. It was proposed that the Bypass would require widening throughout its entire length before relief would be found for the congestion and accidents. Plans were developed

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*The numbers in parenthesis refer to sources listed in the Bibliography.

for reconstruction by the Indiana State Highway Commission and the first stage of the reconstruction was begun in 1968. This first stage was from McCarty Lane on the south to Union Street on the north, a distance of 1.534 miles (see Figure 3). The reconstructed portion was opened to traffic in the late fall of 1969.

When a facility is improved through reconstruction, major benefits accrue to those who use the facility. These road-user benefits are in the form of changes in the cost of motor vehicle operation, reductions in the time required to travel on the facility, and a reduction in the number of accidents occurring. Although the total number of the traffic accidents may be reduced, the severity of those occurring may increase due to the higher speeds attainable on the improved facility. There are also consequences to the nonuser that must be considered, factors such as the change in the land usage along the facility, the effect on highway-oriented businesses and an expansion of industrial activity due to the improvement. In general, highway improvement has the effect of stimulating business activity, especially in or near urban areas.

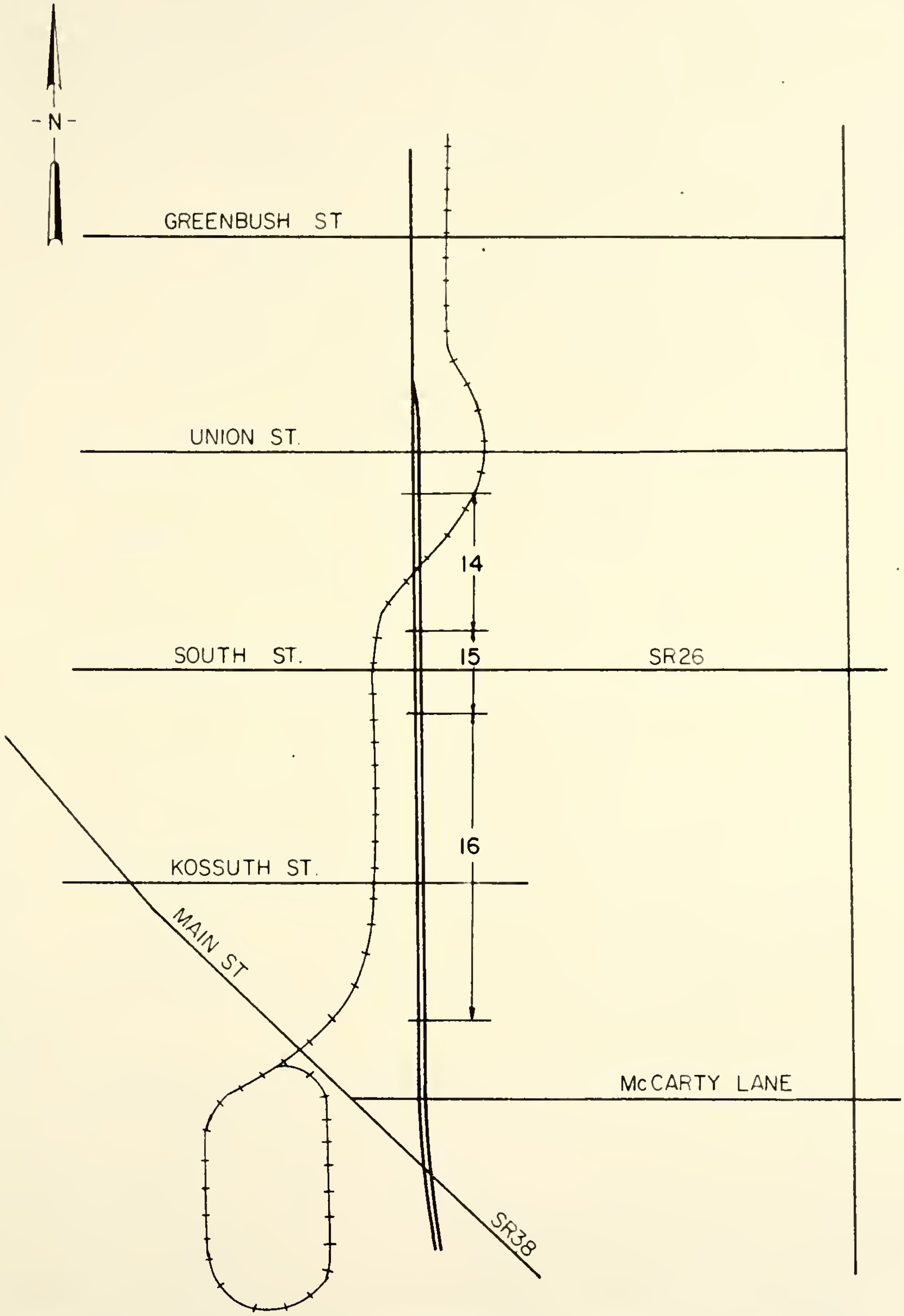

FIGURE 3. FIRST STAGE OF BY-PASS RECONSTRUCTION

CHAPTER II. PURPOSE AND SCOPE

A project was initiated in 1964 by the Joint Highway Research Project at Purdue University, the Indiana State Highway Commission, and the Bureau of Public Roads to evaluate the effectiveness of traffic engineering as applied to a congested urban arterial. The arterial chosen for this research was the U.S. 52 Bypass at Lafayette-West Lafayette, Indiana. Numerous studies of congestion, delay and accidents on this facility were conducted and recommendations made for many traffic engineering improvements. One of the recommendations was that significant improvement for the high volume of traffic using the Bypass would only be possible with reconstruction of the facility to provide additional capacity through widening to a minimum of four traffic lanes. The purpose of the portion of the research reported here was a determination of the road-user and nonuser consequences that have resulted from the reconstruction of the first stage of the Bypass.

Two earlier studies done as part of the early research provided the majority of the before data used in this investigation. One of these projects was a study of the speeds and delays on the Bypass (35). This study, conducted by Theodore Treadway in 1964, had as its purpose the identification of locations of delays on this facility and the determination of the factors causing these delays. The objective was to increase knowledge about the facility so that recommendations could be made to improve traffic flow on the Bypass.

Factor analysis and linear regression were used to express the travel time and delays as functions of factors considered descriptive of the traffic stream, amount of development and roadway characteristics. The factors determined to be most significant by Treadway in accounting for variation in traffic speed between intersections were the amount of stream friction and the roadside development. The recommendations that resulted from this research were limitation of the number of access points along the roadway, improvement in the design of signalized intersections and improvement of signal cycle phases.

The other investigation utilized was a study of all traffic accidents occurring on the U.S. 52 Bypass between January 1, 1961 and December 31, 1963 (28). The objective of this study, conducted by Arvid Peterson, was to make recommendations on traffic engineering improvements to reduce the accident rate on this facility. The 834 traffic accidents involving 374 injuries and 10 deaths were analyzed using multiple linear regression analysis and quality control techniques. Several different types of accident rates were utilized to determine specific causes of accidents at both intersections and non-intersectional study sections. In addition, traffic accident rates for weekend vs. weekday, day vs. night and clear vs. inclement weather were compared. The specific causes of these accidents were determined at different locations and the points of greatest accident concentration located. Collision diagrams were used to analyze each intersection for each of the three years.

To determine benefits that have accrued to both the road-user and nonuser due to the reconstruction of the first stage of the U.S. 52 Bypass, a before and after study was made of the travel times on the facility and the number and severity of the traffic accidents occurring. Some of the effect on the nonuser was also evaluated by examining the land-use changes that have occurred since the reconstruction.

The after travel time data was obtained in the same manner as in the previous research by Treadway. The comparison of these two sets of data was made using the two-way analysis of variance technique. This technique allowed conclusions to be made on whether there was in fact any statistical difference between the two periods. Included in the investigation was a section of the Bypass that had not been reconstructed at the time of the study. If there were any significant differences in the testing methods used in the before or after studies, or if there were other confounding factors due to the time between the two studies, such as improvements in the vehicles themselves, these factors would appear as significant on this control section. If the confounding factors were shown to be insignificant on this control section, any differences in travel times on the improved sections could be attributed to the reconstruction itself.

The traffic accident records from the Indiana State Police and the Lafayette police were examined and all accidents occurring on the improved section of the Bypass in 1964, 1965, 1966, 1967 and 1970 were investigated. Accidents for 1968 and 1969 were not included because this was the period of reconstruction. Spot maps were used to determine the locations of the greatest accident concentration. Collision diagrams were employed to determine the specific causes of the traffic accidents occurring at the intersections within the reconstructed section of the Bypass. The traffic accident rates for the years prior to the improvement were analyzed using statistical methods in an effort to determine if the accident rate was relatively constant before the reconstruction. A comparison was then made of the accident rates before and after the widening.

A third consequence to the road-user which was not considered in this study was reduction in the operating costs of the vehicles using the facility. These operating costs are dependent on a considerable number of factors, including the physical characteristics of the roadway itself, the topography, the vehicle, and the driver. In the determination of operating costs, information is required on the traffic volume, classification of the traffic stream, vehicular speed, and frequency and magnitude of speed changes. Data on speed changes was not available for the period before reconstruction and prevented any estimation of the reductions in operating costs from being made. An examination of a set of running cost tables, such as can be found in <u>Economic Analysis for Highways</u> by Robley Winfrey, however, yields some interesting findings. Although a decrease in the number and magnitude of speed changes on the facility can be expected as a result of the improvement, thus decreasing the running cost, the increased speed on the improved facility increases the running cost. This increase in cost has the effect of making any consequences to the road-user quite small in comparison to the other road-user consequences. It would appear, therefore, that the ommision of operating costs does not seriously affect the results.

Both the travel time and accident consequences of the reconstruction were measured in terms of reductions in the annual expenses incurred by the road-user. A comparison of these benefits with the total direct cost of the improvement was then made to determine the profitability of the improvement.

Nonuser consequences, in the form of changes in land-use along the improved section of the Bypass was also done as part of this research. An investigation of all the land-uses existing in 1964 was done as part of the preliminary data collection by Theodore Treadway. The selection of 1964 as the before period allowed the inclusion of any land-use changes that may have taken place in anticipation of the improvement. The land-uses in 1970 were determined through visual inspection of the improved section.

CHAPTER III. REVIEW OF LITERATURE

The highway literature is replete with the term "benefit" as it applies to both the user of a highway and the nonuser. Mohring and Harwitz define a benefit as a highway investment effect which is viewed favorably by at least some members of the community (25). It can generally be stated that a benefit must be either a reduction in cost or an increase in personal satisfaction and driving pleasure.

In the analysis of user benefits that result from a highway improvement, there exist a number of measurable cost reductions. These reductions are composed of such items as the operating cost of the motor vehicle, the cost of travel time and the cost of traffic accidents.

The reduction in the operating costs of motor vehicles are measured in terms of fuel consumption, oil consumption, and tire wear. Vehicle maintenance and depreciation, also assignable as operating costs, are also affected by highway improvement. An excellent source of operating cost information has been compiled by Winfrey (38). He states that the amount spent on vehicle operation is dependent on such characteristics as the facility itself, the topography of the area, traffic speed and number and magnitude of speed-changes made by the driver. In compiling tables of the running costs of motor vehicles, Winfrey made use of available published sources, test results, correspondence with people in the automotive industry and personal judgment. The tables were developed for a full range of speeds for five typical vehicles. Soberman and Clark developed a method that used a computer program to generate tables of operating costs applicable over a wide range of speed, gradient, highway standard, surface type and level of service (30).

Various studies have attempted to place a value on the travel time of the traveler. The fundamental concept in these studies is that time has a value because of the work that can be done or the satisfaction gained in a certain time period. An AASHO committee recognized that the time saved by trucks and buses has value in direct ratio to those costs of operation directly related to time, such as the hourly rental of equipment (1). The value of time to the driver of a private vehicle is more difficult to determine.

A preliminary report to the U.S. Bureau of Public Roads by the Stanford Research Institute in 1963 evaluated all the studies on travel time reported up to that time (18). Early studies usually placed the value of time at the current minimum or average wage rate being paid. Another early approach tried to determine what amount the traveler would be willing to pay for faster travel times. The first method assumes people will pay the same amount for time as they are paid for an amount of work produced in this time. The second approach often assumes price differentials being paid for other forms of transportation can be applied directly to highway transportation. Neither of these methods has been shown to be correct. One conclusion of the Stanford report was that it was impossible to state with certainty that a statistically confident estimate of the willingness to pay for time will ever be made. A study done by Thomas as part of the final report from the Stanford Research Institute in 1967 attempted to determine the value of passenger-car travel time based on field observations of commuter travel between home and work (33). The opportunity existed for travel by either a toll road or a toll-free road. Thomas arrived at a value of $2.82 per person per hour. This value seems to be what the commuter is willing to pay to reduce travel time. Winfrey suggests that reasonable values for travel time lie in the range of $1.00 to $4.00 per car-hour, depending on prevailing local factors (38).

Accident data, such as the cost of an involvement, are recognized to be factors of considerable significance in the evaluation of engineering improvements. A considerable amount of research has been done on the value of a traffic accident and what factors should be included in the determination of these costs. A study conducted in Massachusetts in 1953, and reported by Dunman, confined the costs of accidents to those that were specifically due to the accident (13). Such direct costs are composed of the money value of damage to property; hospitalization; services of physicians, dentists, and nurses; ambulance use; medicine; work time lost; damages awarded in excess of other direct costs; attorneys' fees; court costs; and other miscellaneous costs. This report determined that of the total economic loss from traffic accidents, fifty-nine percent was due to property damage alone. A report by Twombly on the Massachusetts study demonstrated that highways with full control of access had much lower accident rates than facilities that did not control access, traffic volume being the same (36).

A study undertaken jointly by the Illinois Division of Highways and the U.S. Bureau of Public Roads in 1959 had as its purpose the measurement of the direct costs of all accidents involving Illinois registered vehicles for calendar year 1958 (4). The direct cost classification was similar to that used in the 1953 Massachusetts study. A major difference was that the 1959 Illinois study attempted to determine the costs of unreported accidents in addition to the reported accidents. The law in the State of Illinois required that an accident report be filed for all traffic accidents in which the costs exceeded $100. An interesting finding of this study was that approximately three-fourths of the total number of accidents were unreported. Although these accidents were usually minor involvements, in total they represented a substantial part of the direct cost.

The Washington, D. C. area study of 1964-65 is interesting because some costs were included in the total direct costs that were not considered in the previously reported research (38). Included was the net present worth of future income of the fatalities and persons suffering permanent disability. The present worth of the future incomes is based on the individuals years of productive employment, not the life expectancies. Deductions are made from the earnings to reflect the amount of money required to support the individuals. This deduction results in the net present worth. The Washington study reported that over ninety percent of the total cost of fatal injury accidents was attributable to the net present worth of probable future earnings of the fatalities.

An estimation of the direct costs of traffic accidents on rural highways in Indiana was done by Hejal as part of the development of a priority model for highway improvement (19). All accidents that occurred on Indiana rural state highways for the years 1967 and 1968 were obtained from the Division of Traffic of the Indiana State Highway Commission. A mathematical procedure was developed that made use of the 1959 Illinois study, reported above. The rise in prices and increase in costs of services between 1958 and 1970 were determined through the use of the consumer price index. The following estimates for the total direct costs of reported accidents on rural state highways in Indiana, in 1970 dollars, were made:

Severity Class	Total Direct Cost per Accident
Fatal	$18,605
Nonfatal injury	4,280
Property damage	606
All	2,433

The costs of unreported accidents in Indiana were estimated to be fifteen percent of the total accident costs.

Most people in the community are affected by highway investment in two ways; directly, through highway use and indirectly, through environmental changes induced by the highway. The major direct effects have already been discussed. Winfrey classifies the nonuser consequences into the following categories (38):

1. Spending for highway construction
2. Land use and land values
3. Highway travel oriented business
4. Highway induced expansion of industry and business

The construction of a highway provides employment for a sector of the population, and helps support many industries through the consumption of material and supplies. Money used for highway construction is derived from direct taxation on the motor vehicle. The highway user is therefore getting highways as a direct result of these taxes.

The improvement of a highway facility usually has the effect of stimulating business activity along the facility, with some changes in land-use occurring. Bardwell and Merry propose that this stimulation can be measured by the number of land transactions, the size of the parcels of land sold and the distance from the center of the community, before and after the improvement (2). As would be expected, the number of transactions along a new facility is substantially greater than along an improved facility.

Zettel states that land value should not be considered a nonuser benefit (41). Any increase in the value of land abutting the roadway is simply a manifestation of the fact that the land is made more accessible by the improvement and will therefore become more valuable. Access to the improved facility is of importance whether considering industrial, commercial or residential land use. Much of the land use change that takes place is a conversion of existing facilities to other uses.

An improvement to an existing highway facility can usually be expected to cause an increase in highway-oriented businesses. Where the land is available, other changes can usually be anticipated. In Monroeville, Pennsylvania there were three major highway developments between 1949-1958. During that time business activities increased from 65 to 409, with the greatest increase in retail establishments. Dansereau points out that other usage changes can be expected. Retail is usually the greatest, followed closely by services (9).

An investigation by Bone and Wohl examined the land-use changes that have taken place along Massachusetts Route 128 (39). They determined the principle impact of that highway to be the channeling of industrial development into the towns through which it passes. The essential factors considered by industry were accessibility, land available for future expansion and modernization, adequate labor supply and an attractive site.

CHAPTER IV. DETERMINATION OF TRAVEL TIME BENEFITS

Design of Study

This phase of the study was concerned with evaluating any changes in travel time that have resulted due to the reconstruction of a section of urban arterial. These benefits were then summed with benefits resulting from accident reduction owing to the reconstruction.

The entire U.S. 52 Bypass at Lafayette-West Lafayette, Indiana has been scheduled for reconstruction from a two-lane undivided highway to a four-lane divided facility. At the time of this study only the first phase of this improvement had been completed. This section, located between Union Street and McCarty Lane, is 1.534 miles in length. Reconstruction was begun in 1968 and the section was opened to traffic in late 1969.

The information required for the period before the improvement was obtained as part of a study conducted by Theodore Treadway in 1964 (35). The purpose of that research was to make a detailed analysis of travel speeds and delays on the Bypass. The entire seven mile length of the Bypass was included in this previous research. The Bypass was split into eighteen (18) homogeneous study sections determined by considering the geometry, posted speed limit, roadside development and location of traffic signals. These 18 sections are shown in Figure 4. A distance of 500' on each side of the center of

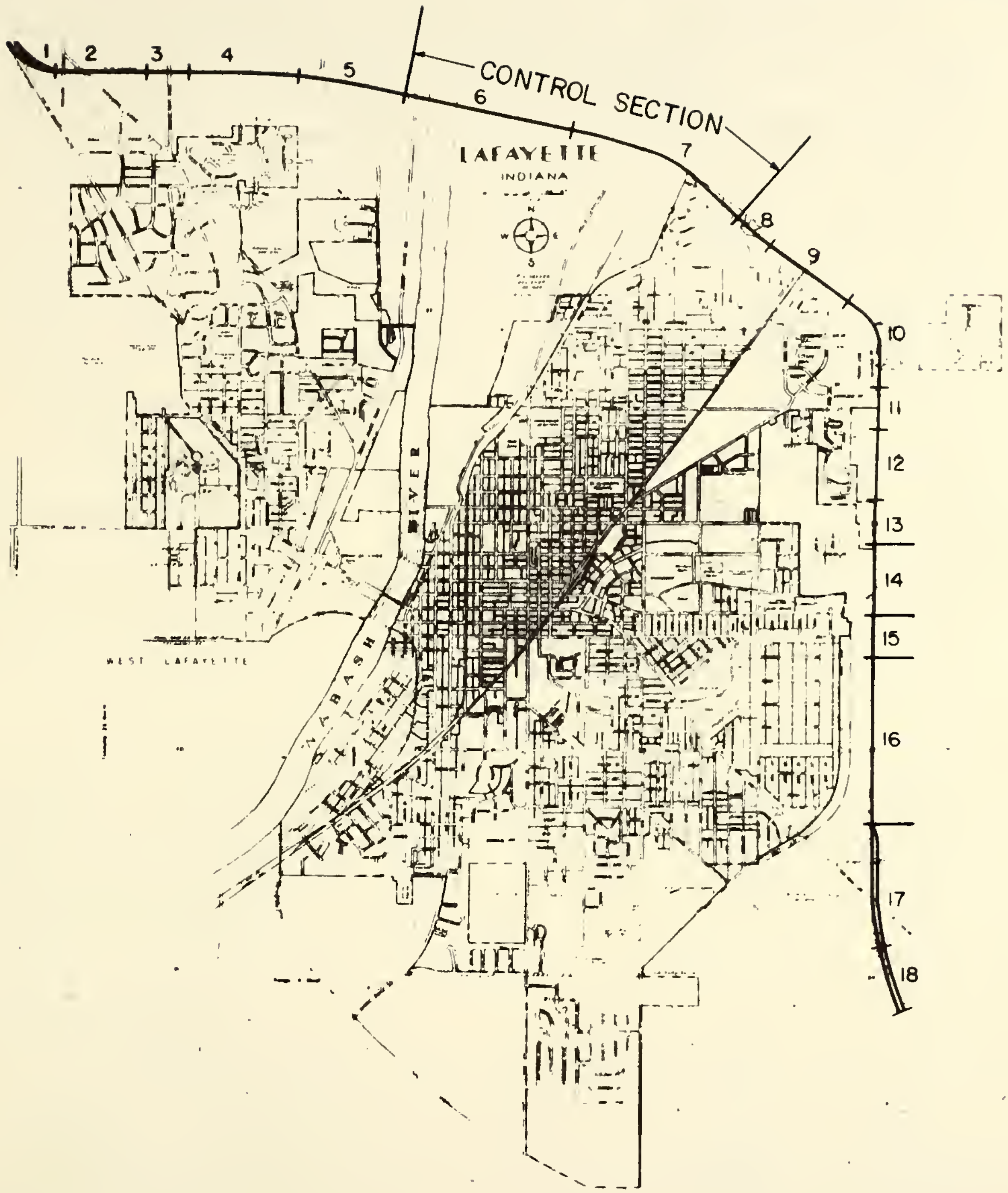

FIGURE 4. TEST SECTIONS FOR 1964 TRAVEL TIME STUDY

a signalized intersection was established to define the zone of influence of a traffic signal. This was an adequate distance to allow for a comfortable stop to be made when a red indication was displayed and a sufficient distance to allow a vehicle to return to a normal operating speed. These intersections were classified as interrupted flow; all other sections of the Bypass were designated as uninterrupted flow. Sections 3, 8, 11, and 15 were placed in the interrupted flow category.

Neither section 1, 17, or 18 were evaluated in the 1964 study. Sections 1 and 17 included transition from a four-lane divided highway to a two-lane roadway, while section 18 was composed entirely of four lanes.

The sections included in the first stage of reconstruction were 13, 14, 15, 16 and 17. Section 17 again was not analyzed in this study because it included a transition from four-lane to two-lane in 1964 and was not included in that research. Section 13 was also ignored because it contained a similar transition at the time of the present study. The sections included in the present analysis were sections 14, 15 and 16 (see Figure 4).

A direct comparison could not be made of the travel times in 1964 and 1970 on sections 14, 15 and 16 because of the possibility that other changes were confounded with time. Any improvement in automobile design, for example, may have improved the travel time on the Bypass even without any highway improvement being made. It was therefore necessary to compare the 1964 and 1970 travel times on sections of the Bypass that had not yet been reconstructed or improved in any way since the 1964 study. Sections 6 and 7, located between the Wabash River Bridge and a point 500' north of S.R. 25, had these desired properties. These sections are also shown in Figure 4. There had been no development along these sections that would generate additional traffic volume or otherwise affect the traffic on this portion of the Bypass. They will hereafter be referred to as the control sections. It was hypothesized that if any changes confounded with time were insignificant in the comparison of 1964 and 1970 travel times on the control sections, they would also be insignificant on the reconstructed sections and could be disregarded.

Data Collection

Forty (40) travel time runs were made in each direction in the 1964 travel time and delay study. For the purposes of this research, these forty runs were classified according to the time of day and the day of the week on which they were made. All travel time runs made during the 1964 study were taken during the hours of 7:00 a.m. to 6:00 p.m. Forty (40) 1970 travel time runs were made in an identical manner using the average car technique.

Volume counts for 1970 were obtained using portable, pneumatic-actuated machines. Determination of the average annual daily traffic (AADT) required the correction of these counts to account for the large percentage of multi-axle vehicles in the traffic stream, seasonal variations and daily variations.

The percentages of the different types of vehicles in the traffic stream on the U.S. 52 Bypass were determined from manual classification counts. In these counts each vehicle was classified as one of five typical vehicles, these being (1) the 4-kip passenger car, (2) 5-kip commercial delivery vehicle, (3) 12-kip single unit truck having dual rear wheels, (4) 40-kip tractor-semitrailer having four axles, and (5) 50-kip tractor-semitrailer having five axles. The volume counts were adjusted to reflect the percentages of these various vehicles.

To determine the factors to be used in the seasonal and daily variations, data from the Indiana State Highway Commission for traffic recorder 40-A was obtained. Traffic recorder 40-A is located on S.R. 25 south of Lafayette, Indiana and was selected because it is located on a main highway in the Lafayette urban area and gives an accurate reflection of the traffic variations in the area. The procedure used for determining the seasonal variation is standard and yielded the monthly traffic volume variations shown in Table 1. The daily traffic variations on S.R. 25 are shown in Table 2.

The adjustments of the volume data collected on the U.S. 52 Bypass were then accomplished. The month in which the volume counts were made and the days of the week when the counts at each location were collected allowed the correction factors in Tables 1 and 2 to be applied, along with the correction for traffic composition.

The 1964 AADT volumes were determined from volume count data supplied by the Indiana State Highway Commission and from data provided by the 1964 travel time and delay study. Turning movement volumes for 1970 at the major intersections within sections 14, 15, and 16 were evaluated by manual counts and for 1964 from data available

TABLE 1. SEASONAL VARIATIONS IN TRAFFIC FLOW*

Month	ADT	Monthly Correction Factor
June 1968	5340	1.03
July	5365	1.03
Aug	5536	1.07
Sept	5380	1.04
Oct	5328	1.03
Nov	5196	1.00
Dec	4875	0.94
Jan 1969	4372	0.84
Feb	4779	0.92
Mar	5145	0.99
Apr	5313	1.02
May	5628	1.08

*Data are from the Indiana State Highway Commission's permanent volume count station No. 40-A on S.R. 25 in the Lafayette, Indiana urban area.

TABLE 2. DAILY VARIATIONS IN TRAFFIC FLOW*

Day	ADT	Daily Correction Factor
Monday	5002	0.964
Tuesday	5026	0.969
Wednesday	5014	0.966
Thursday	5111	0.985
Friday	5821	1.122
Saturday	5618	1.083
Sunday	4733	0.912

AADT=5188

*Data are from the Indiana State Highway Commission's permanent count station No. 40-A on S.R. 25 in the Lafayette, Indiana urban area.

from the 1964 study. The resulting volume counts for the major intersections within the study sections are given in Appendix A for 1964 and 1970. The AADT volume on the reconstructed portion of the U.S. 52 Bypass had increased from approximately 18,500 vehicles per day in 1964 to 25,500 vehicles per day in 1970. (see Appendix A).

The capacity of a highway, as defined in the Highway Capacity Manual (1965), (21) is the maximum number of vehicles that have a reasonable chance of passing over a given section of roadway in a given time period. This capacity is in large measure determined by the physical limitations of the facility itself. Other factors that are of major importance in capacity determinations are fluctuations in traffic demand and the stream friction. The aggregate demand for the use of a facility is expressed in traffic volume. The level of service of a roadway under various operating conditions is a measure of the service to the road-user and is a function of the speed obtainable, the freedom to maneuver in the traffic stream, comfort and convenience, safety, and the cost of operation.

Volume is an indication of traffic demand. Capacity determination is concerned with whether or not a given facility can operate at a certain demand volume at an acceptable level of service. Various reports included in the HCM indicate a direct relationship between the volume of traffic using a facility and the travel speed obtainable. These studies show that for both nonintersectional and intersectional areas, the mean speed decreases as the traffic volume increases.

The U.S. 52 Bypass study sections were considered as urban arterial in the determination of capacity and levels of service. The entire first stage of the reconstruction was considered in this analysis. The major bottlenecks appeared to be the intersection at South Street. An investigation conducted as part of the 1964 travel time and delay study indicated that although no separate turning lanes were provided at this intersection, traffic made extensive utilization of the paved shoulders. These shoulders were shown to be carrying approximately one-third the capacity of a properly constructed and signed turning lane. This result was incorporated into the determination of the capacity of these intersections in 1964. There were no other locations along the test sections that effectively controlled the traffic flow as did this intersection. This intersection was operating at level of service F in 1964, with the demand volume exceeding the capacity. Extensive delays were not uncommon.

The reconstruction of this first stage to a four-lane divided facility with separate turning lanes (signal controlled) has improved the level of service at the South Street intersection. Calculation of 1970 capacity and consideration of the 1970 peak hour volumes indicate that this intersection was operating in the range of levels of service D to E.

Analysis of Data

The major comparison of the travel time data before and after the reconstruction was made only on those runs taken during the peak period of the day. An examination of the volume data previously discussed revealed this peak period to be between 3:00 p.m. and 6:00 p.m. Figure 5 shows the volume counts at one location on the Bypass; the peaking characteristics are clearly visible. The volume during this three hour period is fairly constant. The 15 travel time runs made during this period of the day were separated from the other data and extensively analyzed.

Conclusions on the effect on travel time of the reconstruction could not be made until the effect of volume increase between 1964 and 1970 had been evaluated. Speed-volume curves for urban arterials indicate a linear relationship between volume increases and speed decreases (21). This relationship could have the effect of lessening any change in travel time due to the improvement. It might be necessary, therefore, to adjust travel time for the effect of volume increase so that any possible linear bias in treatment comparisons due to initial differences in volume would be removed. The method by which this adjustment was evaluated is known as covariate analysis. Such an analysis should increase the validity of comparisons made of 1964 and 1970 travel times.

Data that were needed for the covariate analysis included the travel times on each of the three test sections (14, 15 and 16), in seconds; traffic volume estimates for the days on which the runs were made; the direction of the run, either in a northerly or southerly direction on the Bypass; and the year in which the data were collected. The data were punched on IBM cards, verified, and analyzed using programs from the Statistical Library at Purdue University. All analysis was done on the CDC 6500 computer at Purdue University.

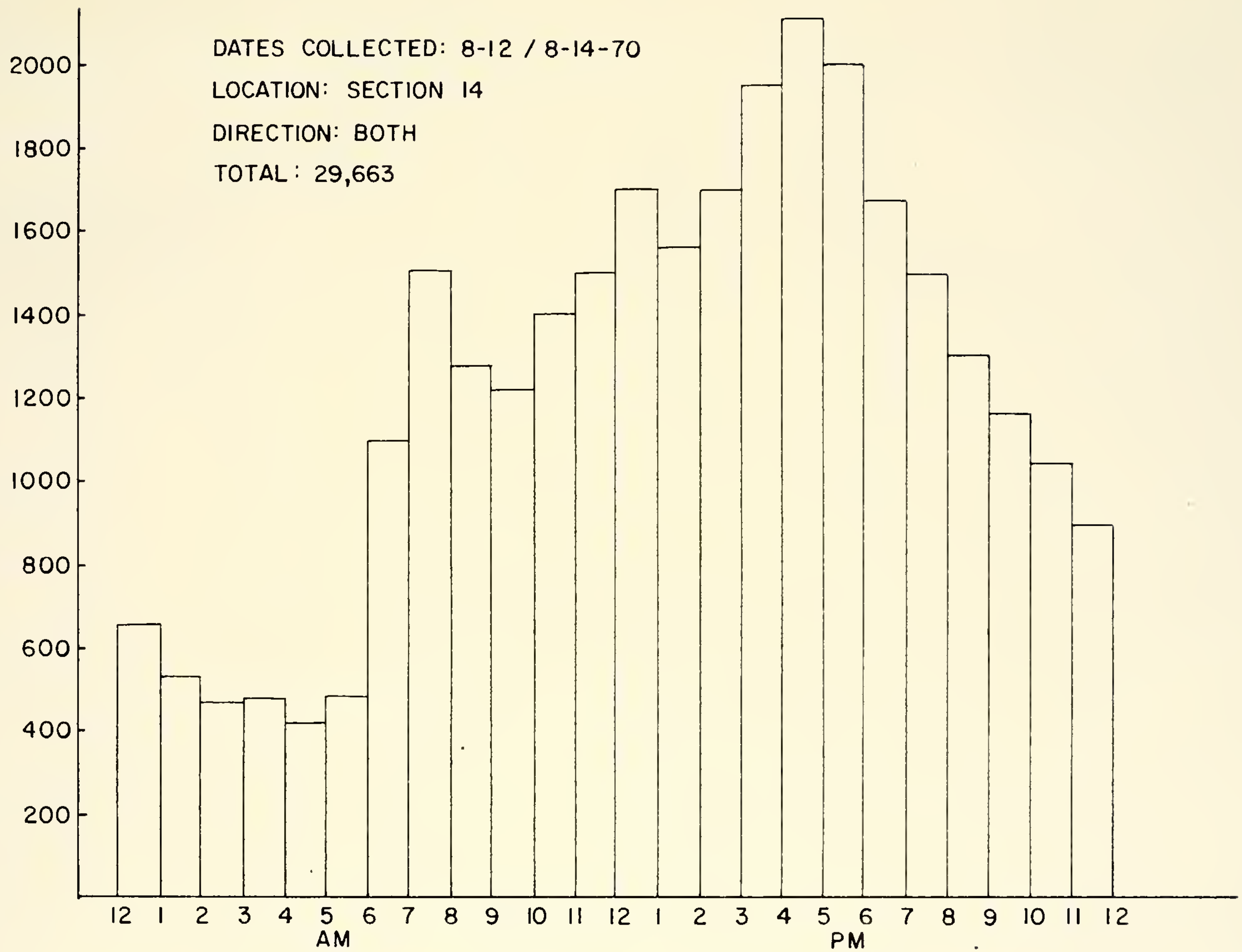

FIGURE 5. HOURLY VOLUME (2-AXLE), SECTION 14

The comparison of the 1964 and 1970 travel time data was initially performed using a two-way analysis of covariance technique. Factors included in the analysis were the year of the run, either 1964 or 1970, and the direction of travel, either northerly or southerly. Model I, developed for the analysis of covariance, was:

$$\text{(I)} \qquad Y = u + A_i + B_j + (AB_{ij}) + \beta(V) + e$$

where Y is the travel time, in seconds; u is an overall mean; A_i is the year in which the run was made, 1964 or 1970; B_j is the direction of travel, either north or south; (AB_{ij}) is the interaction term; $\beta(V)$ represents the covariate term, volume; and e is the residual term. The e is assumed to be an independent random sample from a normal distribution with mean zero and variance σ^2. The null hypothesis that is being tested by the use of Model I is that there is no difference among treatments not due to a difference in the covariate. It will determine if the covariate term is necessary and if there is a difference among the treatments. The assumptions that were made for the covariate are: (15)

1. individuals are randomly assigned to treatment groups.
2. within each treatment group, volume and travel time are linearly related.
3. the slope of the regression line is constant.
4. for runs with the same covariate (volume) in the same treatment group, travel time, is normally distributed.
5. the variance of the distribution of travel time with the same volume in a particular treatment group is the same for all treatments.

The results of the analysis of covariance were obtained using the modified version of BMD5V, and are reported in Tables 3, 4, 5 and 6 for the control sections and sections 14, 15 and 16, respectively.

The most interesting result of this analysis was that in all cases, the test for $\beta = 0$ yielded an F-value less than 1. It was therefore concluded that the analysis of covariance to account for volume increases between 1964 and 1970 was not necessary. The range of volume increases at the volume levels present in this study was not great enough to show volume changes between 1964 and 1970 as being significant.

The covariate term was removed from the model for all subsequent analysis. The model for a two-way analysis of variance remained:

$$\text{(II)} \qquad Y = u + A_i + B_j + (AB_{ij}) + e$$

The results of the analysis of variance are shown in Tables 7, 8, 9 and 10. For the control sections, Table 7, it can be seen from the ANOVA table that neither the year the run was made nor the direction of travel was significant, even at the 10% level. The conclusion was therefore made that the factors which might have been confounded with time are not significant. A direct comparison of the travel times on the improved portion between Union Street and McCarty Lane was therefore valid.

Table 8 shows the results of the analysis for section 14, a section of uninterrupted flow between Union and South Streets. An examination of the ANOVA table reveals that the F-value for the year (A) in which the run was made is equal to 11.25. This is statistically

TABLE 3. TWO-WAY ANALYSIS OF COVARIANCE, CONTROL SECTIONS

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.	Means of Covariates
70N	15	115.13	519.73	37.12	6.09	17592.93
70S	15	119.73	2636.93	188.35	13.72	17592.93
64N	15	112.26	1534.93	109.64	10.47	14095.20
64S	15	119.86	7299.73	521.41	22.83	14095.20

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	1.722	1.722	0.008	N.S.
B	1	558.150	558.150	2.562	N.S.
AB	1	33.750	33.750	0.155	N.S.
Residual	55	11983.762	217.887		
Total	58	12577.384			

F-value for significance of covariate - 0.03475

TABLE 4. TWO-WAY ANALYSIS OF COVARIANCE, SECTION 14

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.	Means of Covariates
70N	15	30.47	401.73	28.69	5.36	27997.47
70S	15	31.53	173.73	12.41	3.52	27997.47
64N	15	37.20	1472.40	105.17	10.26	22951.60
64S	15	37.27	852.93	60.92	7.81	22951.60

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	29.799	29.799	0.565	N.S.
B	1	4.817	4.817	0.091	N.S.
AB	1	3.750	3.750	0.071	N.S.
Residual	55	2898.935	52.708		
Total	58	2937.301			

F-value for significance of covariate - 0.03538

TABLE 5. TWO-WAY ANALYSIS OF COVARIANCE, SECTION 15

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.	Means of Covariates
70N	15	4.53	9333.73	666.69	25.82	28060.13
70S	15	37.20	2852.40	203.74	14.27	28060.13
64N	15	38.87	2285.73	163.27	12.78	22259.87
64S	15	46.47	5523.73	394.55	19.86	22259.87

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	15.158	15.158	0.042	N.S.
B	1	0.267	0.267	0.001	N.S.
AB	1	836.267	836.267	2.301	N.S.
Residual	55	19990.528	363.464		
Total	58	20842.220			

F-value for significance of covariate - 0.01395

TABLE 6. TWO-WAY ANALYSIS OF COVARIANCE, SECTION 16

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.	Means of Covariates
70N	15	67.20	360.40	25.74	5.07	27578.73
70S	15	70.13	539.73	38.55	6.21	27578.73
64N	15	96.53	36219.73	2587.12	50.86	21265.53
64S	15	77.40	1611.60	115.11	10.73	21265.53

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	1007.000	1007.000	1.440	N.S.
B	1	984.150	984.150	1.407	N.S.
AB	1	1826.017	1826.017	2.611	N.S.
Residual	55	38461.173	699.294		
Total	58	42278.339			

F-value for significance of covariate - 0.3865

TABLE 7. TWO-WAY ANALYSIS OF VARIANCE, CONTROL SECTIONS

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.
70N	15	115.13	519.73	37.12	6.09
70S	15	119.73	2636.93	188.35	13.72
64N	15	112.27	1534.93	109.64	10.47
64S	15	119.87	7299.73	521.41	22.83

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	28.017	28.017	0.131	N.S.
B	1	558.150	558.150	2.607	N.S.
AB	1	33.750	33.750	0.158	N.S.
Residual	56	11991.333	214.131		
Total	59	12611.250			

TABLE 8. TWO-WAY ANALYSIS OF VARIANCE, SECTION 14

Cell	No. of Reps.	Mean Y	S. S.	Variance	S.D.
70N	15	30.47	401.73	28.69	5.36
70S	15	31.53	173.73	12.41	3.52
64N	15	37.20	1472.40	105.17	10.26
64S	15	37.27	852.93	60.92	7.81

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	582.817	582.817	11.251	0.005
B	1	4.817	4.817	0.093	N.S.
AB	1	3.750	3.750	0.072	N.S.
Residual	56	2900.800	51.800		
Total	59	3492.183			

TABLE 9. TWO-WAY ANALYSIS OF VARIANCE, SECTION 15

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.
70N	15	44.53	9333.73	666.69	25.82
70S	15	37.20	2852.40	203.74	14.27
64N	15	38.87	2285.73	163.27	12.78
64S	15	46.47	5523.73	394.55	19.86

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	48.600	48.600	0.136	N.S.
B	1	0.267	0.267	0.001	N.S.
AB	1	836.267	836.267	2.342	N.S.
Residual	56	19995.600	357.064		
Total	59	20880.733			

TABLE 10. TWO-WAY ANALYSIS OF VARIANCE, SECTION 16

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.
70N	15	67.20	360.40	25.74	5.07
70S	15	70.13	539.73	38.55	6.21
64N	15	96.53	36219.73	2587.12	50.86
64S	15	77.40	1611.60	115.11	10.73

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	5023.350	5023.350	7.263	0.01
B	1	984.150	984.150	1.423	N.S.
AB	1	1826.017	1826.017	2.640	N.S.
Residual	56	38731.467	691.633		
Total	59	46564.983			

significant (0.005) and it can therefore be concluded that the travel time in 1970 is significantly less than in 1964. The direction of travel (B) was not a significant factor in this analysis.

Section 15 is a section of interrupted flow, comprising the signalized intersection at South Street. Neither the year (A) nor the direction of travel (B) are significant in this analysis. The improvement of this intersection has not had any significant effect on the travel times over this section. Table 9 shows the results of the two-way analysis on this section.

Table 10 shows the results of the test on section 16. The year again shows statistical significance (0.01). This length of roadway is a section of uninterrupted flow. The direction of travel is not significant.

The assumption was initially made that the variance was homogeneous. This assumption was tested and found to be incorrect. There is indeed a difference between the cell variances. The results of the homogeneity of variance tests are shown in Table 11.

As an additional check on the validity of the analysis of variance tests reported above, two one-tailed t-tests for unequal means were performed on 64N vs. 70N and 64S vs. 70S. These t-tests do not require homogeneity of variance. The results of these tests are shown in Table 12.

The results show that when the year was indicated as being significant in the analysis of variance, it was also significant in the one-tailed t-test. For sections 14 and 16 the one-tailed t-test showed an overall α-level of 0.05.

TABLE 11. RESULTS OF THE TESTS ON HOMOGENEITY OF VARIANCE

	Value of
Control section	$\chi^2_3 = 23.24$
Section 14	$\chi^2_3 = 16.16$
Section 15	$\chi^2_3 = 8.67$
Section 16	$\chi^2_3 = 93.13$
Calculated	χ^2_3 5% = 7.81

TABLE 12. RESULTS OF ONE-TAILED t-TESTS FOR UNEQUAL MEANS

Control		All N.S. (0.25)
Section 14	70N vs. 64N t'=2.593	significant (0.025)
	70S vs. 64S t'=2.253	significant (0.025)
Section 15	70N vs. 64N t'=0.76	not significant
	70S vs. 64S t'=1.46	not significant
Section 16	70N vs. 64N t'=2.22	significant (0.025)
	70S vs. 64S t'=2.27	significant (0.025)

A final analysis was performed by totaling the travel times observed on sections 14, 15 and 16 for each of the fifteen (15) travel time runs. The traffic volumes for this total analysis were calculated by weighting the individual section volumes in accordance to their respective lengths.

An analysis of covariance was performed using Model I. The assumptions were the same as stated previously. The results of this covariate analysis are shown in Table 13. It can be seen that the F-test for significance of the covariate is less than 1.0. The covariate analysis was therefore not necessary. Again, the range of volume changes at the volume levels considered were not large enough to show this factor as being significant.

The two-way analysis of variance was made using Model II. The assumptions were again the same as stated in the previous analysis of variance. The results of this analysis are shown in Table 14. An examination of the ANOVA table from Table 14 reveals that the factor for the year in which the runs were made is statistically significant (0.01). The factor for the direction in which the runs were made shows as not significant. These results are in agreement with the results obtained in the previous two-way analysis of variance when the sections were considered independently, with the exception of section 15. It will be remembered that section 15 had both the year (A) and direction (B) as being not significant. There was no basis for believing there was a difference in the travel times in 1964 and 1970 on section 15. When the sections are pooled, however, any adverse

TABLE 13. TWO-WAY ANALYSIS OF COVARIANCE, TOTAL

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.	Means of Covariates
70N	15	142.20	11548.40	842.89	28.72	27763.80
70S	15	138.87	3453.73	246.69	15.71	27763.80
64N	15	172.60	54395.60	3885.40	62.33	21854.40
64S	15	161.13	7835.73	559.69	23.66	21854.40

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	1684.848	1684.848	1.204	N.S.
B	1	821.400	821.400	0.587	N.S.
AB	1	248.067	248.067	0.177	N.S.
Residual	55	76937.667	1398.867		
Total	58	79691.981			

F-value for significance of covariate - 0.21146

TABLE 14. TWO-WAY ANALYSIS OF VARIANCE, TOTAL

Cell	No. of Reps.	Mean Y	S.S.	Variance	S.D.
70N	15	142.20	11548.40	824.89	28.72
70S	15	138.87	3453.73	246.69	15.71
64N	15	172.60	54395.60	3885.40	62.33
64S	15	161.13	7835.73	559.69	23.66

ANOVA

Source	D.F.	S.S.	M.S.	F	Significance
A	1	10401.667	10401.667	7.542	0.01
B	1	821.400	821.400	0.596	N.S.
AB	1	248.067	248.067	0.180	N.S.
Residual	56	77233.467	1379.169		
Total	59	88704.600			

effects in section 15 are suppressed and a difference in year (A) can be seen.

The test for **homogeneity** of variance was performed on these data and the variances of the cells was shown to be unequal. Two one-tailed t-tests were again performed on 70N vs. 64N and 70S vs. 64S. The results of both the test for **homogeneity** of variance and the two one-tailed t-tests are shown in Table 15.

The results of the t-tests for unequal means show the travel time for 1970S to be significantly (0.025) less than the travel time for 1964S. The analysis indicated nonsignificance between 1970N and 1964N. This inconsistency can be attributed to the adverse effect that section 15 is exerting on the total result.

Travel times were also obtained for 25 runs during non-peak hours (from 7 a.m. to 3 p.m.) in both the 1964 and 1970 studies. The average time for the 25 before (1964) travel times for Sections 14, 15, and 16 was 147 seconds. The average time for the 25 after (1970) travel times was 129 seconds. These travel time data were not subjected to a rigorous statistical analysis because adequate volume data during each 1964 run were not available and because of variation in the time of the day when the runs were made in 1964 and 1970. On the basis of the results of the statistical analysis of the peak hour runs and the logical nature of the non-peak average travel times, it appears that the average non-peak hour travel time savings per vehicle is about 18 seconds or approximately 70 percent of the per vehicle savings during the peak hour.

TABLE 15. RESULTS OF HOMOGENEITY OF VARIANCE AND ONE-TAILED t-TESTS*

Test for Homogeneity of Variance		t-Test for Unequal Variance		
Total	$\chi^2_3 = 29.11$	70N vs. 64N	t'=1.73	N.S.
Calculated	χ^2_3 5% = 7.81	70S vs. 64S	t'=3.03	signif. (0.025)

*Total of sections 14, 15, and 16.

Results

The objective of the travel time study was to determine what effect reconstruction has had on the travel times required to cross a reconstructed portion of the U.S. 52 Bypass in Lafayette, Indiana. The data for the period prior to the reconstruction were obtained from a travel time and delay study conducted in 1964 (35). Data collected in 1970 were considered to be representative of travel times after the study sections were reconstructed.

Sections 14, 15 and 16 were analyzed individually and also as a whole. The two-way analysis of variance yielded the following results:

1. Neither the year or the direction of travel were significant for the control sections. There was no difference between the travel times in 1964 and those in 1970 on these 2-lane control sections of the U.S. 52 Bypass. Any confounding factors that existed are not significant and can be ignored.
2. The analysis of variance for section 14 showed the factor for year as being statistically significant (0.005), but the direction of travel as being not significant. It was concluded that the travel time in 1970 over section 14 was significantly (0.005) less than the travel time over this same section in 1964.
3. An examination of the analysis of variance for section 15, the only signalized intersection under investigation in this study, showed neither the year or direction as being

significant. There was no significant change in the travel time over this section due to reconstruction.

4. Section 16 showed the year as being significant (0.01). The direction of travel is not significant. It was therefore concluded that the reconstruction has served to reduce the travel time on this section of the Bypass.
5. The two-way analysis for the total travel time over sections 14, 15 and 16 again showed the year as being significant (0.01). The direction of travel is not a significant factor. The conclusion was therefore made that the travel time was substantially reduced due to the reconstruction of the facility to four-lane divided.

As was stated above, sections 14 and 16 had a significant reduction in travel time in 1970 compared to 1964. These are sections of uninterrupted flow, an absence of traffic signals, stop signs or other traffic control interruptions. There are a number of factors, however, which do affect vehicles traveling on these sections. Noncontrol of access and the large amount of roadside development in these sections are possible causes for interference. With the existence of only two 11' lanes for traffic movement in 1964, any vehicle making a left turn into a driveway from the Bypass effectively blocked traffic until an opening in opposing traffic developed and the movement could be completed. Vehicles turning right into driveway access points caused limited delays. Section 14 was further restricted due to its location between the Union and South Street intersections, two intersections operating at capacity in 1964. Continuous backups occurred on the approaches to these intersections during periods of high demand.

The travel time on section 16 was strongly influenced by the direction of travel. Vehicles traveling north on the Bypass were influenced by the South Street intersection and the backups occurring at this intersection. South bound vehicles were able to move more freely, the interruptions dependent on vehicles turning from and into driveways, vehicle breakdowns and accidents. At the south end of section 16, the roadway widened to four-lanes in 1964. This allowed a much freer flow on this section in a southerly direction.

The reconstruction from two-lanes to four-lanes not only increased the width of the trafficway, it also removed the vehicles desiring to make left turns from the through lanes by providing left turn lanes at specific locations along the roadway. Interruptions due to stops, turning vehicles and accidents have a much greater effect on the operation of a two-lane facility than they do on a four-lane divided facility because these interruptions can cause complete blockage of one or both lanes of travel on a two-lane facility.

Section 15 is the only signalized intersection considered in this study. The two-way analysis of variance revealed there has been no change in the travel time over this section since 1964. In 1964 this intersection was controlled by pretimed signals, in which the cycles were established in accordance with predetermined time schedules. There was no provision made for vehicles wishing to make a left turn into the cross street. Vehicles waiting to make a left turn movement had the effect of blocking the through lane. It was determined in the

1964 travel time and delay study that when no separate right or left lanes were provided, traffic used the paved shoulders as turning and through lanes when the properly marked lane was blocked. This intersection now has provision for two through lanes and separate right and left turn lanes. The traffic signals are fully traffic actuated on all four approaches. Left turning movements are given a separate phase if vehicles are present in the left turn lanes. The left turn lane also provides storage for vehicles wishing to make a left turn, thus removing the interference with through traffic.

Although the benefits of reconstruction are not directly reflected in section 15 by travel time, other factors have been affected which show an improvement due to reconstruction. The level of service of this intersection has gone from level F, where substantial delays were encountered during periods of high traffic demand, to a level of service in the range of D to E. The approach to the intersection usually has no vehicles waiting for more than one cycle, and the turning maneuvers can now be made easily. Under the present conditions the major concern of drivers approaching the intersection is whether the light will be red, or turn red, on their approach.

Figure 6 shows graphically the reduction in total travel time on sections 14, 15 and 16. It will be noticed, as discussed above, that the travel time is lower for travel in a southerly direction for 1964.

Tables 16 and 17 show the travel times, in seconds, and the speeds, in MPH, over the indicated sections and over the total test area. A comparison of the 1964 and 1970 peak-hour travel times over sections

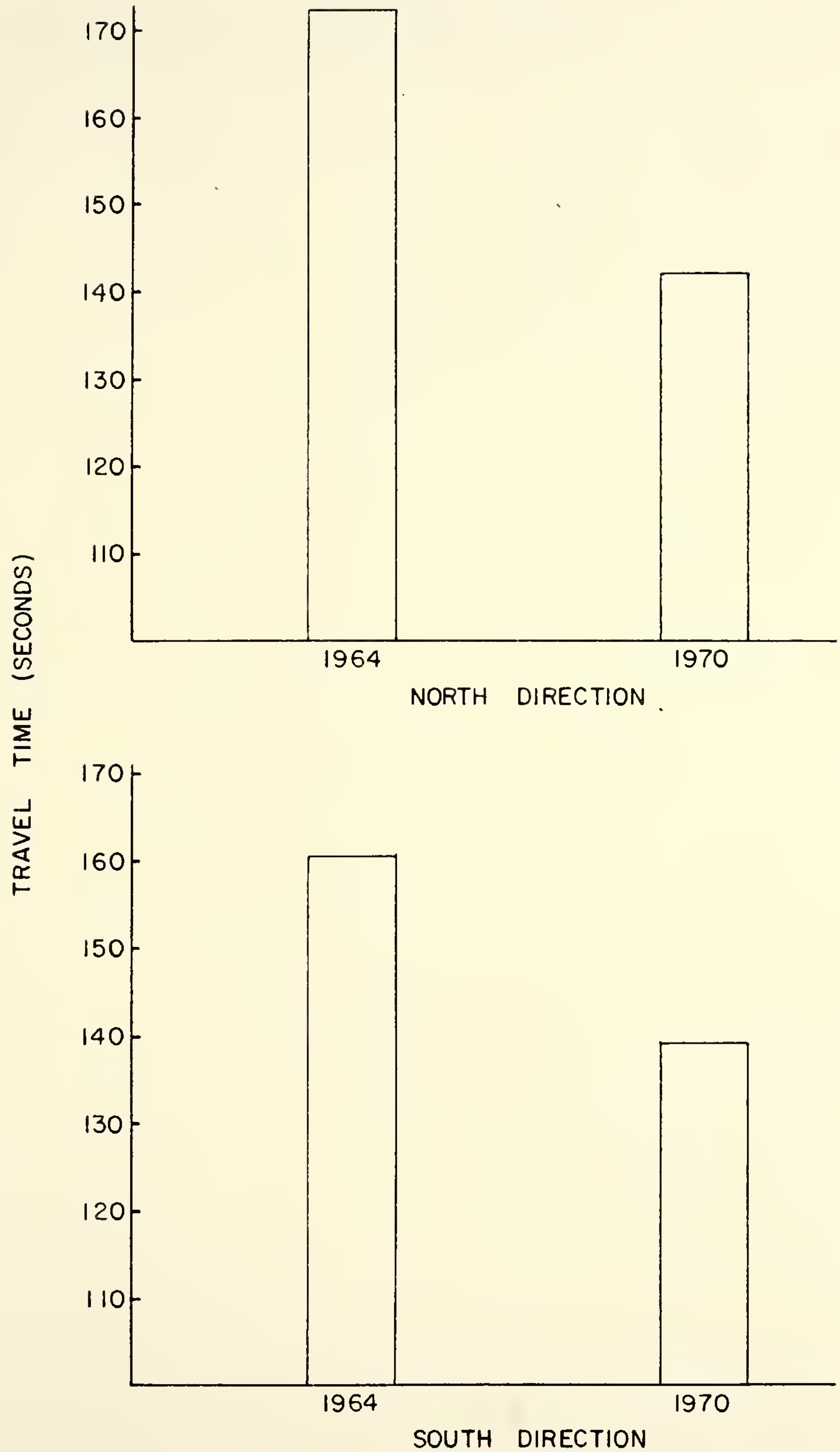

FIGURE 6. TRAVEL TIMES IN EACH DIRECTION

TABLE 16. TRAVEL TIMES ON TEST SECTIONS, SECONDS

	1964		1970	
	NB	SB	NB	SB
Control	112.27 sec	119.87	115.13	119.73
14	37.20	37.27	30.47	31.53
15	38.87	46.47	44.53	37.20
16	96.53	77.40	67.20	70.13
Total	172.60	161.13	142.20	138.87

TABLE 17. TRAVEL SPEEDS ON TEST SECTIONS, MPH

	1964		1970	
	NB	SB	NB	SB
Control	45.46 mph	42.58	44.33	42.63
14	30.57	30.52	37.33	36.10
15	17.54	14.67	15.31	18.33
16	26.50	33.05	38.07	36.48
Total	25.36	27.17	30.78	31.52

14, 15 and 16 show an average reduction in travel time of 26.4 sec/veh. The average travel time savings for non-peak hour conditions was estimated to be 18 seconds per vehicle for travel over sections 14, 15 and 16, or approximately 70 percent of the per vehicle savings in travel time of the peak hours.

Road-User Benefits

A recent study by Hejal (20) makes a good argument for the inclusion of a cost value for the time spent by a passenger car on the highway. He states that if the time consumed while driving a passenger car had no value, and assuming the driver to be rational, then an operating speed of 40 mph would minimize his total operating costs. Free flowing speeds on Indiana two-lane highways average close to 65 mph. In terms of a dollar value, the costs of operation of the vehicle would be minimal at this speed only when the value of travel time was $2.50/hour or more. In discussing the value of travel time, Winfrey (38) suggests that reasonable values of travel time for automobiles lie within the range of $1.00 to $4.00 per car-hour.

Values of travel time used in the above mentioned study by Hejal (20) were used in this study primarily because they were estimated for Indiana highways for 1970 and are reasonable estimates of the willingness to pay.

The time costs employed in the determination of road-user benefits were (1) $3.00/hr. for passenger vehicles, (2) $4.75/hr. for single unit trucks, and (3) $6.50/hr. for combination vehicles. Table 18 shows the percentages of these three typical vehicles in the traffic

TABLE 18. TRAFFIC COMPOSITION ON THE US 52 BYPASS (1970)

Vehicle Type	% of Traffic Stream	AADT	Peak Volume	Peak Yearly Volume
Passenger cars	0.8628	22,420	4504	1,644,034
Single unit trucks	0.0349	907	182	66,470
Combination trucks	0.1023	2,659	534	194,979
Total		25,986 vpd	5220	1,905,483

TABLE 19. TRAVEL TIME BENEFITS DUE TO RECONSTRUCTION ($/YR)

Vehicle Type	Time Cost $/hr	Time Savings hr/yr	Travel Time Benefits $/yr
Passenger car	$3.00	12,056.24	36,168.72
Single unit truck	4.75	487.45	2,315.38
Combination vehicles	6.50	1,429.85	9,294.02
Total			47,778.12

stream. Passenger cars represent approximately 86% of all vehicles traveling this section of the Bypass, with single unit trucks comprising slightly over 3% and combination vehicles the remaining 10%.

Vehicles traveling the reconstructed study portions of the U.S. 52 Bypass realized a savings in travel time of 26.4 sec/veh, based on a comparison of travel times in 1964 and 1970 that were measured during the peak period of the day. The actual benefit to the road-user can therefore only be determined for vehicles passing over the facility during this peak period. An examination of the volume count data collected as part of this study indicates that slightly more than 20% of the total traffic volume occurs during this three hour peak period.

The benefits to these road-users due to the decrease in travel time of 26.4 sec/veh are shown in Table 19. The travel time benefits that accrued to those road-users using the facility during the hours of greatest demand amounted to about $48,000 for 1970.

During the non-peak periods, some benefits also accrue to motorists, except possibly during the very low volume hours of midnight to 6 a.m. For the non-peak hours, 6 a.m. to 3 p.m. and 6 p.m. to midnight the average number of vehicles using the Bypass in 1970 was about 17,000 vehicles per day. Using the estimate that per vehicle travel time savings during the non-peak hour was 70 percent of that per vehicle during the peak hour results in travel time benefits of approximately $108,000 for the non-peak traffic. This added to the peak hour benefits of $48,000 results in total travel time benefits of approximately $156,000 in 1970 for sections 14, 15 and 16.

CHAPTER V. DETERMINATION OF ACCIDENT BENEFITS

Design of Study

An objective of this research was to incorporate costs of traffic accidents into an evaluation of road-user benefits that have accrued due to reconstruction of an urban arterial. These benefits were then added to travel time benefits determined previously. Again the first phase of this improvement, between Union Street and McCarty Lane, was the subject of this investigation.

All traffic accidents included in the investigation were classified in accordance with their location and type. Standards developed by the National Safety Council and presented in the Manual on Classification of Motor Vehicle Traffic Accidents were used in the development of these classifications (23). All accidents occurred either at or between an intersection and were therefore classified in relation to these intersections. The locational classifications were:

1. At an intersection
2. Intersection related
3. Driveway access
4. Non-junction

An intersection is defined in the above mentioned publication by the National Safety Council as that portion of the roadway included in the extension of the curb lines or, if none exist, then the lateral boundary lines of the two roads that join. For an accident to be classified as an intersection accident, it had to actually occur within this well defined zone.

An intersection related accident is one which occurs on either the approach to or exit from an intersection and which is caused by an activity, control or behavior that exists at the intersection. The distance that the accident occurs from the intersection has no bearing on the classification of a traffic accident as being intersection related. The factors causing the accident are the sole determination of classification.

A driveway access accident involves a vehicle turning into or leaving a driveway, or crossing a roadway from a driveway on one side to a driveway on the other side. Any traffic accident that could not be placed in one of these three classifications was classified as a non-junction accident. The four classifications were subdivided when applicable to provide information on the direction of travel of the vehicle or vehicles prior to the accident. Intersectional accidents, for example, were further classified to determine the number of right angle, same direction and opposite direction of travel accidents occurring.

The severity of a traffic accident is dependent on the most severe injury sustained by any person involved in the accident. The severity classifications used in this study were fatal injury, nonfatal injury and property damage only accidents.

Comparisons were made of traffic accidents occurring for a period before the improvement of the facility and after the improved facility had been opened to traffic for a period of time. To provide a better understanding of the accident characteristics before the reconstruction, four years were selected. The traffic accidents for 1964, 1965, 1966 and 1967 were chosen as representative of the period before reconstruction. Neither 1968 or 1969 were considered due to these being the years in which the Bypass section was being improved. The accidents occurring during 1970 afforded the required information for the period after reconstruction.

Collection of Data

The majority of accident data was obtained from Post No. 3 of the Indiana State Police, located in West Lafayette, Indiana. Information for the years no longer retained at Post No. 3 were acquired from the microfilm library of the Accident Records Division of the Indiana State Police. The records of the Lafayette city police were also examined for accident data pertaining to the study sections.

Indiana law during the accident years required motorists to report any accident on a public highway that involved property damage in excess of $50 and/or injury. The information obtained from the accident reports included the location of the traffic accident in relation to a junction, the time and date of the accident, weather conditions, direction of travel before the collision, the number of vehicles involved and the severity of the accident.

Preliminary Analysis

Only those traffic accidents that occurred on the U.S. 52 Bypass itself were considered in this investigation. Involvements occurring on the cross streets outside of in the intersection were not considered in this report.

Spot maps were first prepared for the five years considered in the before and after study and are shown in Figures 7 through 11. These maps are quite useful in that they allow points of greatest accident concentration to be located. It can be seen that the greatest number of accidents, both before and after the improvement, were in the vicinity of the intersections at Union and South Streets. It is also apparent that the total number of traffic accidents has decreased substantially since the reconstruction. The.total number of involvements for each of the five years were:

Year	Total Number of Accidents
1964	124
1965	134
1966	142
1967	140
1970	71

The greatest number of traffic accidents occurred in 1966, when 142 involvements were reported. The difference, however, between any of the four years before reconstruction was not very great. In 1970 this total dropped to 71 involvements, almost half the average value of the four years before the improvement.

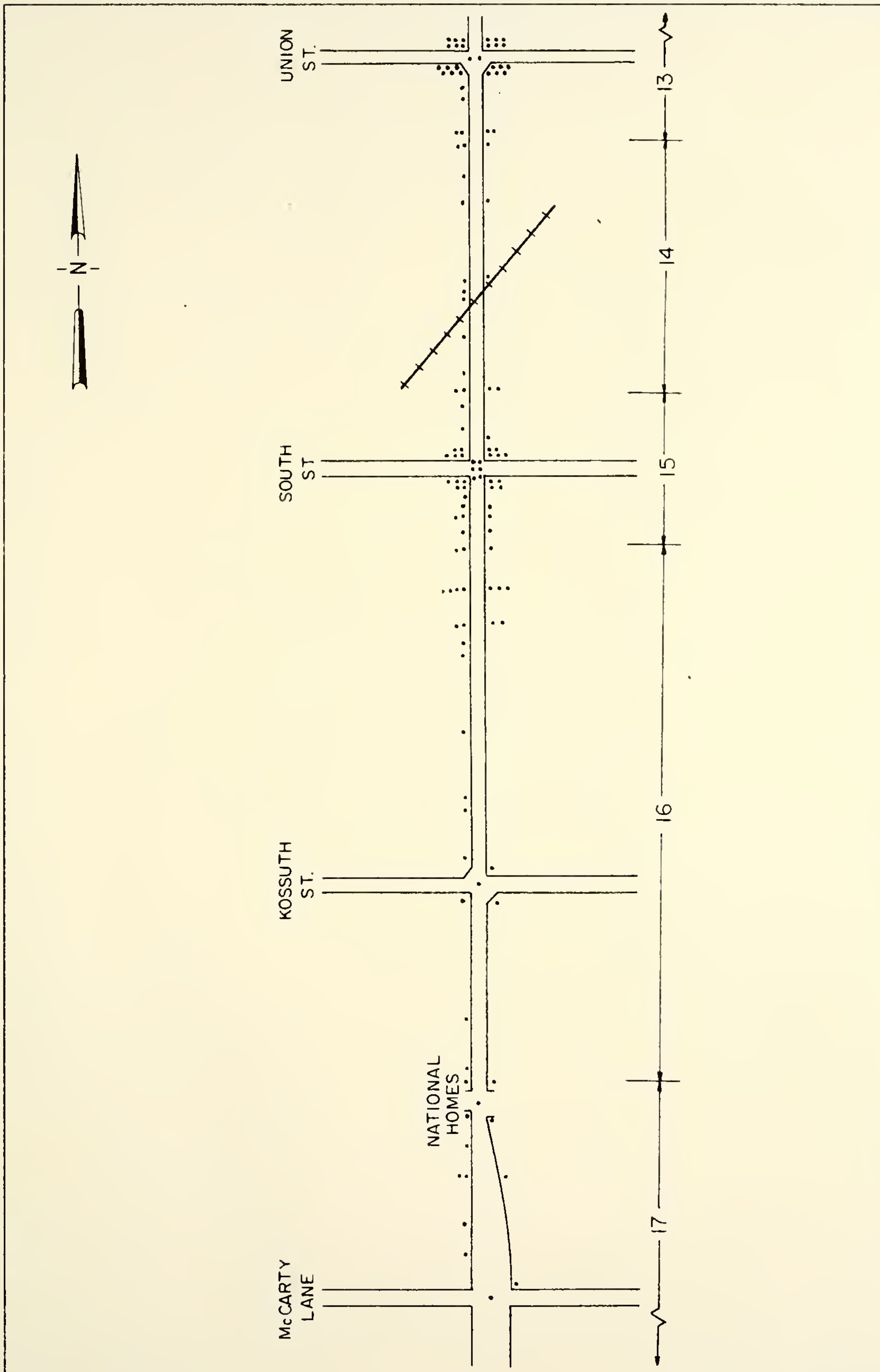

FIGURE 7. 1964 ACCIDENT SPOT MAP FOR U.S. 52 BY-PASS

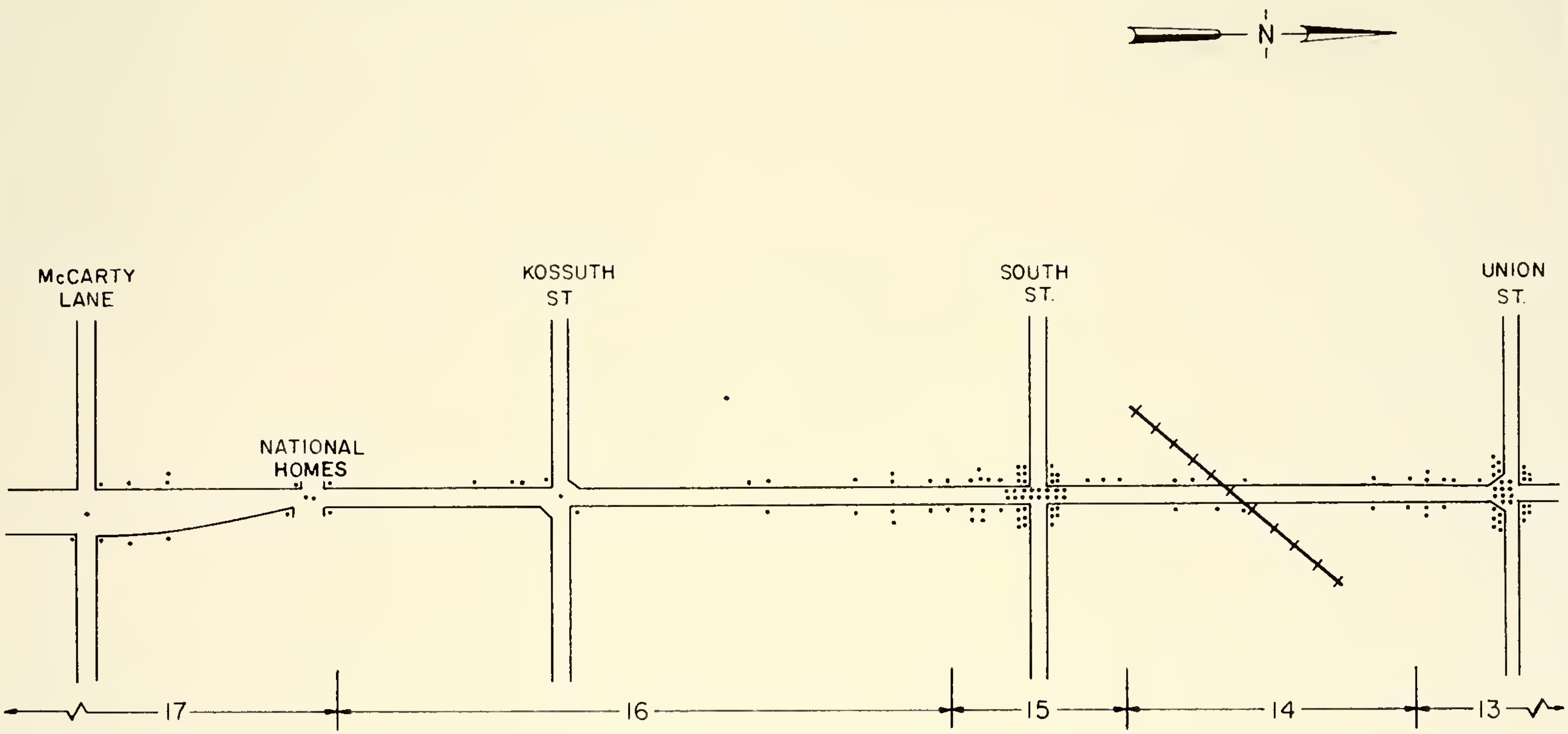

FIGURE 8. 1965 ACCIDENT SPOT MAP FOR U.S. 52 BY-PASS

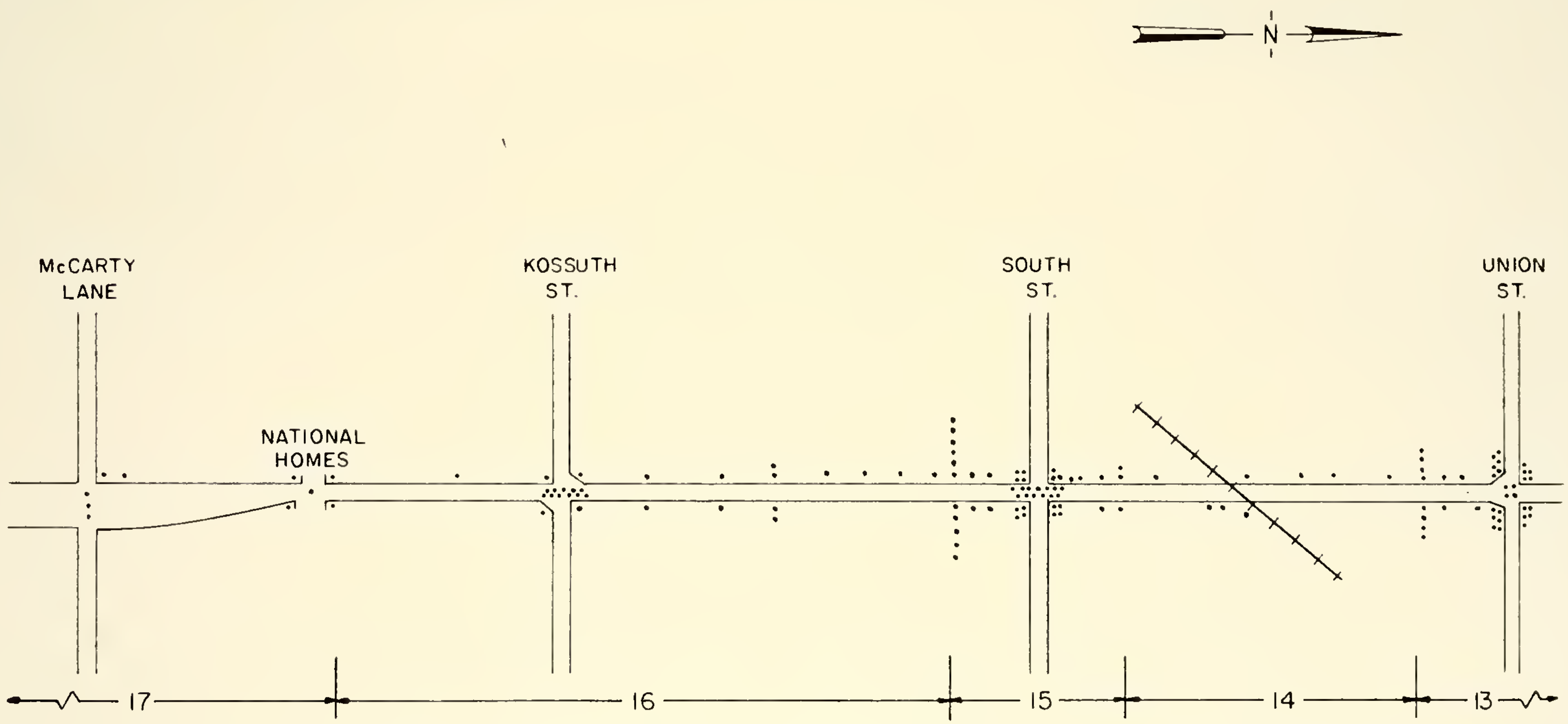

FIGURE 9. 1966 ACCIDENT SPOT MAP FOR U.S. 52 BY-PASS

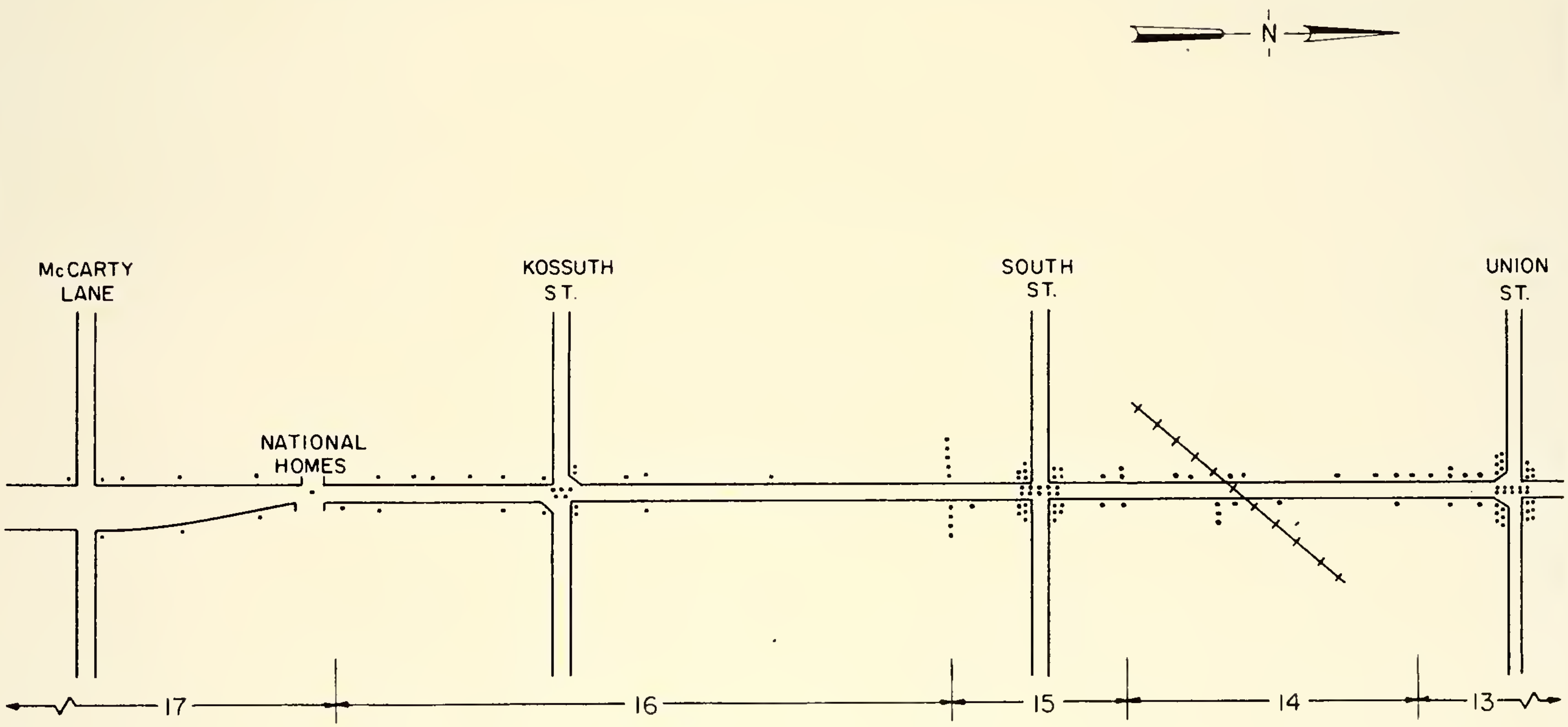

FIGURE 10. 1967 ACCIDENT SPOT MAP FOR U.S. 52 BY-PASS

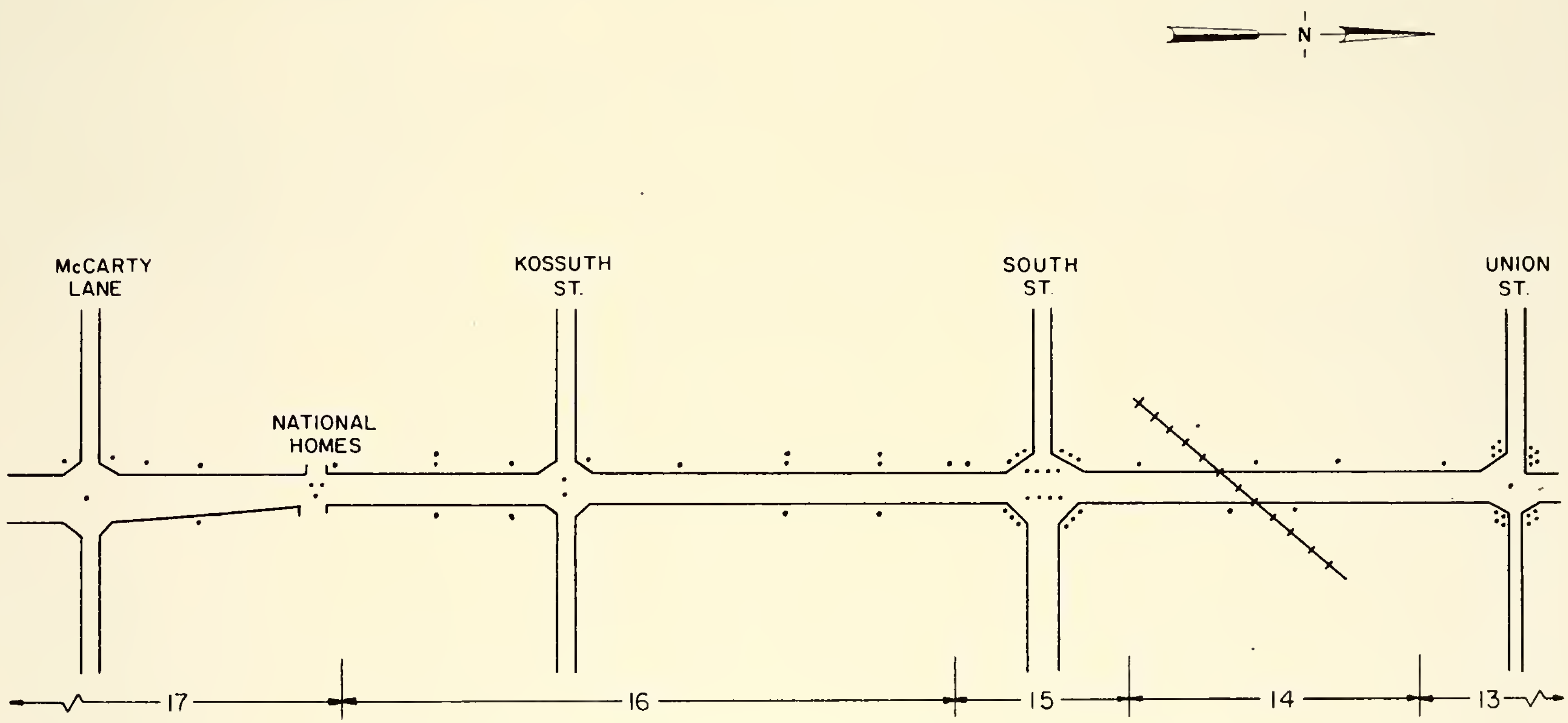

FIGURE 11. 1970 ACCIDENT SPOT MAP FOR U.S. 52 BY-PASS

The location of the greatest accident concentration for all years is the South Street intersection. It is interesting to note at this point that the cross traffic on South Street is the highest of any intersecting street in the study section. A report by Syrek (32) showed that the accident rates at intersections are highly sensitive to the major and minor street volumes.

The Union Street intersection is next in the ranking of total number of traffic accidents. The cross street volume is lower on Union Street that on South Street, which may explain the lesser number at this location.

Vehicles traveling on the Bypass are not required to stop at either the Kossuth Street or McCarty Lane intersections. These locations are, however, points of conflict as vehicles attempt to either leave or enter these streets. The spot maps indicate these locations as having relatively few involvements throughout the study period.

A truck entrance to National Homes, Incorporated is signalized to allow a very low volume of vehicles to either cross or turn on to the U.S. 52 Bypass from National Homes. The number of accidents at this location seem to be in the same range of magnitude as those at Kossuth Street and McCarty Lane.

Intersection and Intersectional Related Accidents

The traffic accidents occurring at or because of an activity at an intersection were analyzed by using the collision diagrams shown in Appendix B. The results of this analysis are listed below.

1. Union Street

The vehicular traffic on Union Street has always been quite heavy. Reference is made to the figures shown in Appendix A. In 1964 the west approach had an AADT of approximately 8000 vpd. The volume on the east approach was in the range of 4600 vpd. The volume on the Bypass was approximately 18300 vpd in 1964. The large amount of cross street traffic was a cause of severe traffic conflict at this junction. Table 20 gives a breakdown of all traffic accidents occurring during the study period.

A slight but steady increase is seen in the total number of traffic accidents from 1964 to 1967, with the greatest number of accidents occurring in 1967. After the reconstruction, the total number has dropped to slightly half of this value.

An inspection of the conditions existing prior to 1968 is essential to an analysis of the traffic accidents occurring at this location. Before reconstruction, this portion of the U.S. 52 Bypass was composed of two 11' lanes, one for each direction of travel. Vehicles desiring to make a left turn from the Bypass were required to wait until oncoming traffic had cleared sufficiently to allow the move to be completed. While waiting to turn, this vehicle effectively blocked traffic in that direction. Vehicles wishing to continue on through the intersection were forced to either wait behind the turning vehicle or attempt to go around this vehicle on the right. A

TABLE 20. SUMMARY OF REPORTED ACCIDENTS AT UNION STREET

	1964	1965	1966	1967	1970
Intersection					
Angle		2	4	5	1
Same Dir.		2	2	3	
Opp. Dir.	2	4	2	2	
Others					
Inter. Rel					
Same Dir.	29	24	29	30	17
Opp. Dir.		3	2		1
Parked Car					
Others					
Total	31	35	39	40	19

previous study showed that the paved shoulder carried approximately one-third the volume of a properly marked lane. This volume was composed of both right turning vehicles and vehicles attempting to continue on through the intersection. When the turning vehicle had completed the movement, waiting vehicles continued through. The situation developed where vehicles traveling on both the shoulder and the through lane attempted to use the one lane at the same time. These maneuvers were responsible for the large number of side-swipe accidents in the intersectional area.

Reconstruction provided for separate left turning lanes, adequate storage facilities for left turning vehicles, and a separate turn indication so that these movements can be made easily. The results of the reconstruction are readily apparent in Table 20. The intersection accident is quite low. The number of same direction of travel accidents are still high but not nearly as great as before.

2. South Street

The conditions existing at this intersection prior to reconstruction were very similar to Union Street. Table 21 is a listing of all intersection and intersection related accidents.

The greatest number of accidents at this junction occurred in 1965. The number of intersectional accidents showed a sharp increase in that year for no apparent reason. The number of intersectional related accidents declined in 1967, again for no apparent reason.

TABLE 21. SUMMARY OF REPORTED ACCIDENTS AT SOUTH STREET

	1964	1965	1966	1967	1970
Intersection					
Angle	2	5	3	1	5
Same Dir.	2	4	2	1	2
Opp. Dir.	2	6	8	8	1
Others		1			
Inter. Rel.					
Same Dir.	38	36	34	26	14
Opp. Dir.		1		4	
Parked Car	1				
Others					1
Total	45	53	47	40	23

The reconstruction of this intersection substantially reduced the number of accidents occurring in or related to this intersection. The major change in intersectional accidents has been in the frequency of accidents between vehicles traveling in opposite directions. This is itself a satisfactory result, as these accidents are usually more severe than same direction of travel accidents.

The consequences of the improvement are also apparent in the intersection related category. These accidents have been reduced to approximately one-half the before reconstruction value.

The effect of the minor street volume on the number of traffic accidents has already been stated. The volume of traffic using each approach on South Street in 1964 was approximately 7000 vehicles per day. This cross street traffic is heavier at this point than at any other location along the study sections and helps to explain the large number of involvements at this intersection.

3. Kossuth Street

Kossuth Street has not been a point of major interference and traffic interruptions. The interference that does exist is caused by vehicles attempting to turn into Kossuth Street from the U.S. 52 Bypass or turn on to the Bypass from Kossuth Street. Table 22 is a summary of the accidents at this intersection.

TABLE 22. SUMMARY OF REPORTED ACCIDENTS AT KOSSUTH STREET

	1964	1965	1966	1967	1970
Intersection					
Angle			4		
Same Dir.	1		4	2	1
Opp. Dir.		1	3	3	1
Others					
Inter. Rel.					
Same Dir.	2	1	4	6	1
Opp. Dir.	1	1			
Parked Car					
Others					
Total	4	3	15	11	3

The situation in the before years when a vehicle attempted a left turn from the U.S. 52 Bypass into Kossuth was the same as outlined previously; vehicles traveling on the Bypass were blocked from continuing on through the junction. Vehicles attempting to turn on to the Bypass were also required to wait until traffic in both directions cleared sufficiently. At the present time vehicles make use of the median and complete this move in two steps. This would seem to reduce the hazard appreciably.

4. National Homes Driveway

A traffic signal was installed at this location in June 1965 to allow vehicles leaving the National Homes loading docks and one small parking lot to complete their move without interference from the through traffic. Table 23 is a listing of all accidents related to this junction. Prior to the installation of the traffic signal there was a total of three accidents at this junction. The number of accidents for the years prior to 1964 were not investigated. The accident with the greatest frequency is the same direction of travel accident, specifically the rear-end accident. Because of the small number of accidents at this intersection and the short history since reconstruction, nothing can be said about accident improvement.

TABLE 23. SUMMARY OF REPORTED ACCIDENTS AT NATIONAL HOMES

	1964	1965	1966	1967	1970
Intersection					
Angle	1	2	1	1	2
Same Dir.					1
Opp. Dir.					
Others					
Inter. Rel.					
Same Dir.	2	4	4	8	1
Opp. Dir.					
Parked Car					
Others					
Total	3	6	5	9	4

5. McCarty Lane

The junction of McCarty Lane and the U.S. 52 Bypass had been improved prior to the 1968 reconstruction. Table 24 lists all accidents occurring during the study period. It can be seen that the number of accidents at this junction has always been low.

The major cause of interference at this junction is vehicles attempting to either cross the U.S. 52 Bypass, turn on to the U.S. 52 Bypass from McCarty Lane or turn into McCarty Lane from the U.S. 52 Bypass. The traffic accidents at this location are fairly well distributed between intersectional and intersectional related. It cannot be stated whether reconstruction has affected this junction or whether it remained the same. It would appear from Table 24 that it has remained the same.

Driveway Access Accidents

A driveway access accident involves a vehicle either turning into or leaving a driveway. These accidents were analyzed by listing their frequency and location in relation to the junctions. Table 25 is a listing of all driveway access accidents that occurred during the years of interest.

The amount of development along this portion of the U.S. 52 Bypass is quite high. The highway oriented businesses include motor vehicle service stations, food businesses and one large motel. There were also a number of local businesses and some industry. Prior to reconstruction,

TABLE 24. SUMMARY OF REPORTED ACCIDENTS AT MCCARTY LANE

	1964	1965	1966	1967	1970
Intersection					
Angle	1	1	2	1	1
Same Dir.			1		
Opp. Dir.					
Others					
Inter. Rel.					
Same Dir.	1	3	1	3	1
Opp. Dir					
Parked Car					
Others					
Total	2	4	4	4	2

TABLE 25. SUMMARY OF DRIVEWAY ACCESS ACCIDENTS

	1964	1965	1966	1967	1970
Union St. to South St.	1	2	2	6	2
South St. to Kossuth St.	6	4	7	5	3
Kossuth St. to National Homes	2	1	-	1	1
National Homes to McCarty Lane	2	2	-	2	1
Total	11	9	9	14	7

there were no left turn lanes for turning movements into these establishments. The effect of turning vehicles was thus the same as at an intersection; the through traffic was partially blocked. A number of the accidents between South Street and Kossuth Street could be traced directly to vehicles attempting to turn into or leave the motel. Reconstruction of this portion of the Bypass with a median has helped to reduce this type of accident by providing separate left turn lanes where left turns can be made. These locations are provided with adequate storage so that a turning vehicle does not interfere with the through traffic on the Bypass.

Non-junction Accidents

Any accident that could not be classified as intersectional, intersectional related or driveway access was classified as a non-junction accident. These accidents are very similar to intersectional related accidents, the difference being that they cannot logically be attributed to an activity, control or behavior at the intersection. Table 26 is a summary of all accidents in this category. As can be seen from the Table, the number of non-junction accidents prior to reconstruction shows very little change from year to year. After the reconstruction, the total has dropped to approximately one-half the before value.

The total number of accidents occurring in each year is shown in Figure 12. The similarity in traffic accidents before reconstruction is quite apparent. The substantial decrease after the reconstruction is also obvious.

TABLE 26. SUMMARY OF NONJUNCTION ACCIDENTS

	1964	1965	1966	1967	1970
Union St. to South St.	11	9	8	6	3
South St. to Kossuth St.	12	11	11	6	3
Kossuth St. to National Homes	1	2	1	5	4
National Homes to McCarty Lane	4	3	2	6	1
Total	28	25	22	23	11

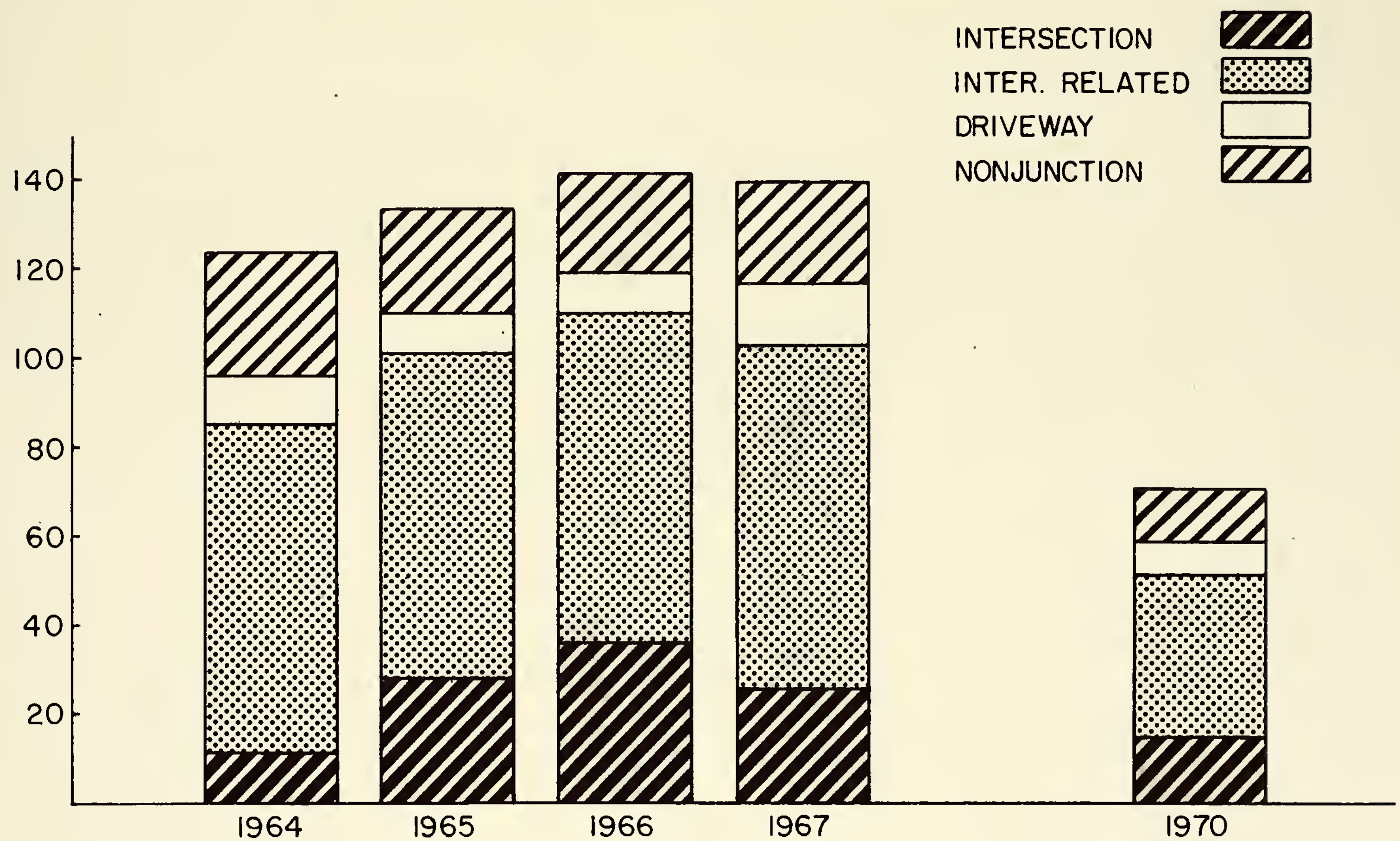

FIGURE 12. TOTAL NUMBER OF TRAFFIC ACCIDENTS, BY LOCATION

Severity Classification of Accidents

The traffic accidents that occurred during the study period were also classified according to the most severe injury occurring to any person. If there were no injuries, the entire accident was classified as a property damage only accident. An analysis was made to determine if the reconstruction not only reduced the number of accidents, but also minimized the severity of these accidents. This analysis required conversion of the total number of accidents into a figure representing the number of vehicles using the facility in a given time period. The accidents were converted into accidents per million vehicle-miles and are shown in Table 27.

The traffic accident rates both before and after the improvement must be considered high but it is important to note that the accident rate after reconstruction is less than one-half of what it was before.

For the four year period before the improvement, there was only one fatality. The rates for nonfatal and property damage accidents before reconstruction are fairly consistent. There was a reduction in the number of nonfatal injury accidents in 1967 which cannot be explained.

Although the number of traffic accidents has been substantially reduced in the period after reconstruction, the proportion of the three classifications of severity has remained constant. In the period before the improvement, 84 percent of all accidents were property damage only accidents. In 1970 this type of accident again constituted approximately 84 percent of all accidents.

TABLE 27. SUMMARY OF TRAFFIC ACCIDENT RATES (PER MILLION VEHICLE-MILES)

Item	1964	1965	1966	1967	1970
Vehicle-miles of travel, million	10.316	10.955	11.593	12.232	14.147
Number of accidents					
Fatal injury	0	0	1	0	0
Nonfatal injury	27	22	28	16	11
Property damage	97	112	113	124	60
	124	134	142	140	71
Accident rate per mvm					
Fatal injury	0.0	0.0	0.08	0.0	0.0
Nonfatal injury	2.62	2.02	2.42	1.33	0.8
Property damage	9.40	10.21	9.74	10.12	4.22
Total	12.02	12.23	12.25	11.45	5.02

Costs (1970) of Traffic Accidents

A recent study by Salim Hejal presents a logical method for determining the total direct costs of reported rural state highway accidents in Indiana (19). The direct costs of any accident are composed of five groups:

1. Property damage
2. Hospital treatment costs
3. Doctor, dental, and other medical costs
4. Legal fees and court costs
5. Miscellaneous costs

A mathematical technique was developed by Hejal that made use of the comprehensive accident study conducted in Illinois in 1959 for all accidents occurring during a calendar year. Adjustment, modification, updating and inflation were employed to estimate the direct costs (1970) of accidents on Indiana rural state highways. Tables of property damage cost, classified by the type of collision and severity, were presented. An estimate of the property damage cost element as a percentage of the total direct cost for each of three severity classifications was also made as part of that research. It was therefore possible to estimate the total direct cost of an accident or group of accidents by knowing only the severity of the involvements and the property damage costs.

Previous studies have shown that rural accidents are much more severe and costly than urban accidents (4, 19). It was necessary, therefore, to adjust the accident costs reported in the Hejal study to reflect urban conditions. This adjustment was accomplished by again making use of the 1959 Illinois study. The property damage costs found in Hejal's research were adjusted to urban conditions by using rural and urban results of the 1959 Illinois study. The property damage costs for urban accidents in Indiana thus resulting are shown in Table 28. The breakdown of total direct accident costs into the five cost elements was accomplished in a similar manner and the results are shown in Table 29. Some significant observations are worth emphasizing. In the fatal category, property damage amounts to only about 10 percent of the total cost. This is considerably less than for the rural condition, and is attributable to the lesser property damage because of lower speed for urban accidents. Legal fees and court costs constitute about 65 percent of the total cost of a fatal accident in urban areas.

Consequences to the Road-User

All traffic accidents occurring on the reconstructed sections of the U.S. 52 Bypass between Union Street and McCarty Lane were included in the determination of the consequences to the road-user of the improvement. The accidents for each year were assigned costs dependent on the location, type and severity of the accident. The property damage costs for each of the three severity classes for each year are shown in Table 30. The conversion to total direct costs/year was accomplished using the breakdown of total accident costs given in Table 29, the results being as indicated in Table 31. It can be seen that the total cost of accidents was greatest in 1966, due primarily to

TABLE 28. PROPERTY DAMAGE COSTS CLASSIFIED BY TYPE OF COLLISION AND SEVERITY FOR URBAN ACCIDENTS IN INDIANA (1970)

Type of Accident	Fatal Accidents $	Nonfatal Accidents $	Property Damage Only Accidents $
Intersection			
Angle	1120	767	421
Same Dir.	1490	537	331
Opp. Dir.	1731	844	475
Others	4830	291	310
Intersection Related			
Same Dir.	1490	537	331
Opp. Dir.	1731	844	475
Parked Car	2321	667	352
Others	662	610	389
Driveway Access	2453	661	419
Nonjunction Accident			
Same Dir.	2052	810	384
Opp. Dir.	2220	1210	483
Parked Car	2321	667	352
Others	662	610	389

TABLE 29. ESTIMATE OF COST ELEMENTS AS PERCENTAGES OF TOTAL DIRECT COST, FOR URBAN ACCIDENTS IN INDIANA (1970)

Cost Elements	Fatal Injury Accidents	Nonfatal Injury Accidents	Property Damage Accidents
Property Damage Costs	10.10%	26.20%	97.20%
Hospital Treatment Costs	14.25	11.10	--
Doctor, Dentist and Other Medical Expenses	4.00	7.75	--
Legal Fees and Court Costs	64.40	42.25	1.11
Misc.	7.25	12.70	1.69
Total	100.00	100.00	100.00

TABLE 30. PROPERTY DAMAGE COSTS CLASSIFIED BY SEVERITY, UNION STREET TO MCCARTY LANE (1970)

	1964	1965	1966	1967	1970
Fatal Accidents	--	--	1,731	--	--
Nonfatal Accidents	17,105	13,915	17,019	10,407	7,864
Property Damage Accidents	34,841	41,936	42,404	46,074	21,910
Total	51,946	55,851	61,154	56,481	29,774

TABLE 31. TOTAL DIRECT COSTS, CLASSIFIED BY SEVERITY, UNION STREET TO MCCARTY LANE (1970)

	1964	1965	1966	1967	1970
Fatal Accidents	--	--	17,150	--	--
Nonfatal Accidents	65,300	53,100	64,900	39,700	30,000
Property Damage Accidents	36,700	43,300	43,650	47,400	22,550
Total	102,000	96,400	125,700	87,100	52,550

the fatality that occurred in that year. Values for all the years before the improvement are in the same range of magnitude, however, when compared to the total cost in 1970. It appears that there has been a sharp decline in the total direct cost of traffic accidents for the period immediately after reconstruction.

These total direct costs of traffic accidents occurring during the study period were converted into a figure representative of the number of vehicles using the facility in a given year. The costs of traffic accidents per million vehicle-miles were determined and are shown in Table 32. From an inspection of Table 32, it is apparent that there was a reduction in the total accident cost/mvm that must be attributed to the reconstruction. A statistical test was desired, however, that would confirm the observation of a reduction in accident rate.

If the costs/mvm before the reconstruction could be shown to be equal, a comparison could be made between this period and the period after the reconstruction. A linear relationship was postulated for the years before the reconstruction and the accident costs associated with these years. This assumption seems valid for the range of values indicated in the table. If the accident rates were equal for the four years before the reconstruction, the regression line would be horizontal. The hypothesis tested, therefore, was that the slope of the regression line was zero.

Using the BMD3R program from the Statistical Library at Purdue University, the F-tests for the regression coefficients for injury,

TABLE 32. SUMMARY OF TOTAL DIRECT COSTS OF ACCIDENTS PER MVM, UNION STREET TO MCCARTY LANE

Item	1964	1965	1966	1967	1970
Vehicle Miles of Travel, million	10.316	10.955	11.593	12.232	14.147
Total accident Costs Per mvm (1970 dollars)					
Fatal Accidents	0	0	1478.	0	0
Nonfatal	6330.	4840.	5600.	3250.	2120.
Property damage	3540.	3950.	3760.	3870.	1590.
Total	$9870	8790	10838	7120	3710

property damage only, and the total costs per mvm were obtained. Tables 33, 34 and 35 show the ANOVA tables for these three groupings.

An examination of the injury classification reveals an F-value of 4.3496. This classification showed the highest F-value of the three groupings. This value is not significant (0.10), allowing the conclusion to be made that the cost of injury accidents/mvm were equal for the four years considered representative of the period before the reconstruction. Neither the property damage or total cost classifications showed statistical significance.

Based on the results of this test, the hypothesis that there was no difference in the accident costs/mvm before the reconstruction could not be rejected. The costs/mvm were equal for 1964, 1965, 1966 and 1967.

A one-tailed t-test was used to evaluate the costs/mvm before and after the improvement. It was postulated that the only change that could be brought about by reconstruction would be a reduction in the number of accidents/million vehicle-miles. This justified the use of the one-tailed test. The results of these t-tests are shown in Table 36.

The costs of injury accidents per million vehicle-miles have been reduced substantially. This factor showed significance at the (0.10) level. The total cost of traffic accidents/mvm has also been reduced significantly (0.05), as has the cost of property damage only accidents. The property damage only classification shows the greatest statistical significance (0.01). It can be concluded that the reconstruction of

TABLE 33. ANALYSIS OF VARIANCE FOR LINEAR REGRESSION, INJURY

Source of Variation	D.F.	Sum of Squares	Mean Squares	F-value
Due to regression	1	3518766.05	3518766.05	4.3496
Deviation about regression	2	1617968.70	808984.35	
Total	3	5136734.75		

TABLE 34. ANALYSIS OF VARIANCE FOR LINEAR REGRESSION, PDO

Source of Variation	D.F.	Sum of Squares	Mean Squares	F-value
Due to regression	1	52531.25	52531.25	1.4278
Deviation about regression	2	73581.50	36790.75	
Total	3	126112.75		

TABLE 35. ANALYSIS OF VARIANCE FOR LINEAR REGRESSION, TOTAL

Source of Variation	D.F.	Sum of Squares	Mean Squares	F-value
Due to regression	1	1.15517	1.15517	0.6009
Deviation about regression	2	3.84483	1.92241	
Total	3	5.00000		

TABLE 36. ONE-TAILED t-TESTS FOR TWO NORMAL POPULATIONS

Item	$S^2_{\bar{x}_1-\bar{x}_2}$	$S_{\bar{x}_1-\bar{x}_2}$	t	Significance
Nonfatal injury	2173708.33	1474.35	1.956	0.10
Property Damage	39583.33	198.96	11.007	0.01
Total	2174294.58	1781.63	3.005	0.05

this section of the U.S. 52 Bypass has, in fact, reduced the traffic accident costs/mvm significantly.

Accident Benefits

The benefits which accrued to the road-users from the reduction in accident costs on the reconstructed Bypass were also determined for sections 14, 15, and 16, the sections for which travel time benefits were previously evaluated. Table 37 shows all traffic accidents on these three sections of the roadway, the total direct costs of these accidents, and the total costs per million vehicle-miles of travel.

A linear relationship was again postulated for the years before the reconstruction and the hypothesis that there was no difference in the total cost per mvm for these four years was tested. If the four years did have equal accident costs per mvm of travel, the slope of the regression line would be zero.

The BMD3R program was used to generate the analysis of variance table shown in Table 38. The F-value is statistically not significant, allowing the conclusion to be reached that the costs per mvm of the accidents before the reconstruction were equal for the four years tested.

A one-tailed t-test was again employed to evaluate any differences in the before and after costs. The justification for the use of this test was the same as stated previously. The results of this t-test are shown in Table 39. It can be seen that the total cost of traffic accidents per million vehicle-miles has been reduced significantly (0.05).

TABLE 37. SUMMARY OF TOTAL DIRECT COSTS OF ACCIDENTS PER MVM, SECTIONS 14, 15 and 16

Item	1964	1965	1966	1967	1970
Number of Accidents	91	95	98	97	48
Fatal accidents	--	--	1	--	--
Nonfatal	16	15	17	12	9
Property damage	75	80	80	85	39
Total vehicle miles of travel, millions	8.310	8.825	9.340	9.854	11.623
Total accident costs per mvm (1970 dollars)	$8413	7770	9620	6307	3518

TABLE 38. ANALYSIS OF VARIANCE FOR LINEAR REGRESSION, SECTIONS 14, 15 AND 16

Source of Variation	D.F.	Sum of Squares	Mean Squares	F-value
Due to regression	1	999492.05	999492.05	0.4240
Deviation about regression	2	4715042.70	2357521.35	
Total	3	5714534.75		

TABLE 39. ONE-TAILED t-TEST FOR TWO NORMAL POPULATIONS

Item	$S^2_{\bar{x}_1-\bar{x}_2}$	$S_{\bar{x}_1-\bar{x}_2}$	t	Significance
Total	2379622.08	1542.6	2.92	0.05

Based on the results of the linear regression discussed above, an average value was determined for the total cost of traffic accidents for the period before the improvement. This average value was $8028/mvm in 1970 dollars. The total cost/mvm for 1970 was $3518/mvm, or a reduction of $4510/mvm. In terms of the total reduction in accident costs for 1970, this reduction amounts to approximately $52,000.

Summary of Results

The major results and findings of this phase of the determination of road-user benefits due to the reconstruction of the first stage of the U.S. 52 Bypass are summarized in the following paragraphs.

1. The total numbers of accidents occurring for each of the four years before reconstruction remained fairly constant. The greatest number of involvements occurred in 1966 when 142 accidents were reported. The total number of accidents for the period immediately after reconstruction, 1970, was 71, almost half the average value of the four years before reconstruction.

2. The location of greatest accident concentration both before and after the improvement was the South Street intersection. The average volume of traffic on the approaches of South Street is higher than at any other intersecting street in the study section. This substantial cross street volume helps explain the large number of accidents occurring at this intersection. The total number of accidents at the South Street intersection has been reduced by one-half the before rate due to the reconstruction.

A large number of the intersectional and intersectional related accidents that occurred prior to the improvement were due to vehicles either changing lanes or attempting to pass a turning vehicle on the right. Accidents also occurred when two vehicles passed through the intersection side by side and attempted to use one lane at the same time. The reconstruction has provided left-turn lanes at all intersections, thus allowing these movements to be made easily.

3. The greatest number of driveway access accidents before reconstruction occurred between the South Street and Kossuth Street intersections. A number of these accidents could be traced directly to vehicles attempting to enter or leave the one large motel in the study sections. The left turn lanes for driveway access has substantially reduced this type of accident.

4. Non-junction accidents have been reduced by one-half due to the reconstruction of the first-state of the Bypass.

5. Although the total number of accidents occurring on the improved sections of the roadway has been substantially reduced, the relative numbers of accidents in each of the three severity classifications has remained unchanged. For the period before reconstruction, 84 percent of all accidents were property damage only accidents. During 1970, this percentage was again 84 percent of the total.

6. The total direct costs of accidents occurring during the study period were determined in 1970 dollars. Statistical tests were employed to show equality between the accident costs/mvm for the years before the reconstruction, therefore allowing tests to be made on these

total direct costs/mvm both before and after the improvement. It was concluded that the reconstruction of the first stage of the U.S. 52 Bypass has significantly reduced the total direct accident costs/mvm.

7. The benefits to the road-users that have resulted from the reduction in accident costs were determined for sections 14, 15, and 16 of the U.S. 52 Bypass. These accident benefits amounted to approximately $52,000 for 1970, the first full year the improved section was open to traffic.

CHAPTER VI. TRAVEL TIME AND ACCIDENT BENEFITS

Benefits that accrued to the road-users in 1970 due to the reconstruction of the first stage of the U.S. 52 Bypass have been determined for travel times and accidents. Both before and after travel times and accidents were evaluated on a portion of the reconstructed facility, specifically sections 14, 15, and 16.

Chapter IV was devoted to an analysis of the travel times in 1964 and 1970 during the peak period of the day. This analysis revealed travel time savings per vehicle to be 26.4 seconds, or stated in terms of the value of travel time to motorists, approximately $48,000 for 1970. Additional benefits were also realized by motorists using the facility during off-peak periods, except possibly when the demand was extremely light. This additional savings per vehicle was shown to be about 70 percent of that realized during the three hour peak period. When totaled for non-peak hour traffic this amounted to $108,000. The total travel time benefits realized, therefore, amounted to $156,000 in 1970.

In Chapter V, the accident costs for a four year period before the improvement were evaluated and compared with the accident costs on sections 14, 15, and 16 after the improvement. The total direct costs/mvm for the before period were analyzed and shown to be statistically similar, thus allowing a comparison with the accident costs from 1970 to be made. Statistical tests indicated a significant (0.05) reduction in the total direct costs of accidents per million vehicle-miles on test sections 14, 15, and 16. The road-user benefits realized by the motorists were calculated to be about $52,000 in 1970.

Based on the results of these two above mentioned studies, the travel time and accident benefits due to the reconstruction of the first stage of this roadway amounted to $208,000 for sections 14, 15, and 16.

The total expenditures for this first phase of the reconstruction are listed in Table 40.

Maintenance costs are not included in annual cost determination because it was felt the maintenance costs on the reconstructed section of the Bypass would be no greater than those before reconstruction. The above costs are for the entire 1.534 mile length of facility. The costs for sections 14, 15, and 16 reduced on a mileage basis to an uniform equivalent annual cost were $185,000.

Assuming the benefits from travel time reductions and accidents remain the same for the years after 1970, the benefit/ cost ratio using only these benefits is 1.12.

There are, of course, many other benefits which were not evaluated. Benefits due to reductions in the operating costs of motor vehicles were not determined in this research due primarily to the lack of operational data for the period before reconstruction. It is probable, however, that operating costs did decrease because of the reduction in frequency and magnitude of speed changes and only a slight increase in speed. There are also nonmarket consequences that are realized by the traveler, including the lessening of travel strains, increased comfort and

TABLE 40. RECONSTRUCTION COSTS, FIRST PHASE, U.S. 52 BYPASS, LAFAYETTE, INDIANA*

Cost Item	Initial Cost $	Analysis Period Yrs.	Rate %	Uniform Equivalent Annual Cost $/yr.
Preliminary Engineering	$ 96,500.00	30	7%	7,776.55
Total Construction	1,951,071.95	30	7$	157,229.08
Supervision and Inspection	191,447.35	30	7%	15,427.98
RR Improvement	1,933.78	30	7%	155.83
Utilities	15,120.00	30	7%	1,218.46
Right of Access	710,815.00	80	7%	49,980.25
Total				$231.788.15

*All costs provided by the Indiana State Highway Commission convenience, and increased freedom of movement within the traffic stream. Although these consequences do not have monetary values associated with them, they often determine whether a trip was pleasant, enjoyable and satisfying, or whether it was annoying, tiring and produced mental strain. There have also been benefits to the community itself not considered in this analysis. The improved accessibility should lead to increased business activity along the reconstructed sections and the conversion of some land to higher type uses. The reconstruction has no doubt improved the communities image to the through traveler, in addition to improving the overall transportation system of the two cities. When consideration is given to these other factors, in addition to the benefit/cost analysis previously presented, it seems apparent that the reconstruction of the U.S. 52 Bypass was a good investment.

CHAPTER VII. LAND-USE CHANGES

Design of Study

When an existing facility is improved through reconstruction, an increase in business activity along the highway can often be anticipated. The traffic volume and ease of accessibility provide an appeal for the businessman seeking a new location. Highway oriented businesses - motor vehicle services, food and lodging - are very sensitive to their location with respect to the facility. There may be other changes in land-use as access is of importance whether industrial, commercial or residential development. The factors considered by industry for a new location include the resources of labor, cost of available land, taxes, presence of utilities and shorter or faster transportation routes and access to these routes. Commercial developers are concerned with accessibility to both their customers and employees and faster transportation routes. The amount of exposure that they will obtain at the location is also a factor of prime importance, along with the cost of the land and the tax assessment situation. Residential development is also dependent on accessibility, in this case the accessibility to shopping centers and work locations.

This land use study was interested in determining what effect, if any, the improvement of the U.S. 52 Bypass between Union Street and McCarty Lane has had on land-uses along this section.

The comparison was made between land-uses in 1964, when the Bypass was a two-lane facility, and land-use data collected in 1971, after the section under consideration had been reconstructed to four-lane divided. A standard system for identifying and coding land-use developed in 1965 by the Housing and Home Finance Agency and the Bureau of Public Roads was used in this investigation (31). For the purpose of this study the land-uses were categorized at the one-digit level of detail.

Collection of Data

An inventory of all commercial, industrial and residential land-uses along the U.S. 52 Bypass in Lafayette and West Lafayette, Indiana was made as part of the travel time and delay study conducted by Theodore Treadway in 1964 (35). This land-use data, supplemented by aerial photographs taken in 1963, provided the required data for the period prior to the reconstruction. The selection of 1964 as the period before the improvement enables any activity that may have come about in anticipation of the improvement to be included in the analysis. The land-uses after the reconstruction were determined by visual field inspection in the spring of 1971.

Analysis of Data

The land-uses in 1964 and 1971 were first classified in accordance with the code established by the Housing and Home Finance Agency in 1965 (31). Figure 13 represents the types of land-uses and the location of these uses at the time of the 1964 inventory. In 1964 there were 56 business and residential (codes 1 through 8) activities

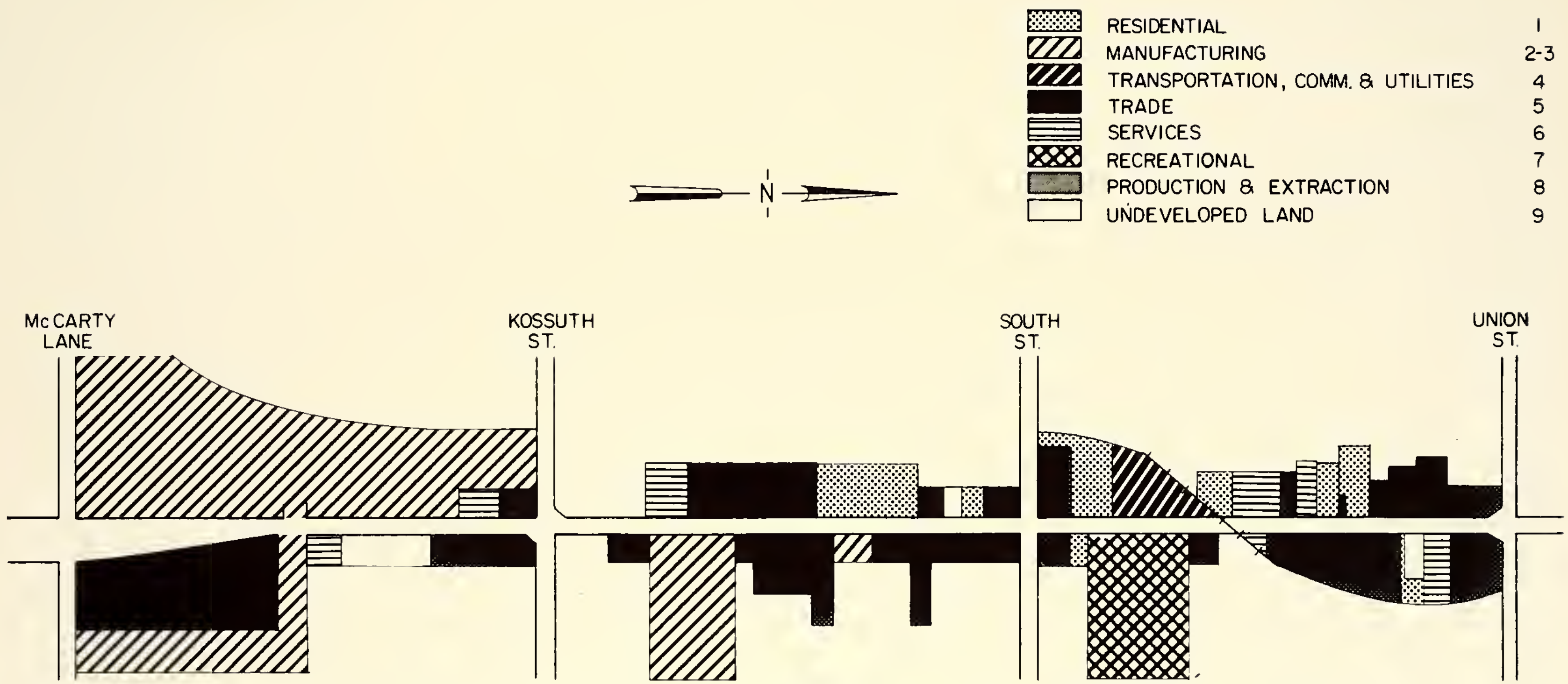

FIGURE 13. LAND-USES ADJACENT TO BY-PASS STUDY AREA (1964)

on this portion of the Bypass. Of this total, 40 were trade and service. Businesses that were dependent to a large extent on highway traffic numbered 22. There were 15 motor vehicle services, 5 food and 2 commercial lodging establishments. Considering that this study section is only 1.534 miles in length, this comprises a high concentration of highway oriented activities.

Commercial, industrial and residential growth on the study sections increased to 63 in 1971. These activities are shown in Figure 14. The predominant use was again trade and services. Of the total number of activities in 1971, 23 were highway oriented, 13 were motor vehicle services, 8 food and 2 commercial lodging.

There were 13 business establishments that ceased operation on the Bypass between 1964 and 1971. All of these activities were in the trade and service classifications. In the trade classification, 3 were gasoline service stations, 2 were motor vehicle sales, 1 furniture sales, 1 appliance and 2 other retail trade establishments. The defunct service establishments included 2 automobile repair, 1 cleaning service and 1 advertising service.

Of the 19 business establishments opened since the 1964 inspection, one was manufacturing, 1 was communications, 13 trade and 4 services. In the trade category, 1 was a gasoline service station, 2 motor vehicle sales, 1 motor vehicle accessory, 2 eating places and 4 home furnishing and appliance, and 3 mobile home sales. The services included beauty service, contract construction, auto service and rental service. No trends in development for the future are apparent at this time.

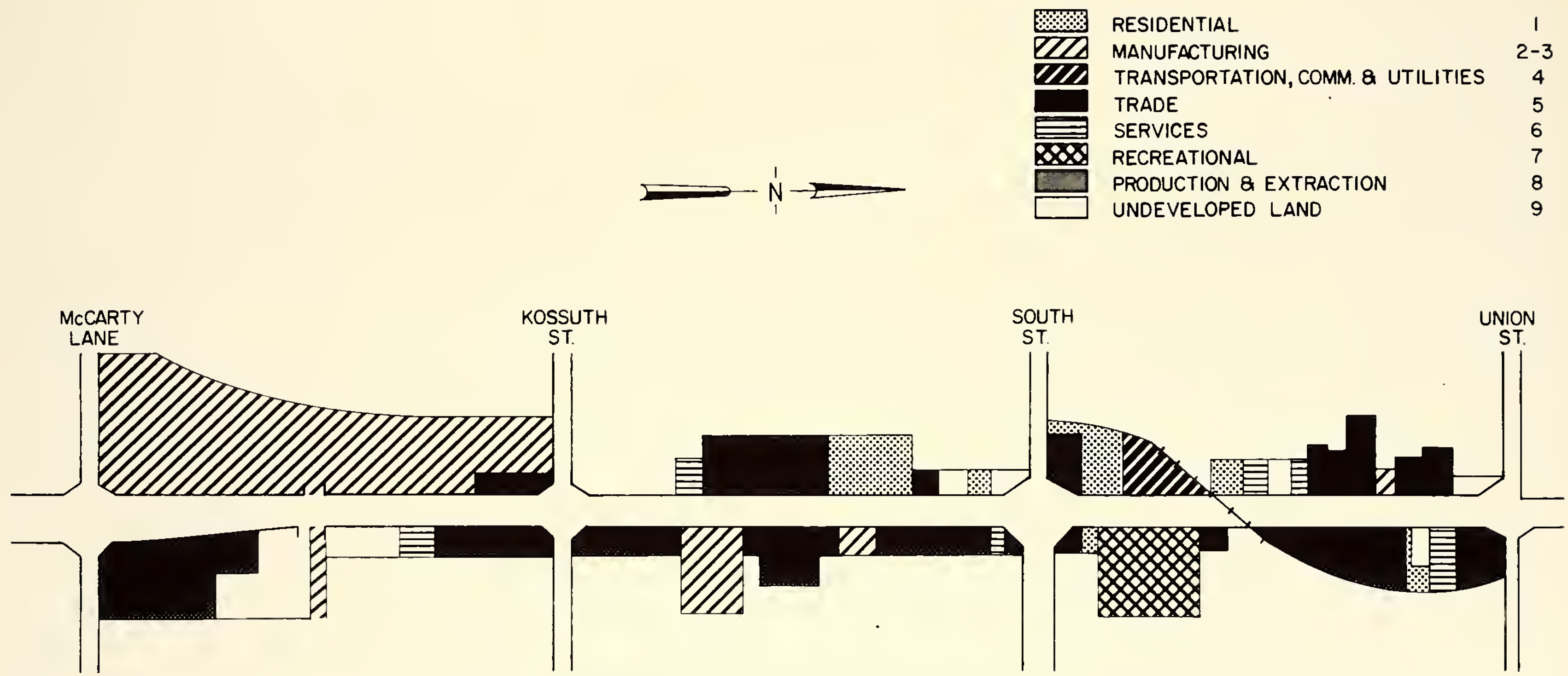

FIGURE 14. LAND-USES ADJACENT TO BY-PASS STUDY AREA (1971)

CHAPTER VIII. SUMMARY OF RESULTS AND CONCLUSIONS

The purpose of the research summarized here was to determine some of the benefits to the road-user and nonuser that have accrued due to the reconstruction of the first stage of the U.S. 52 Bypass at Lafayette-West Lafayette, Indiana. The results of this research and the conclusions drawn from these results are presented in the following paragraphs:

1. The travel time information required for the before period was obtained from a previous research study (35). In that study, the entire seven-mile length of the Bypass was included in the investigation of travel times and delays. The Bypass was split into eighteen (18) homogeneous study sections by considering the geometry, roadside development, and location of traffic signals. The sections included in the first stage of reconstruction and investigated in this study were sections 14, 15, and 16. These sections were analyzed individually and also as a whole.

Travel time data for 1964 and 1970 were analyzed using a two-way analysis of variance technique. The year in which the runs were made (1964 or 1970) and the direction of travel on the Bypass (north or south) were the factors included in the model to determine the travel times. Of the forty (40) travel time runs collected in each year, only those fifteen (15) runs made during the three hour peak period from 3:00-6:00 p.m. were extensively analyzed. This analysis indicated the year the runs were made as being significant at the one percent level. The direction of travel was not significant.

The average travel time reduction during the peak hour of 26.4 seconds (for the 1.22 miles of the sections studied) and 18 seconds for the non-peak hours were also evaluated in terms of dollar benefits. Costs of travel time were determined for three typical vehicles, thus allowing an estimate of the peak period benefits to be made. There were also benefits to those using the facility during the off-peak periods, except when the demand was extremely light. The total travel time benefits realized by motorists using the reconstructed facility during peak and off-peak periods of the day amounted to an estimated $156,000 in 1970.

2. All reported traffic accidents occurring on the reconstructed portion of the Bypass for a four year period before the improvement and one year after the improvement were analyzed in depth. All traffic accidents included in the investigation were classified in accordance with their location and type, the classification based on standards developed by the National Safety Council (23).

The total number of traffic accidents on the reconstructed portion of the Bypass was reduced from approximately 140 accidents/year before the improvement, to 71 accidents for 1970. A reduction was found for all classifications of accidents. It was also found that the relative numbers of accidents in the fatal, injury, and property damage only categories has remained virtually unchanged.

The total direct costs of accidents occurring during the study periods were determined in 1970 dollars. Statistical tests indicated the total direct costs/million vehicle-miles for the years before the improvement were not significantly different. The average direct costs (in 1970 dollars) of accidents for the before years was $8,028/mvm. The average direct cost of accidents for 1970 was$3,518/mvm. A statistical test showed these costs to be significantly different. It was concluded that the reconstruction has substantially reduced the total direct costs of accidents/mvm.

The road-user benefits resulting from this reduction were determined for sections 14, 15, and 16. These benefits due to the reconstruction amounted to $52,000 in 1970.

3. The travel time and accident benefits that were realized by the road-users due to the reconstruction of the first stage of the U.S. 52 Bypass amounted to $208,000 for sections 14, 15, and 16. The uniform equivalent annual cost of the reconstruction of sections 14, 15, and 16 only was $185,000. Using only the benefits from travel time and accident reductions, this yields a benefit/cost ratio of 1.12. Other consequences, such as reductions in the costs of operating motor vehicles, the lessening of travel strains, increased comfort, and the benefits to the community itself, indicate that the expenditure for the reconstruction was a sound investment.

4. Land usages in 1964 and 1971 were compared along the reconstructed portion of the Bypass to determine what effect the improvement has had on this usage. There has been little change in the

one year, probably due in large measure to the unavailability of land. Prior to the reconstruction there were 56 developments, primarily commercial in nature. At the end of 1971 there were 63 developments of similar land use type. No trends in development for the future are apparent at this date.

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APPENDIX A

1964 AND 1970 AADT AND TURNING MOVEMENTS

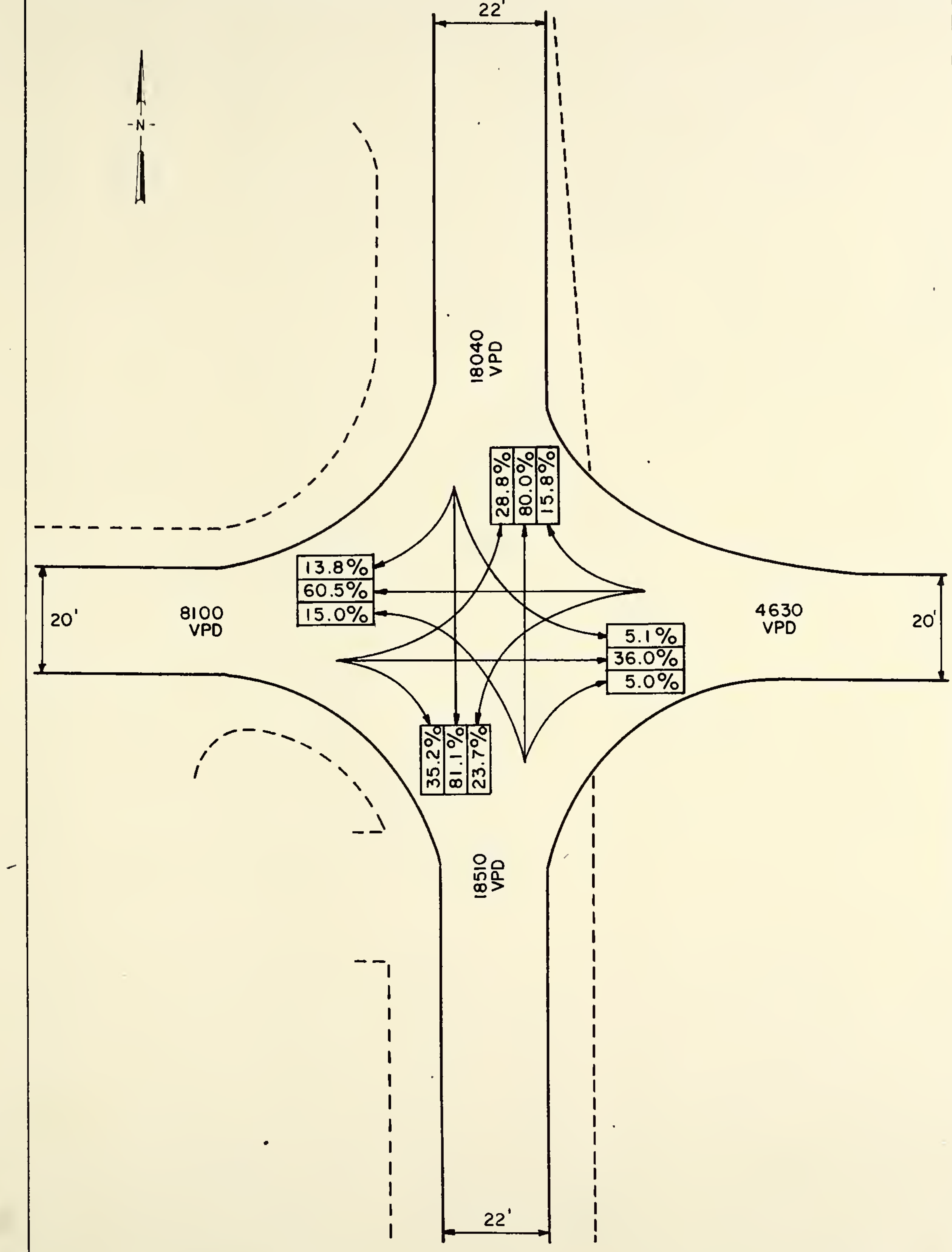


FIGURE A1. U.S. 52 BY-PASS & UNION (1964)

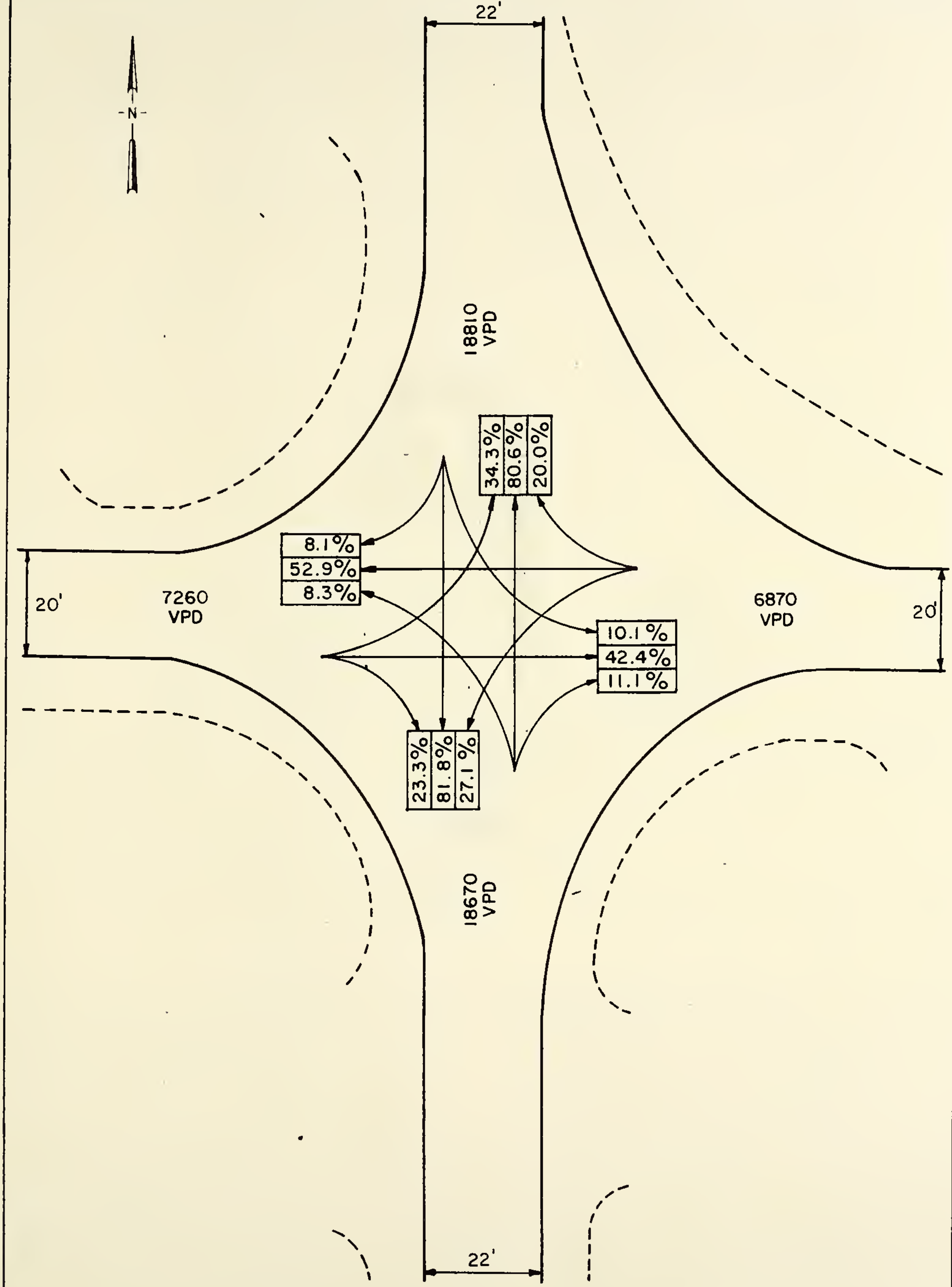


FIGURE A2. U.S. 52 BY-PASS & S.R. 26 (1964)

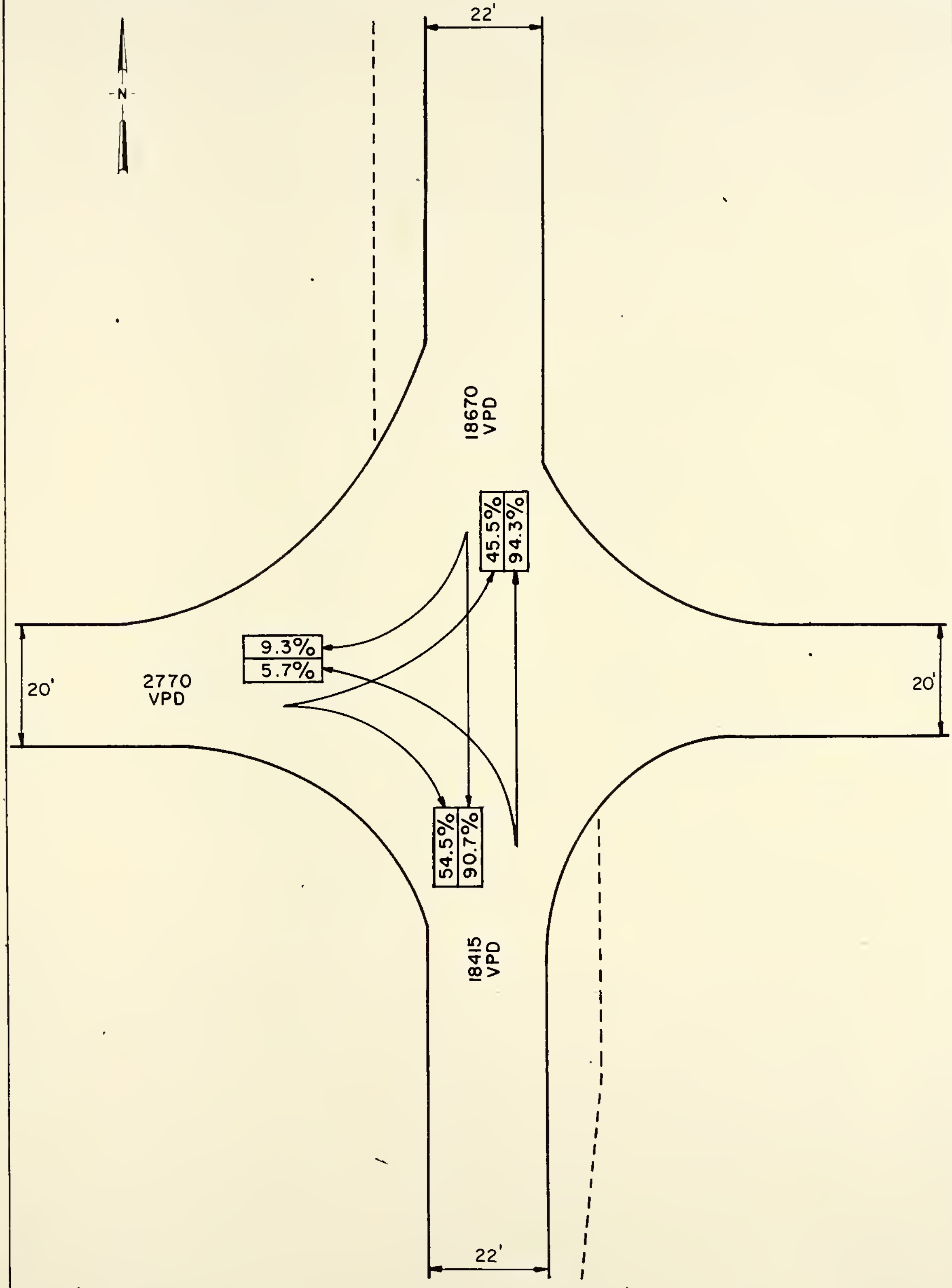


FIGURE A3. U.S. 52 BY-PASS & KOSSUTH (1964)

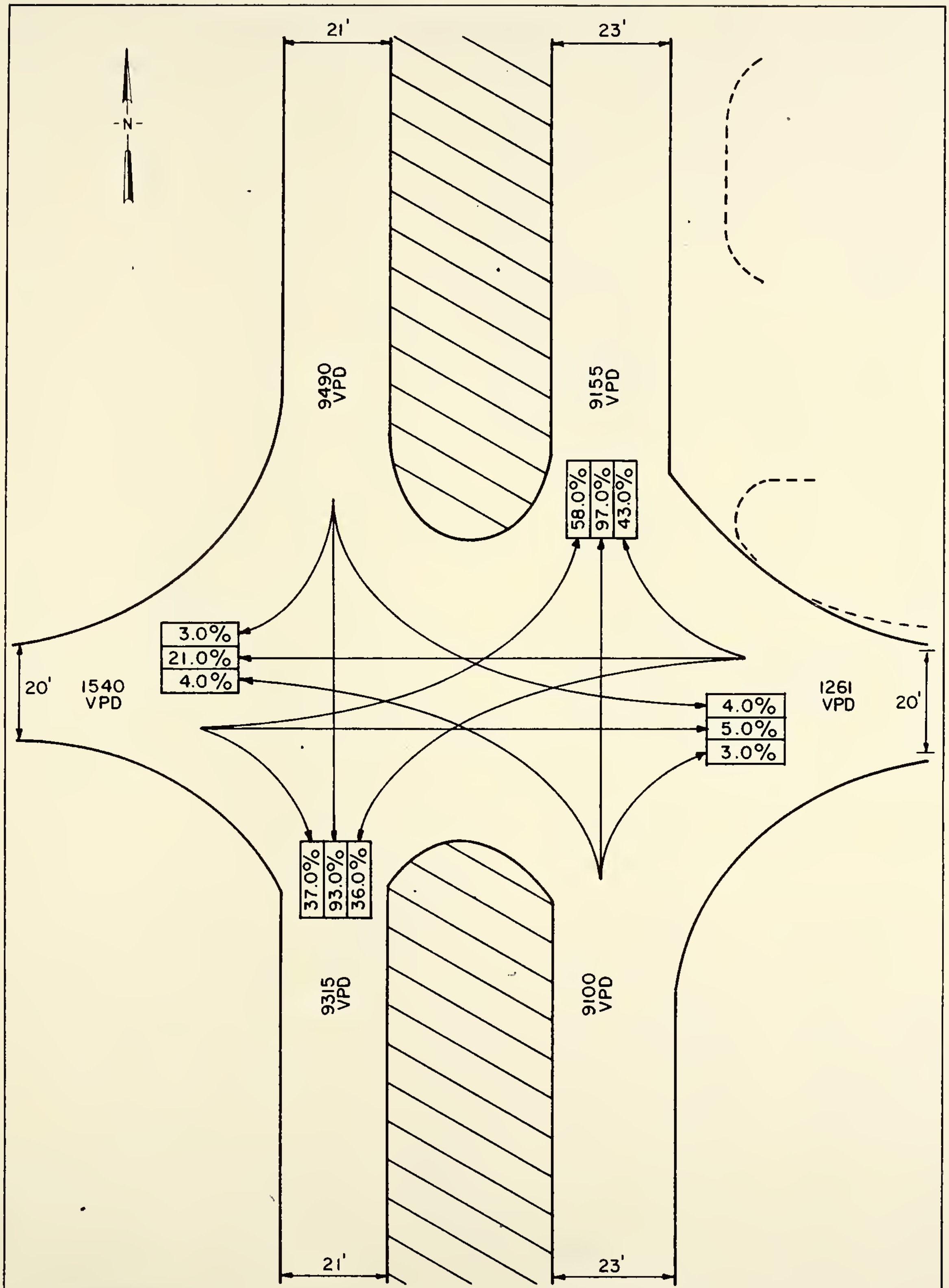


FIGURE A4. U.S. 52 BY-PASS & McCARTY LANE (1964)

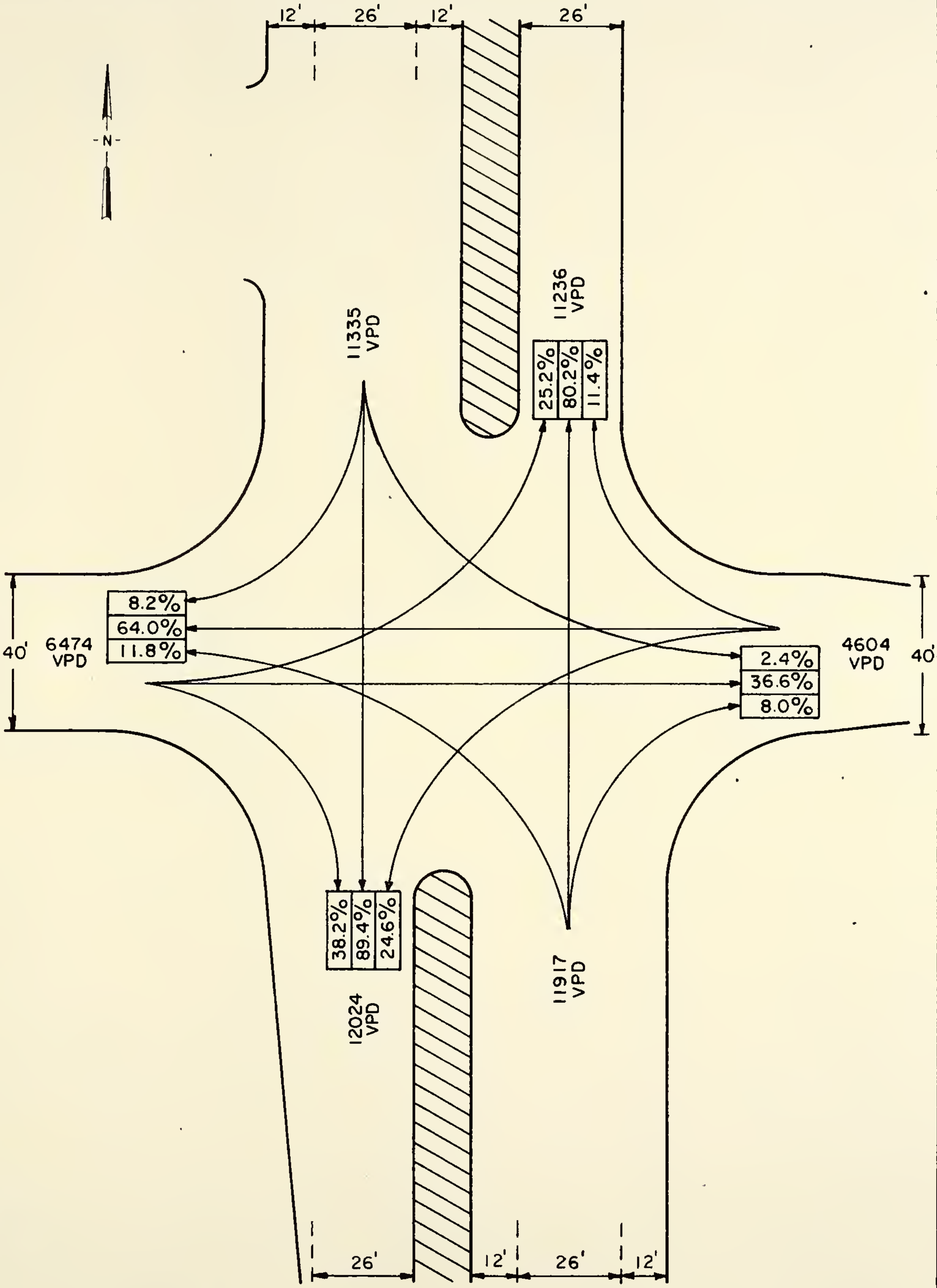


FIGURE A5. U.S. 52 BY-PASS & UNION (1970)

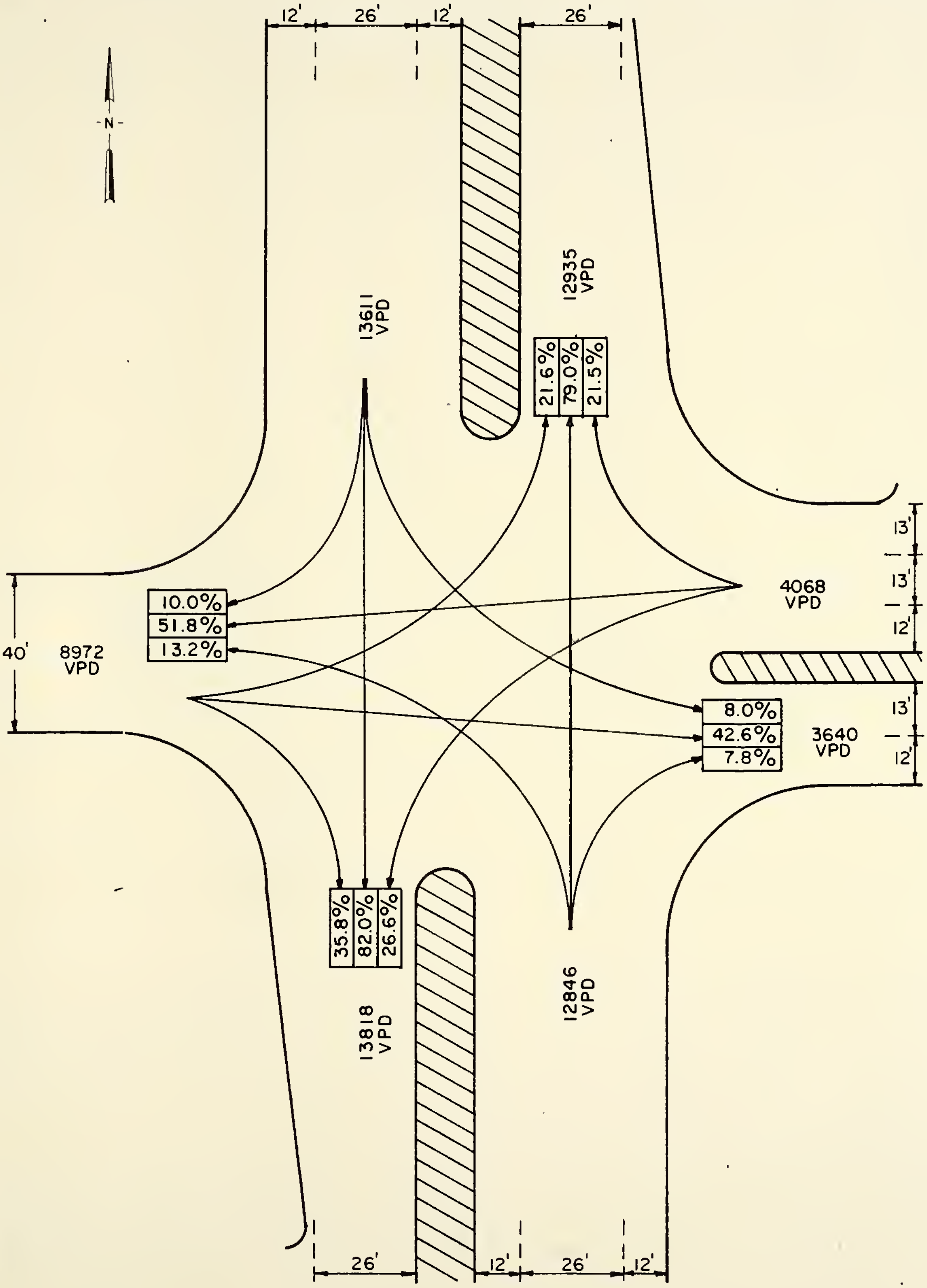


FIGURE A6. U.S. 52 BY-PASS & S.R. 26 (1970)

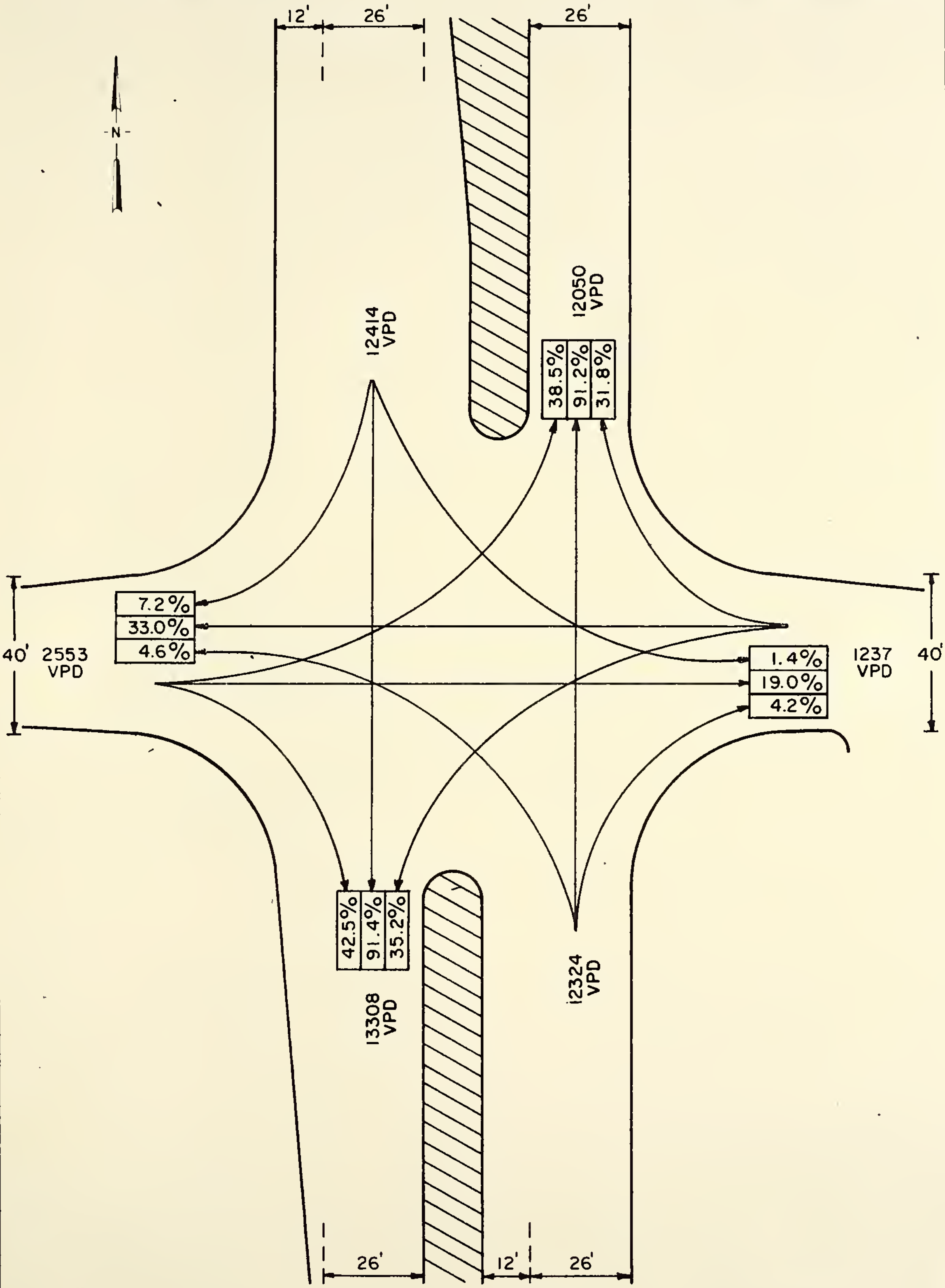


FIGURE A7. U.S. 52 BY-PASS & KOSSUTH (1970)

APPENDIX B

COLLISION DIAGRAMS FOR INTERSECTIONS ON U.S. 52 BYPASS IN 1964, 1965, 1966, 1967, 1970

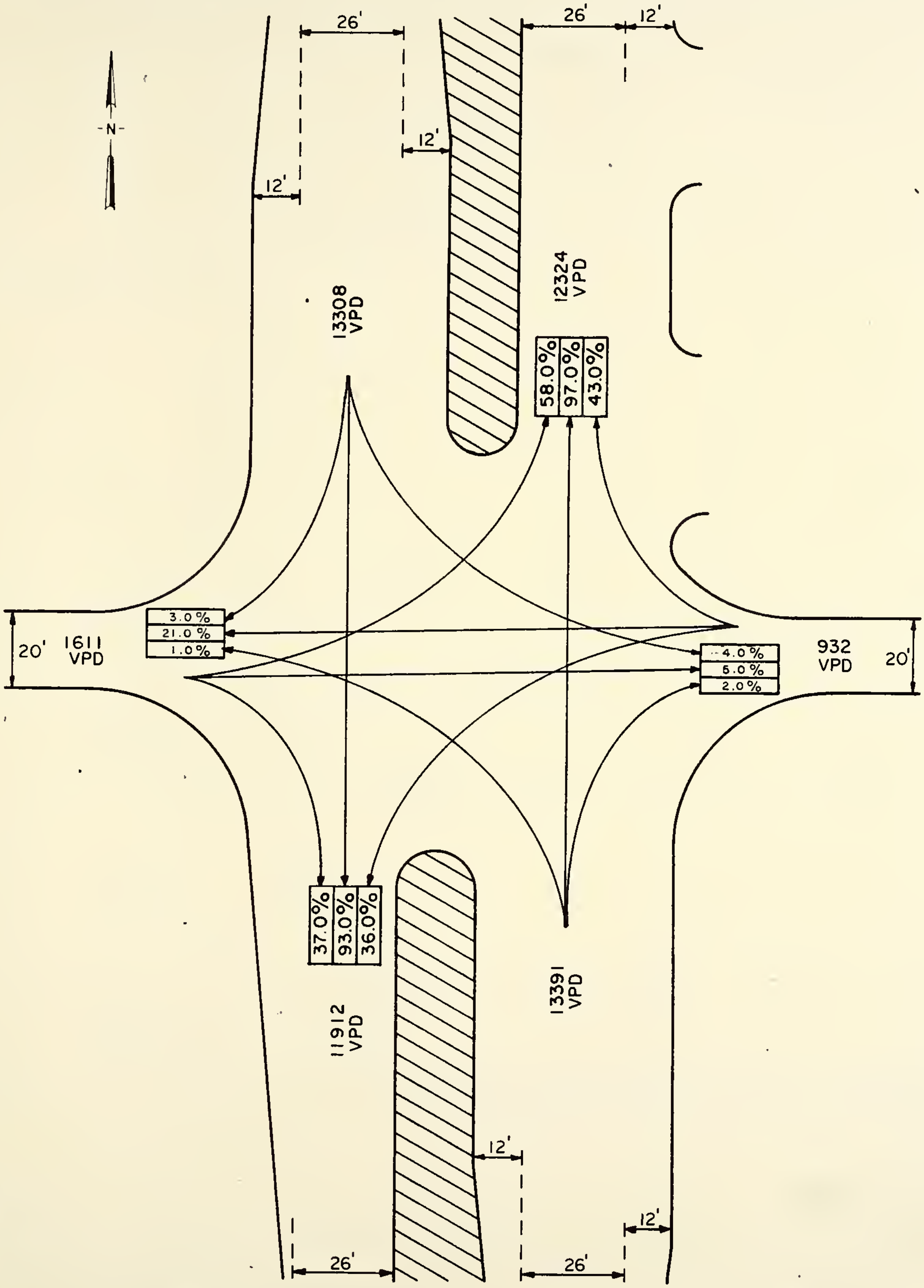
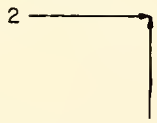
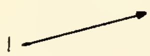
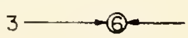


FIGURE A8. U.S. 52 BY-PASS & McCARTY (1970)

APPENDIX B

The coding on the following collision diagrams is as given in the following examples:

Code	Meaning
Example A:	
	Three same direction of travel accidents with a total of one injury.
Example B:	
	Two right angle accidents with no injuries.
Example C:	
	The others category includes this single car accident with no injuries.
Example D:	
	Three opposite direction of travel accidents in which a total of six persons were injured.

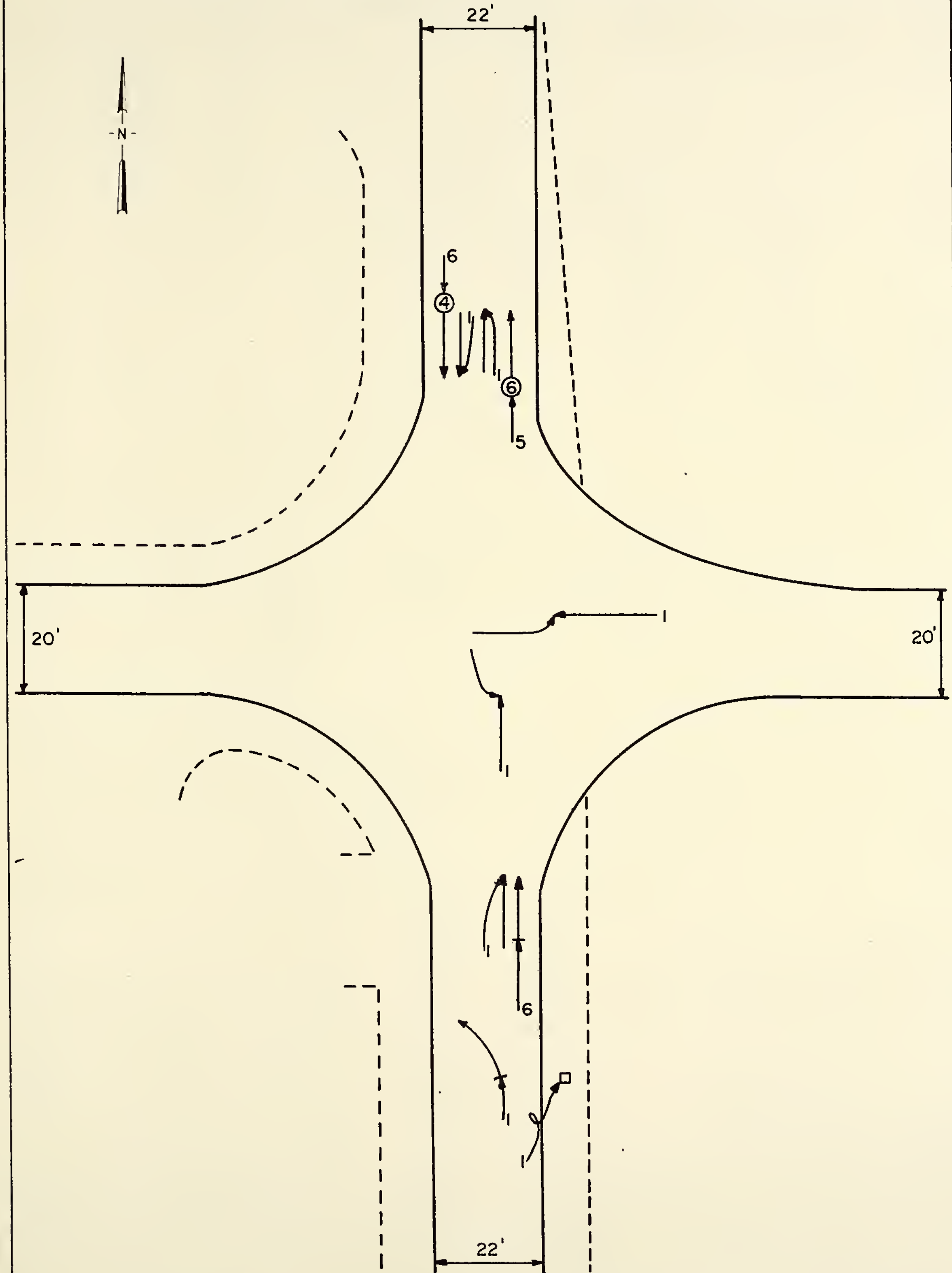


FIGURE BI. U.S. 52 BY-PASS & UNION (1964)

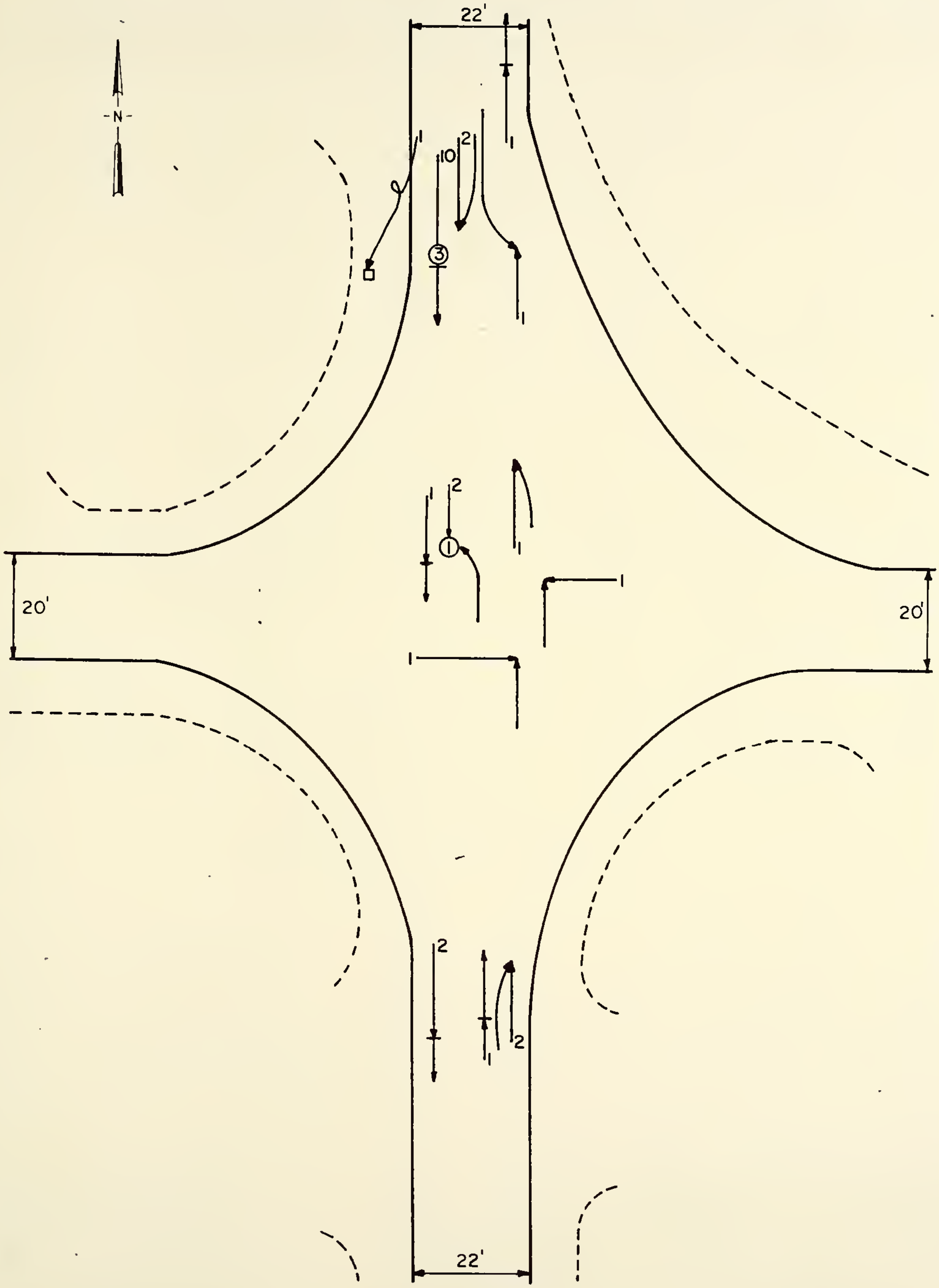


FIGURE B2. U.S. 52 BY-PASS & S.R. 26 (1964)

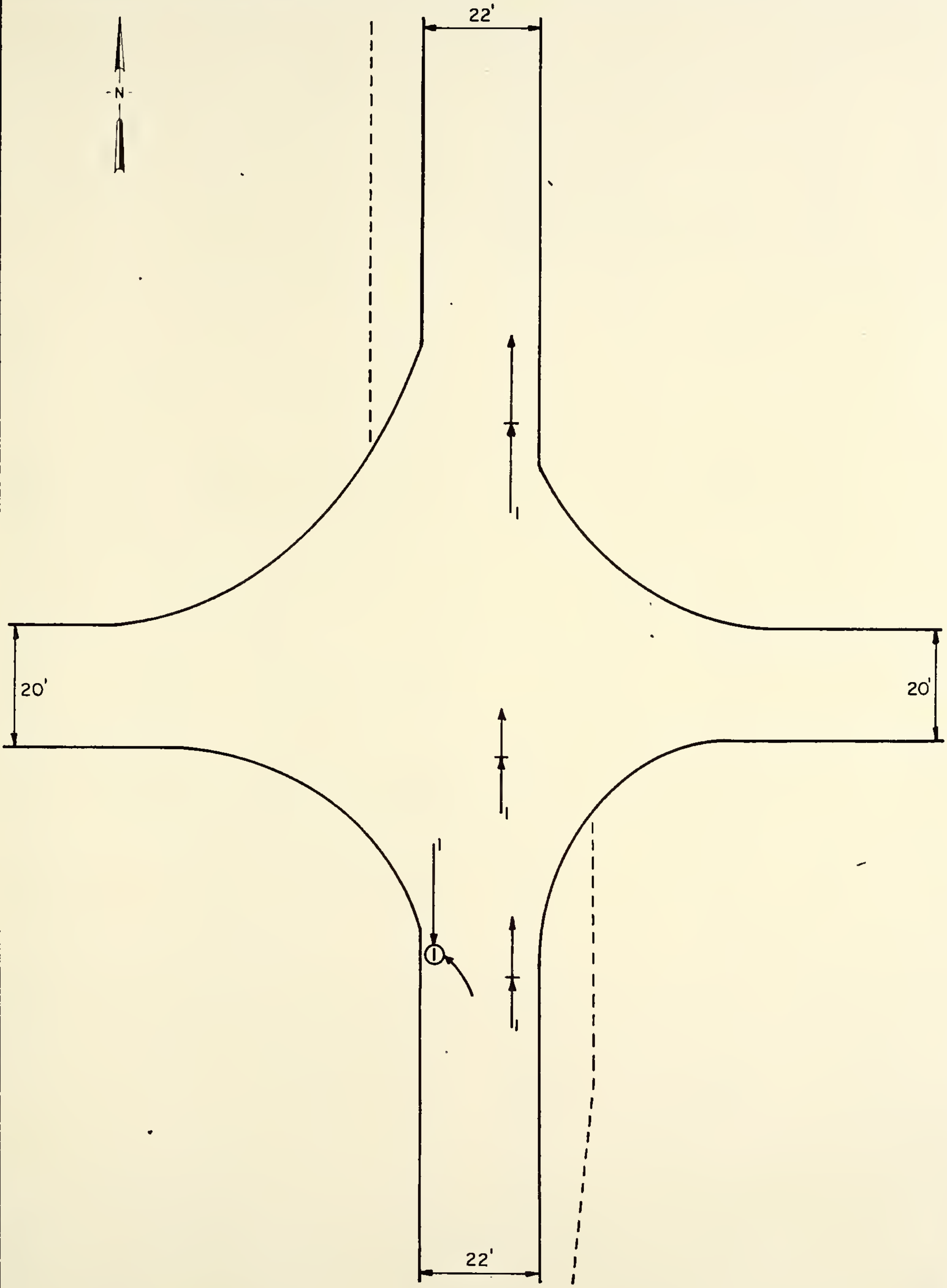


FIGURE B3. U.S. 52 BY-PASS & KOSSUTH (1964)

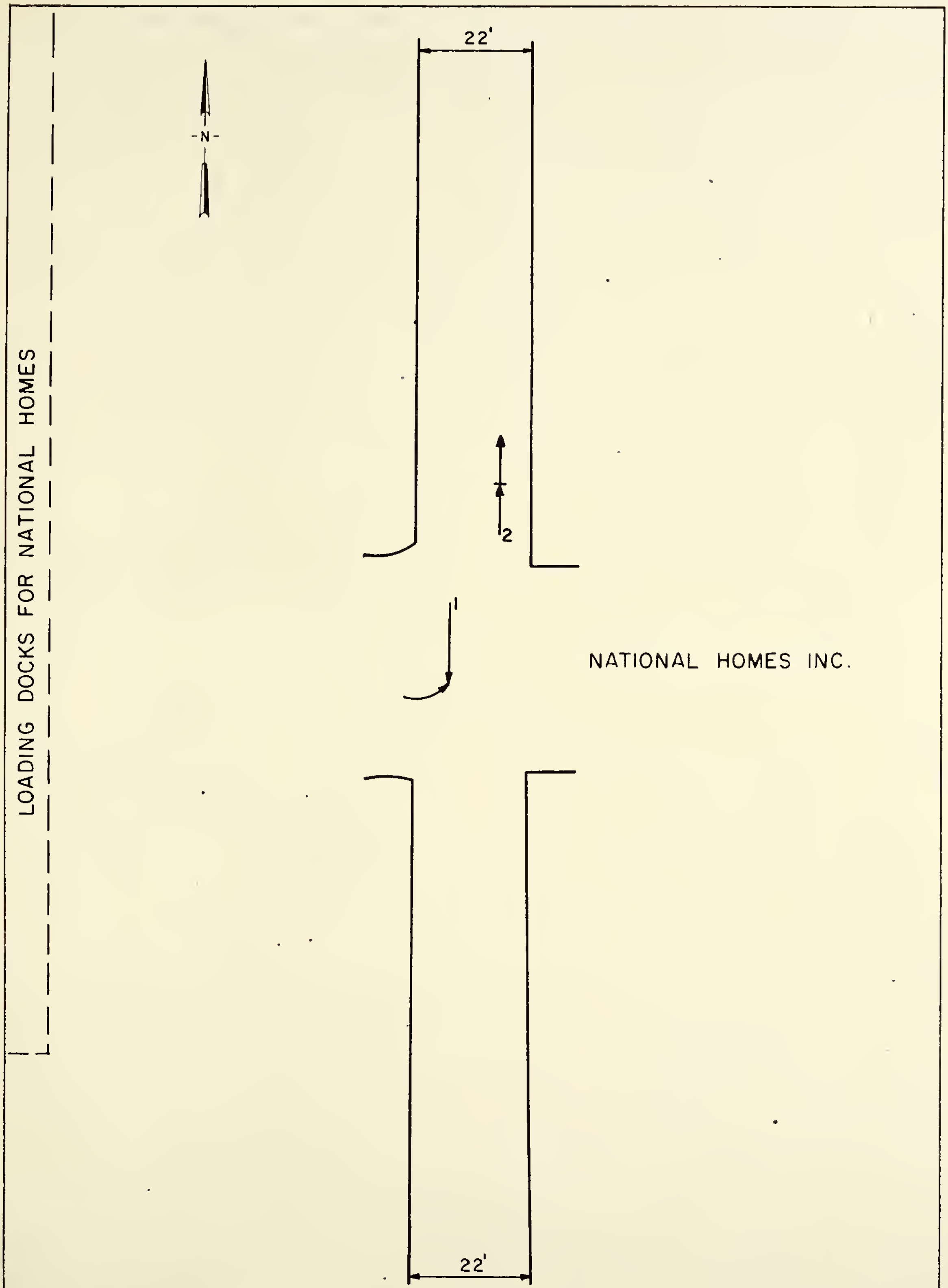


FIGURE B4. U.S. 52 BY-PASS & NATIONAL HOMES (1964)

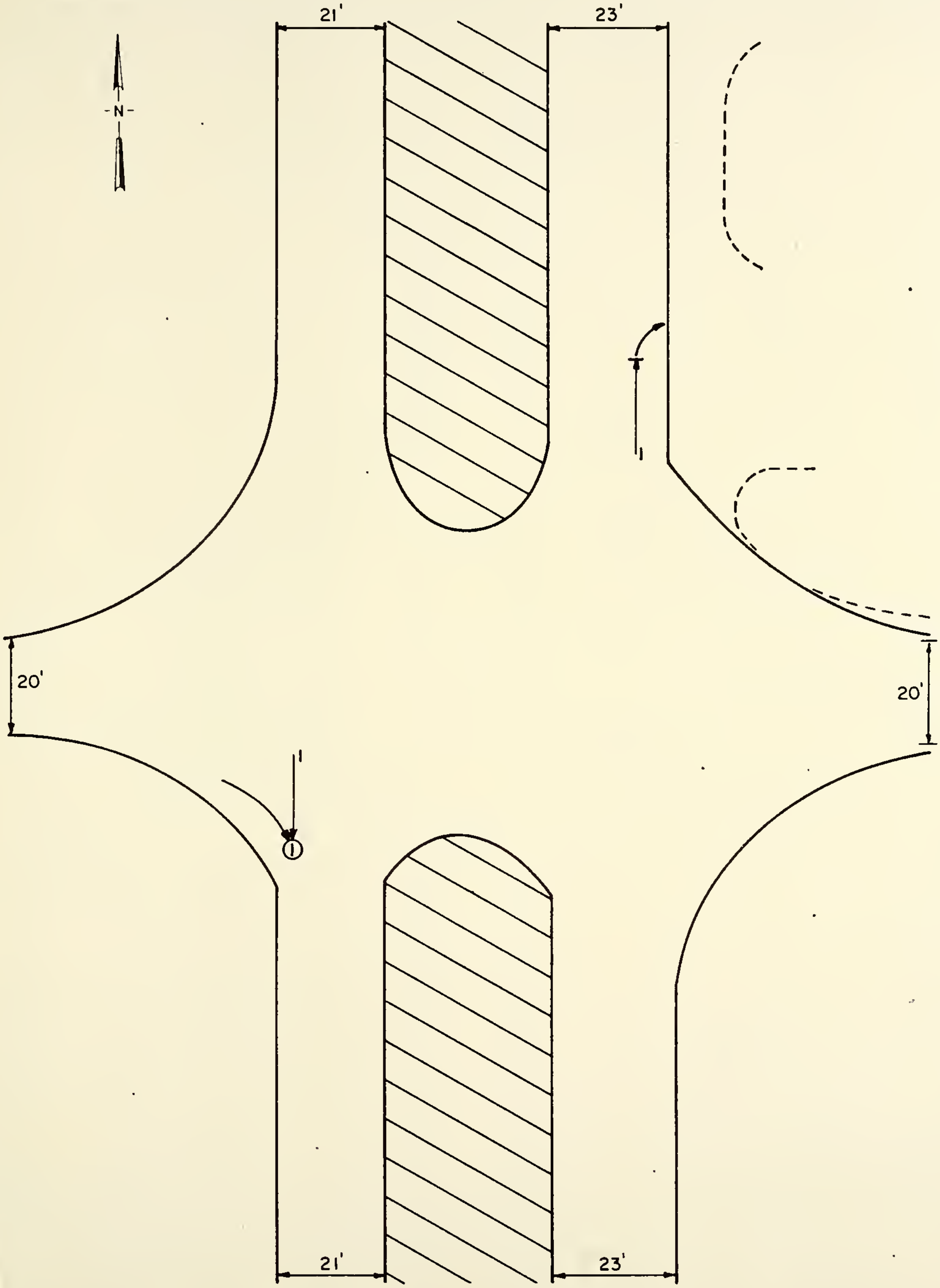


FIGURE B5. U.S. 52 BY-PASS & McCARTY LANE (1964)

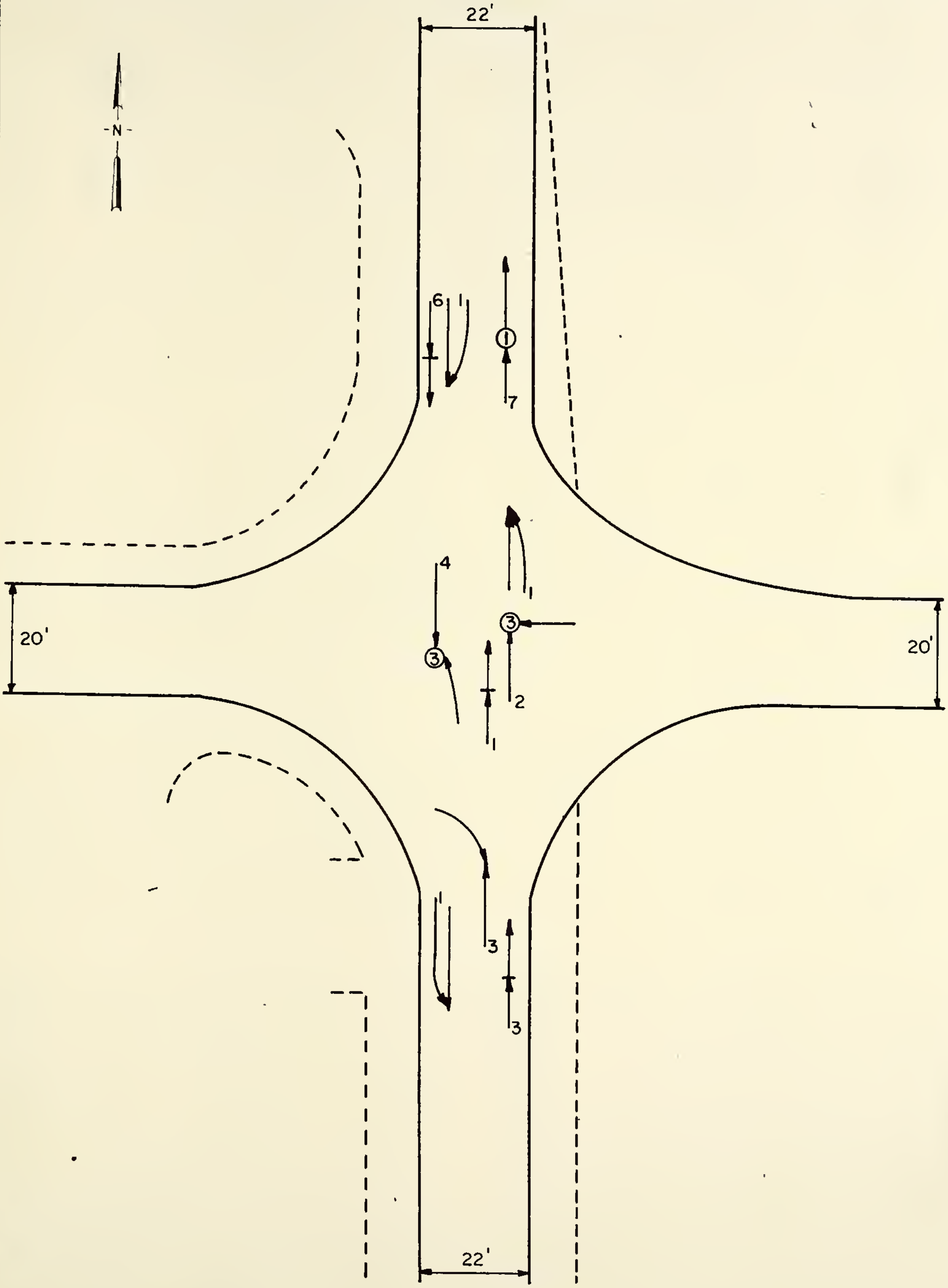


FIGURE B6. U.S. 52 BY-PASS & UNION (1965)

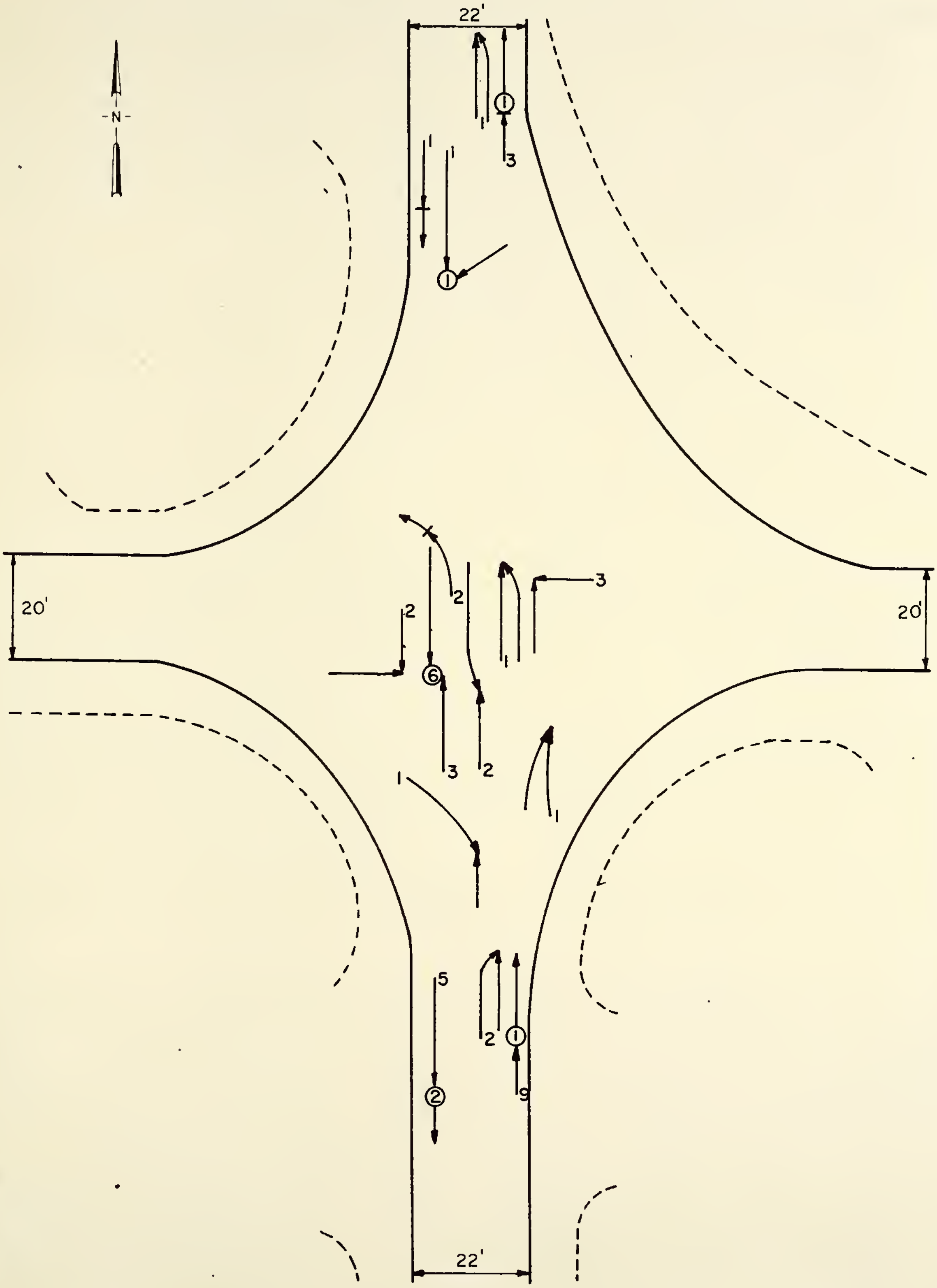


FIGURE B7. U.S. 52 BY-PASS & S.R. 26 (1965)

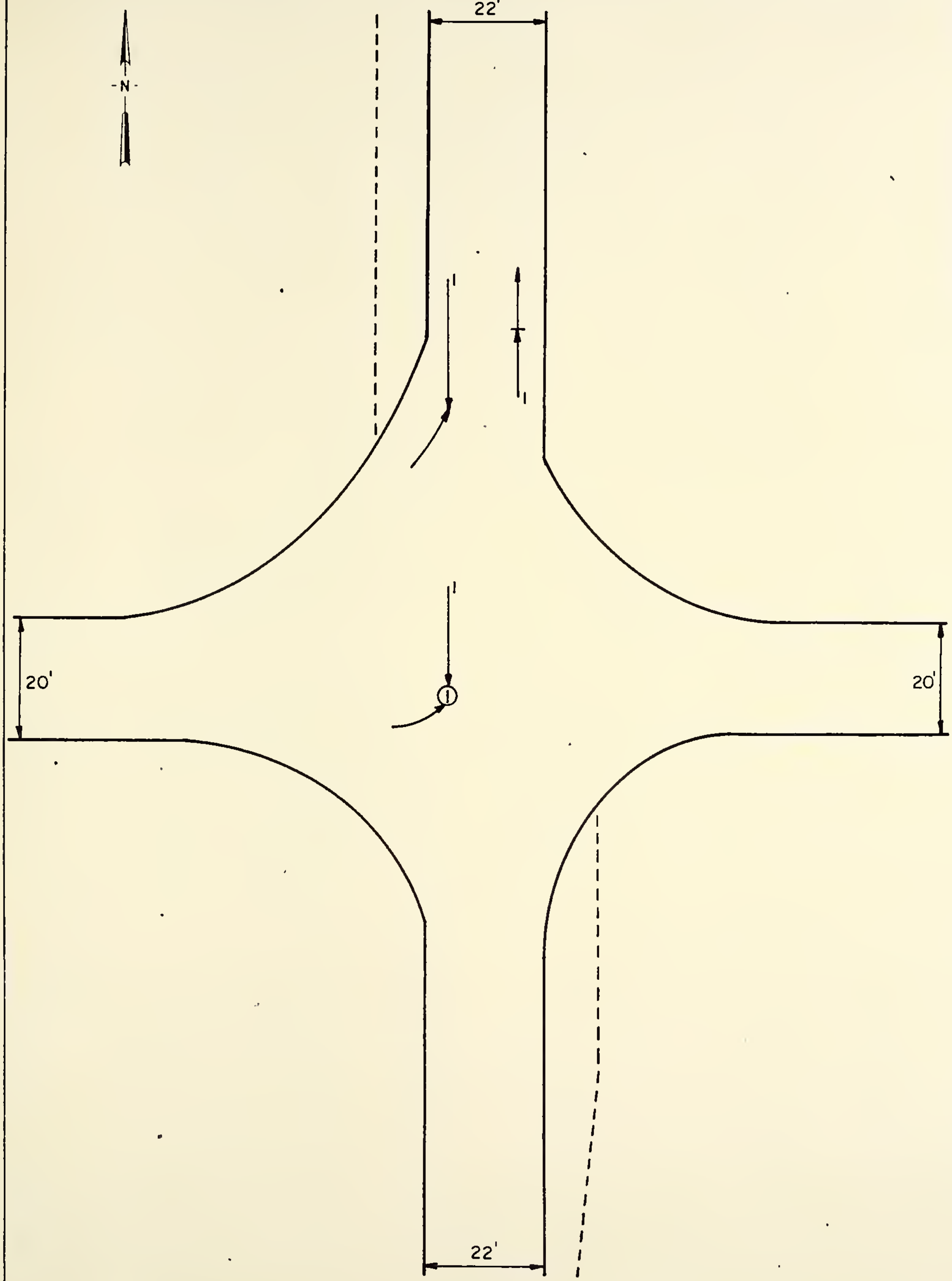


FIGURE B8. U.S. 52 BY-PASS & KOSSUTH (1965)

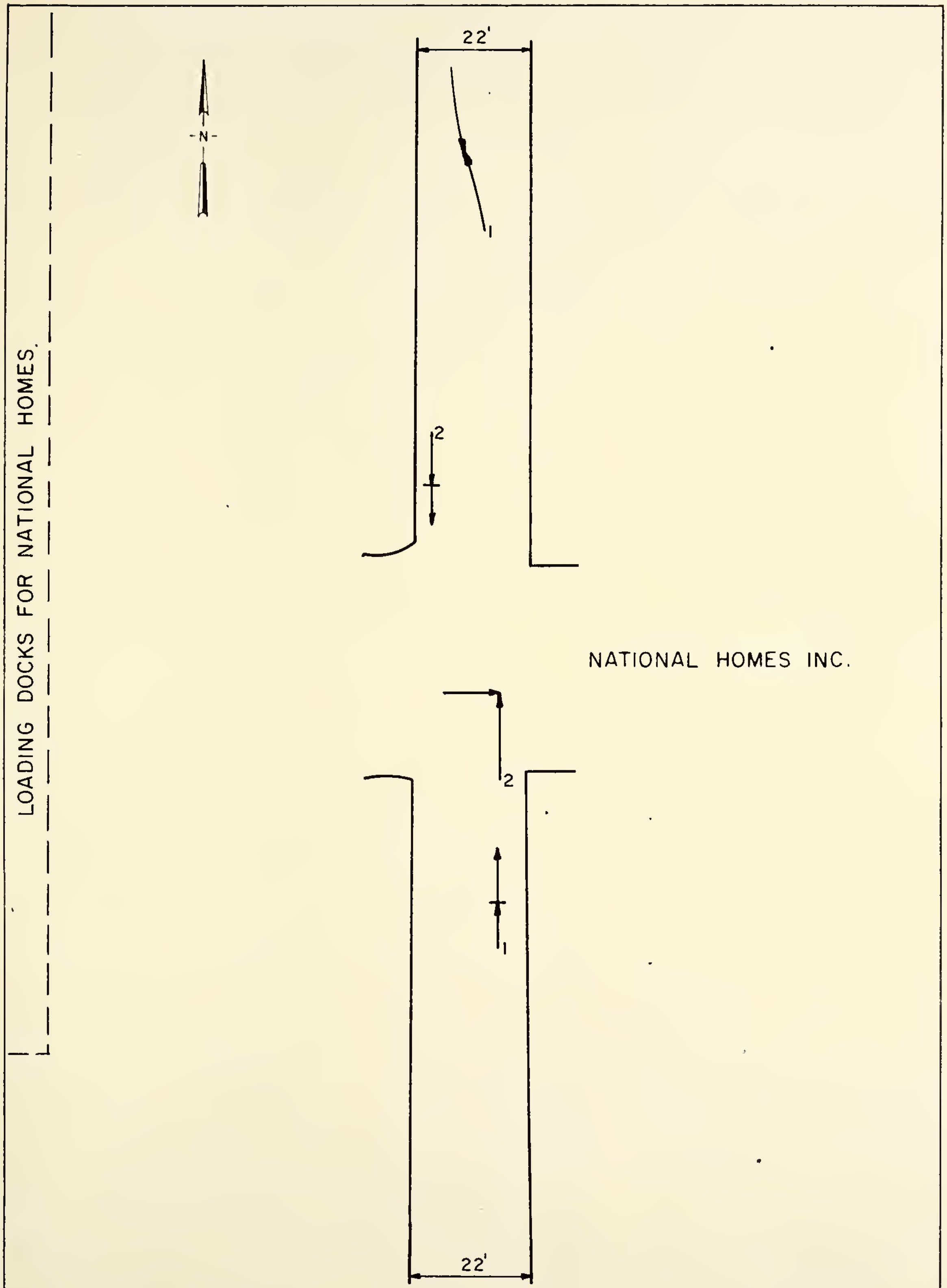


FIGURE B9. U.S. 52 BY-PASS & NATIONAL HOMES (1965)

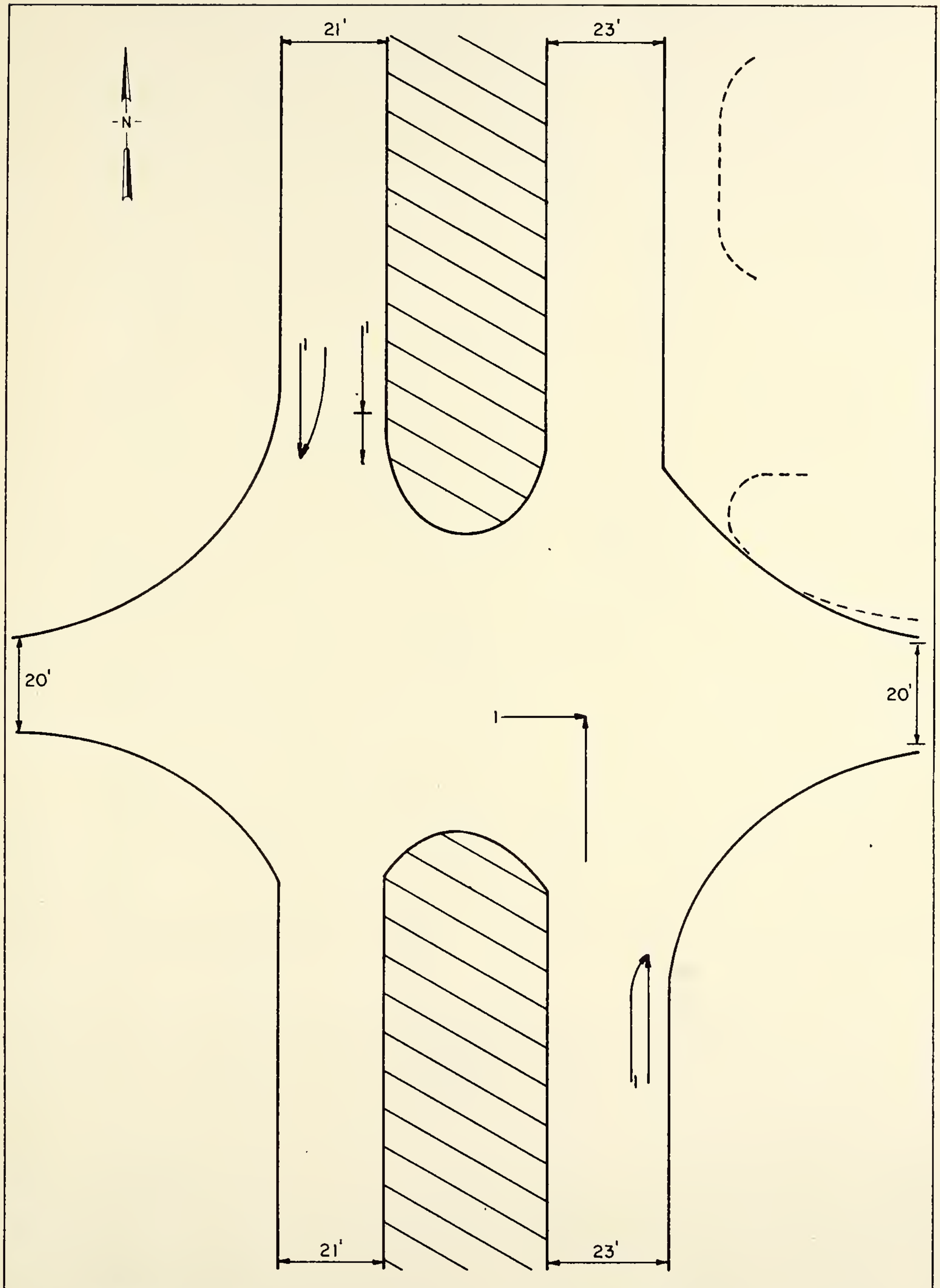


FIGURE B10. U.S. 52 BY-PASS & McCARTY LANE (1965)

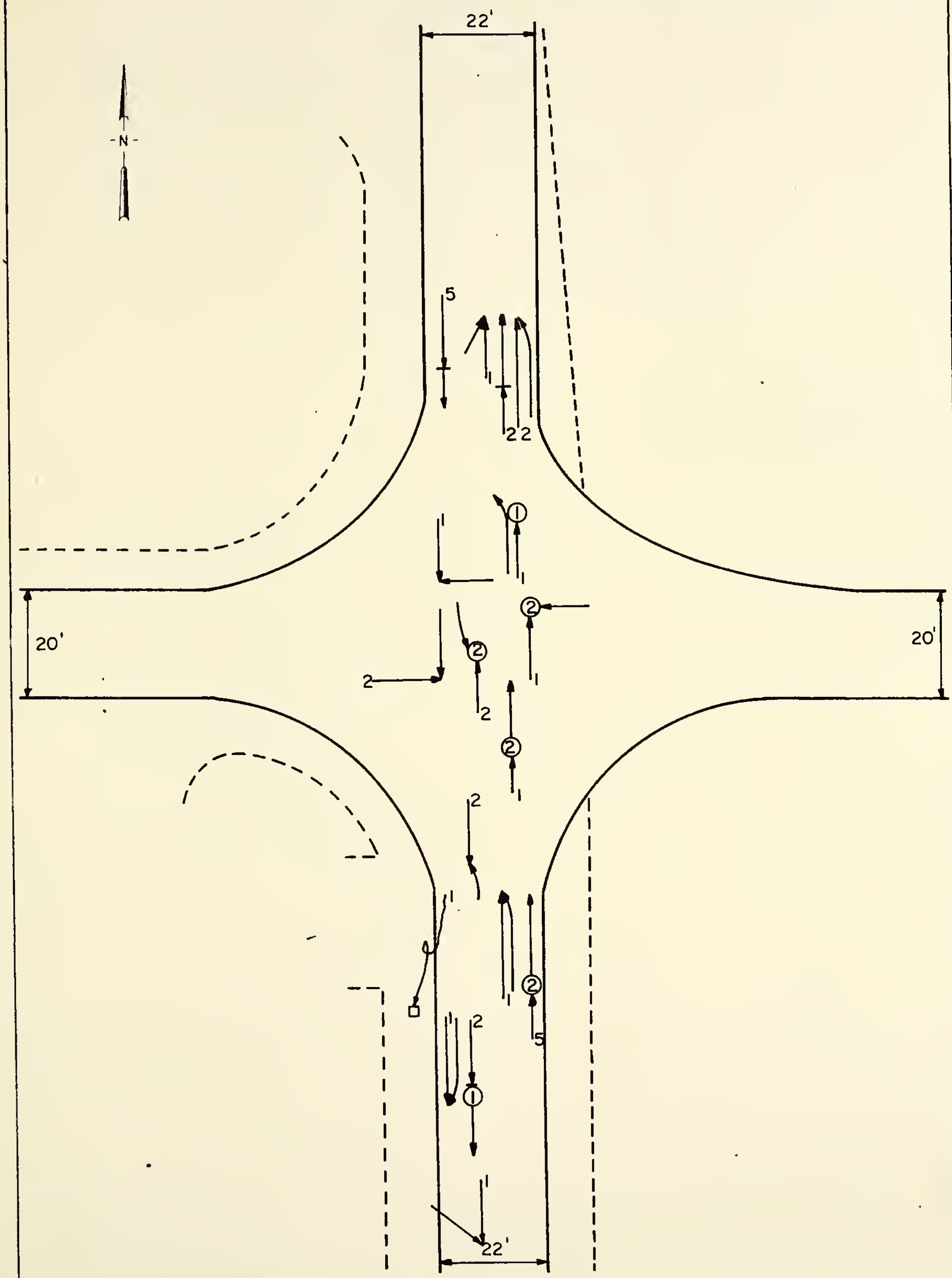


FIGURE B11. U.S. 52 BY-PASS & UNION (1966)

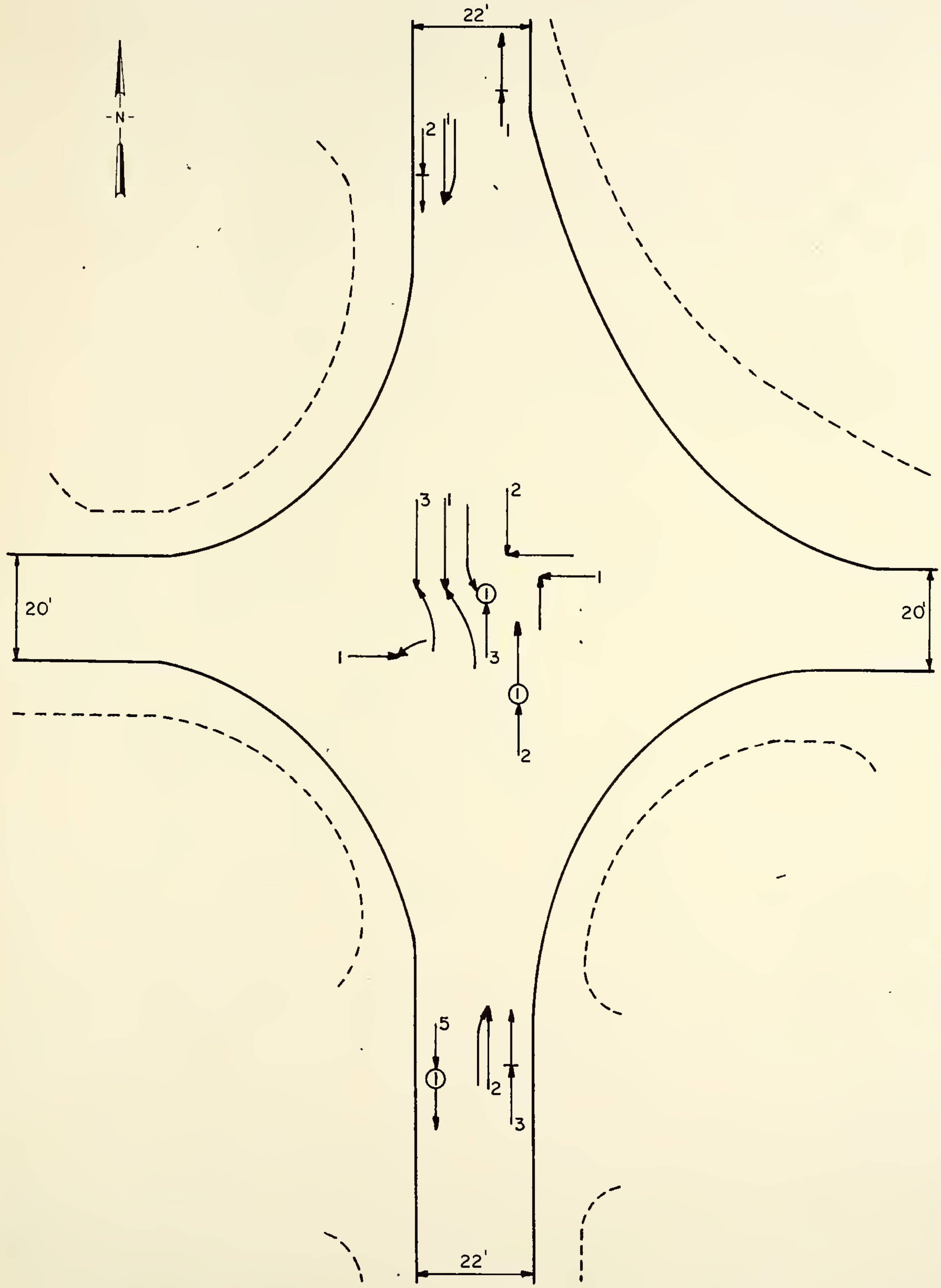


FIGURE B12. U.S. 52 BY-PASS & S.R. 26 (1966)

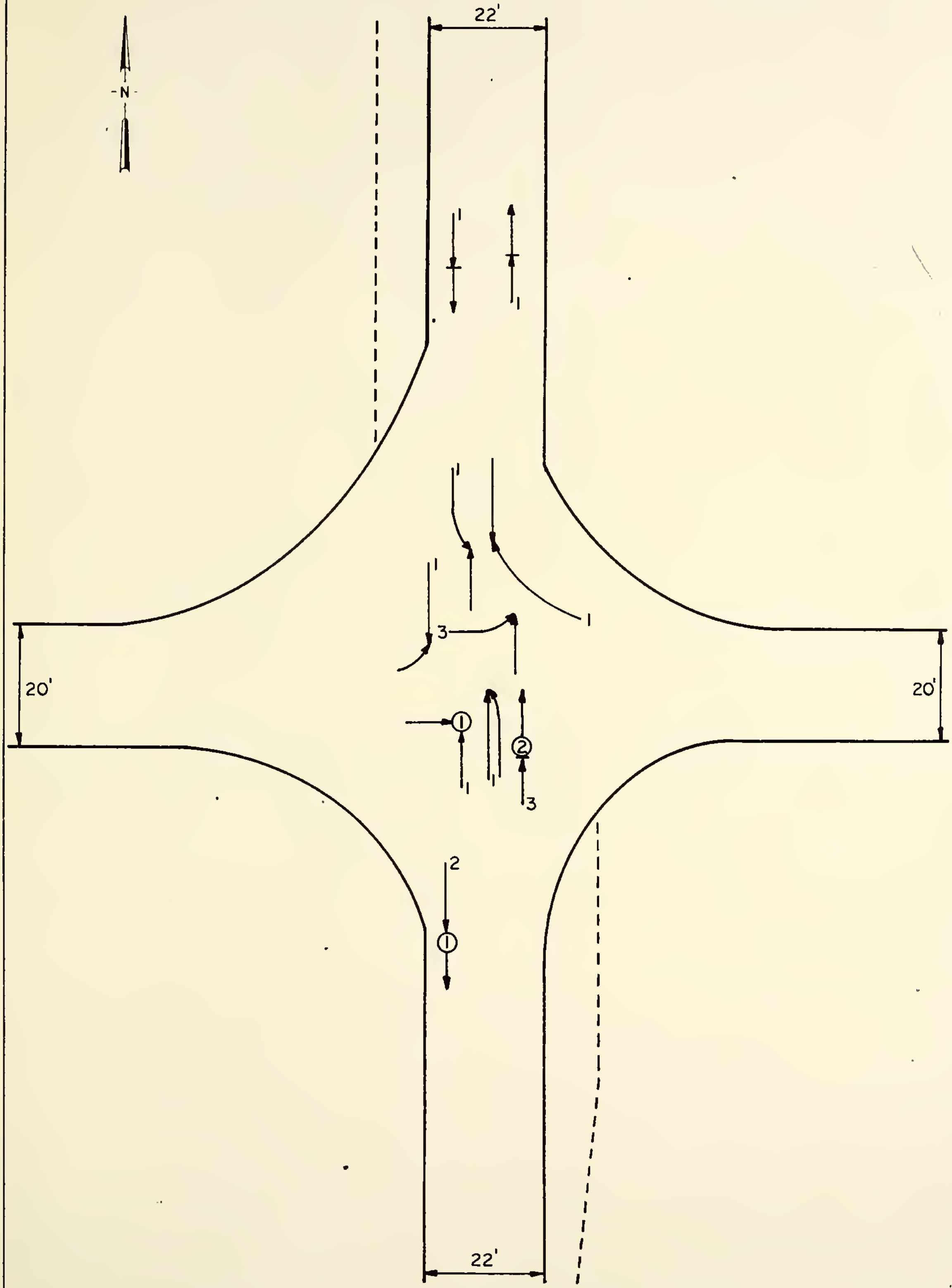


FIGURE B13. U.S. 52 BY-PASS & KOSSUTH (1966)

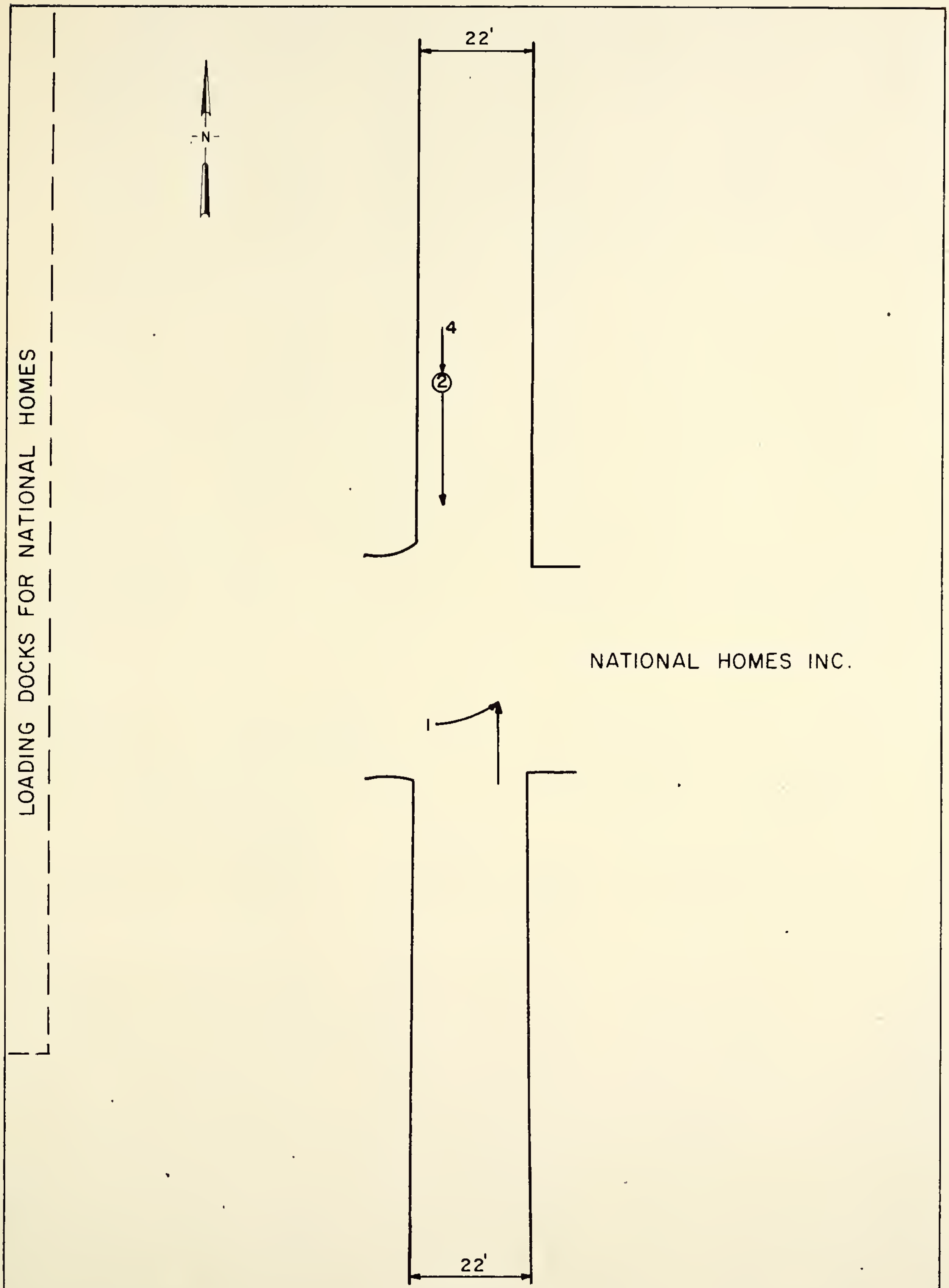


FIGURE B14. U.S. 52 BY-PASS & NATIONAL HOMES (1966)

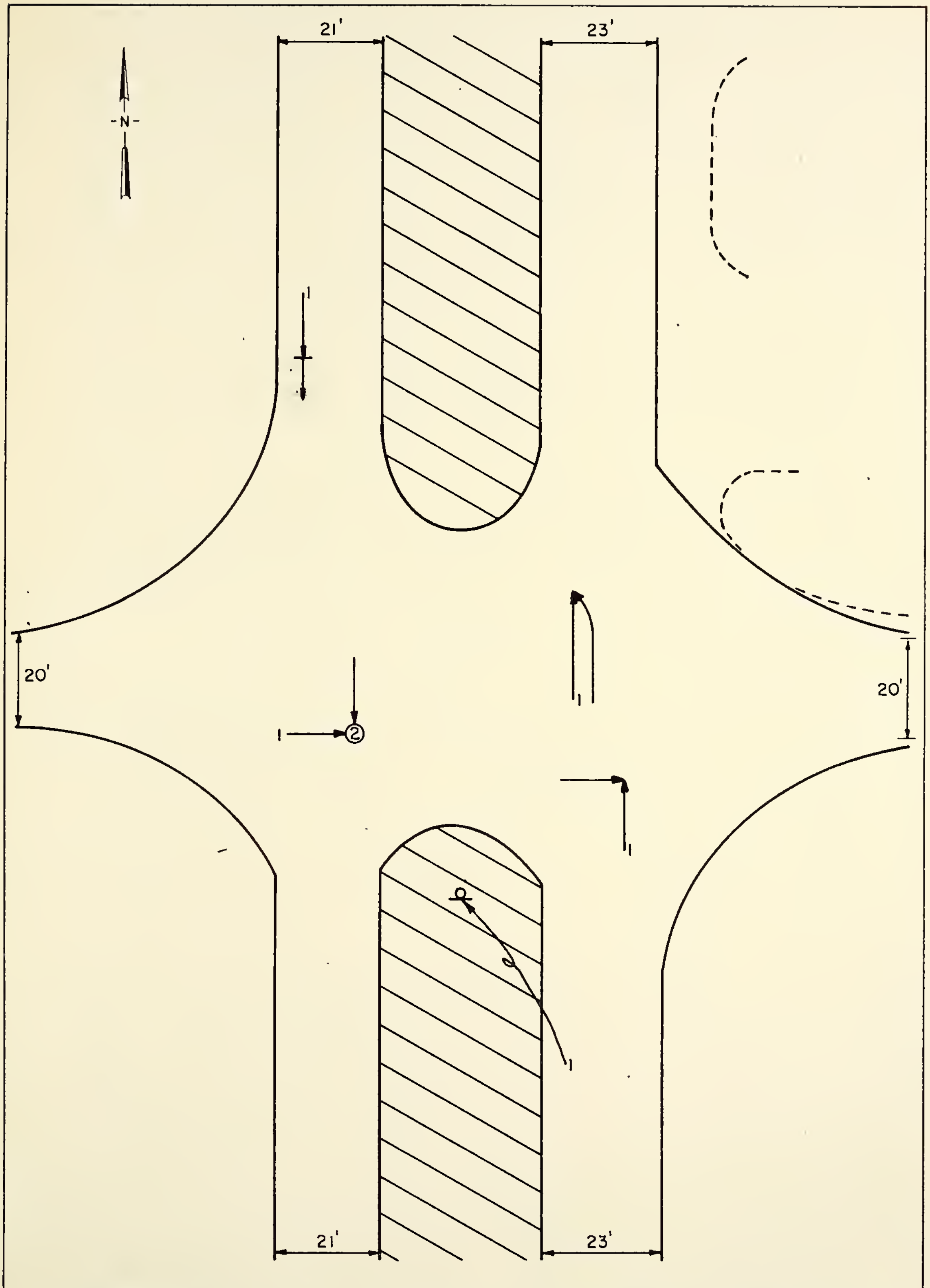


FIGURE B15. U.S. 52 BY-PASS & McCARTY LANE (1966)

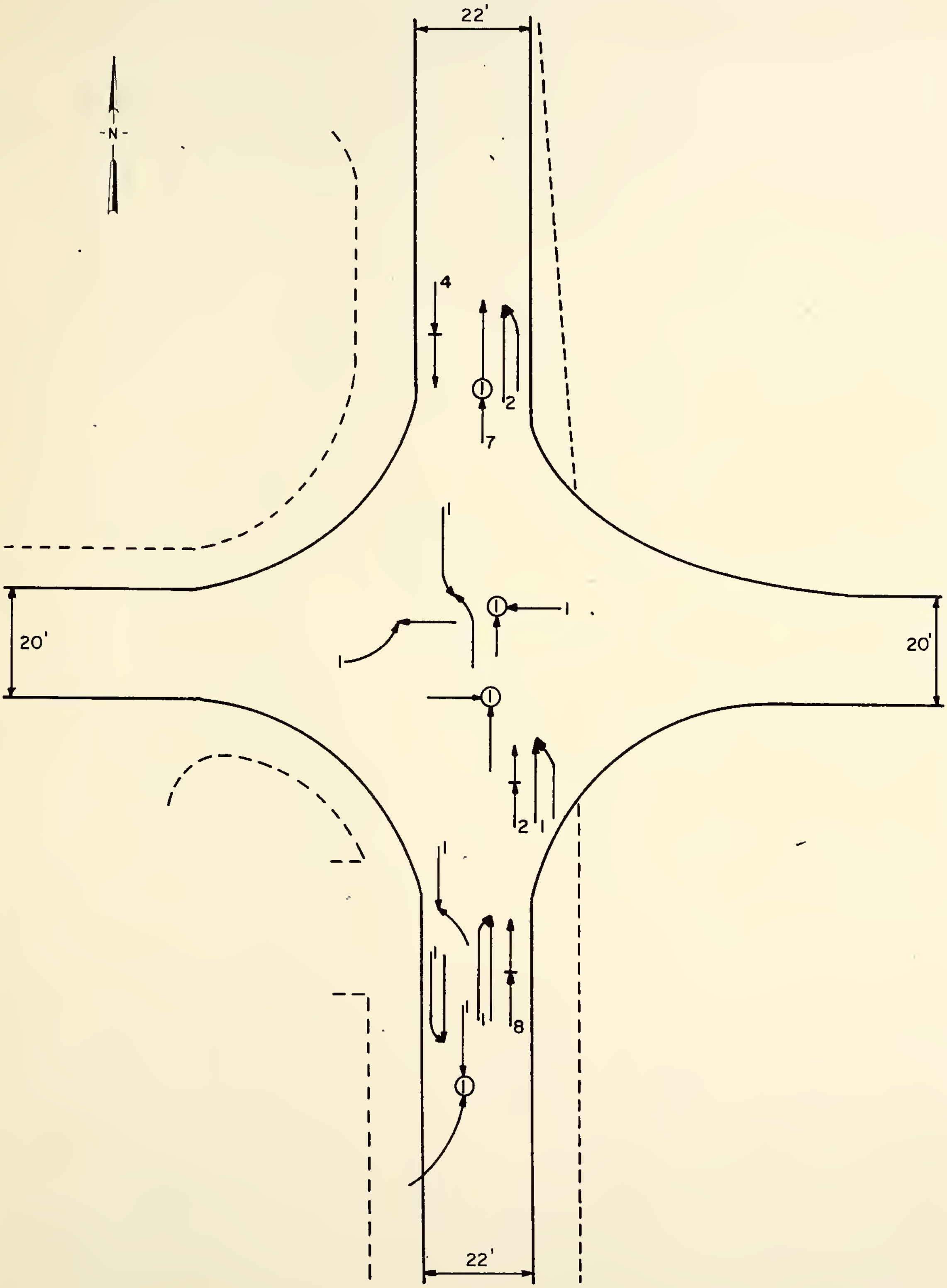


FIGURE B16. U.S. 52 BY-PASS & UNION (1967)

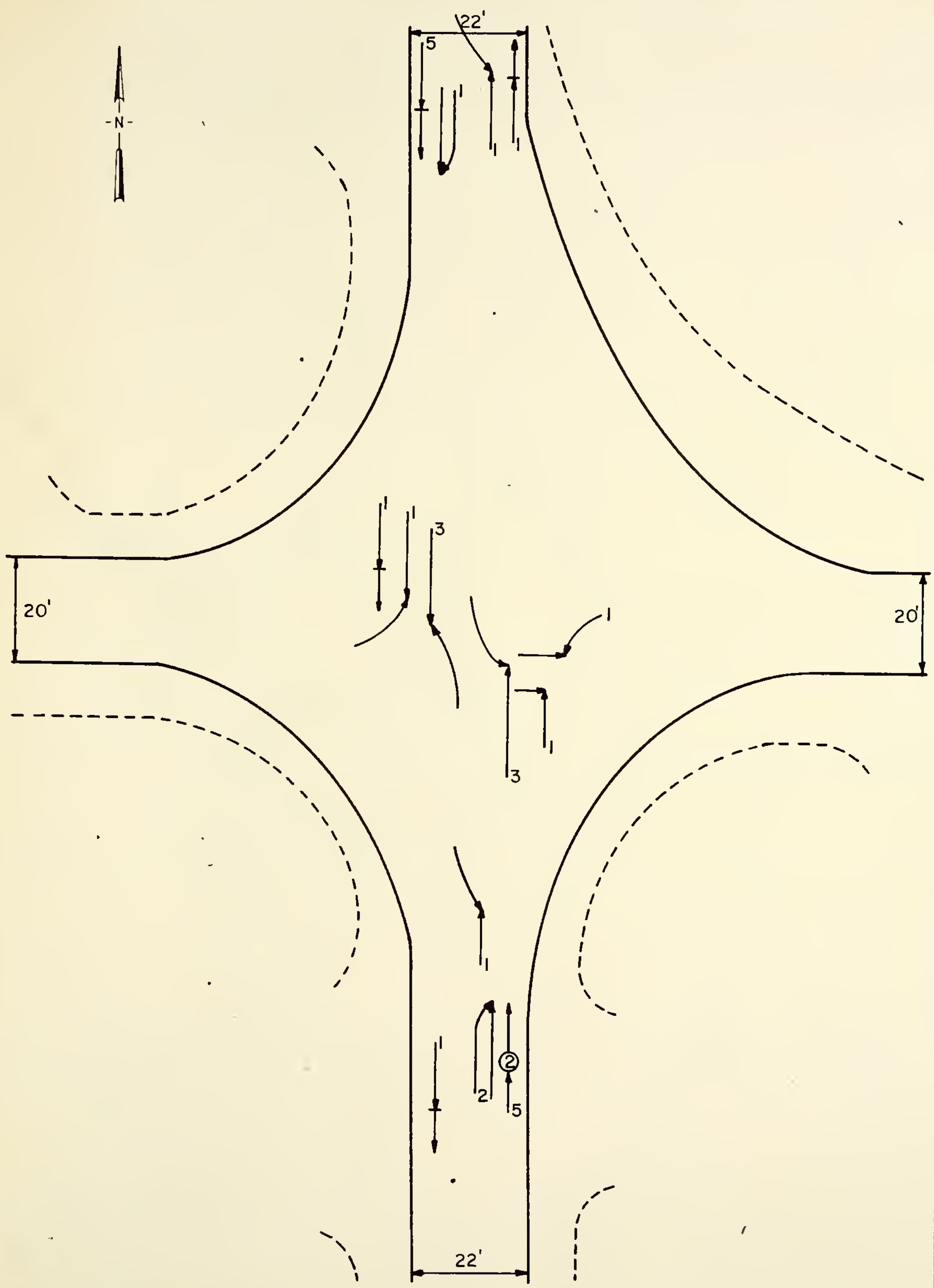


FIGURE B17. U.S. 52 BY-PASS & S.R. 26 (1967)

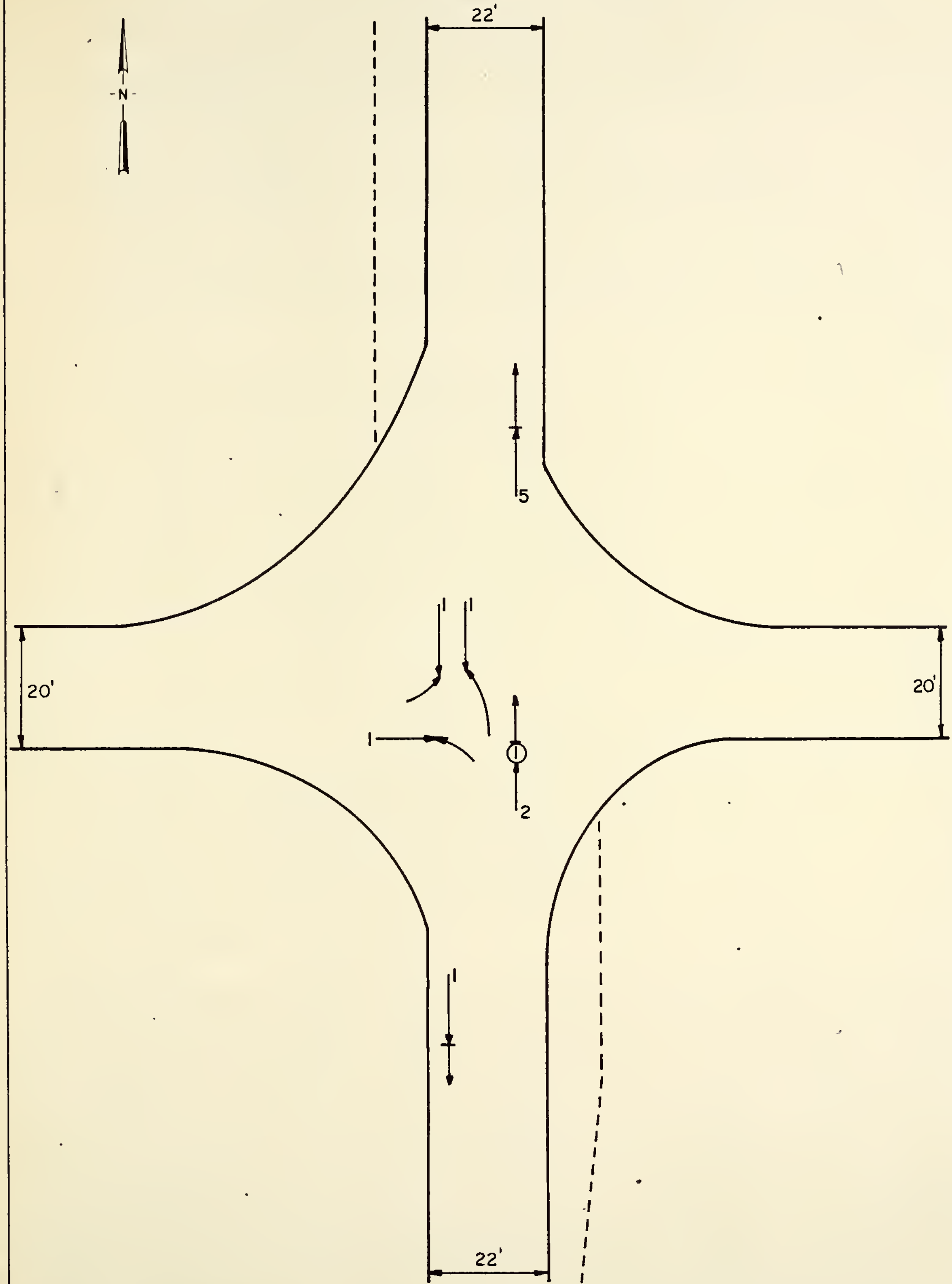


FIGURE B18. U.S. 52 BY-PASS & KOSSUTH (1967)

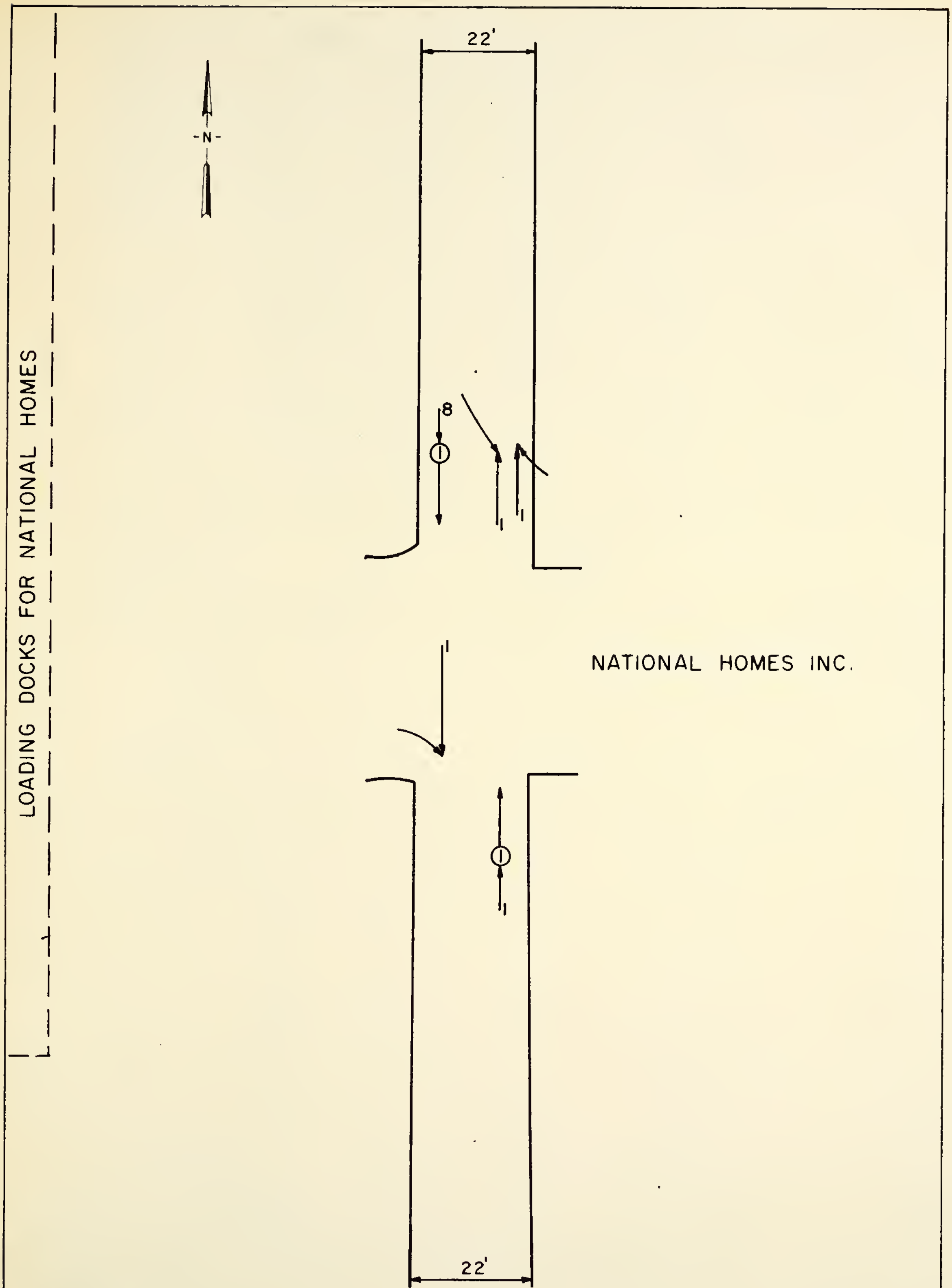


FIGURE B19. U.S. 52 BY-PASS & NATIONAL HOMES (1967)

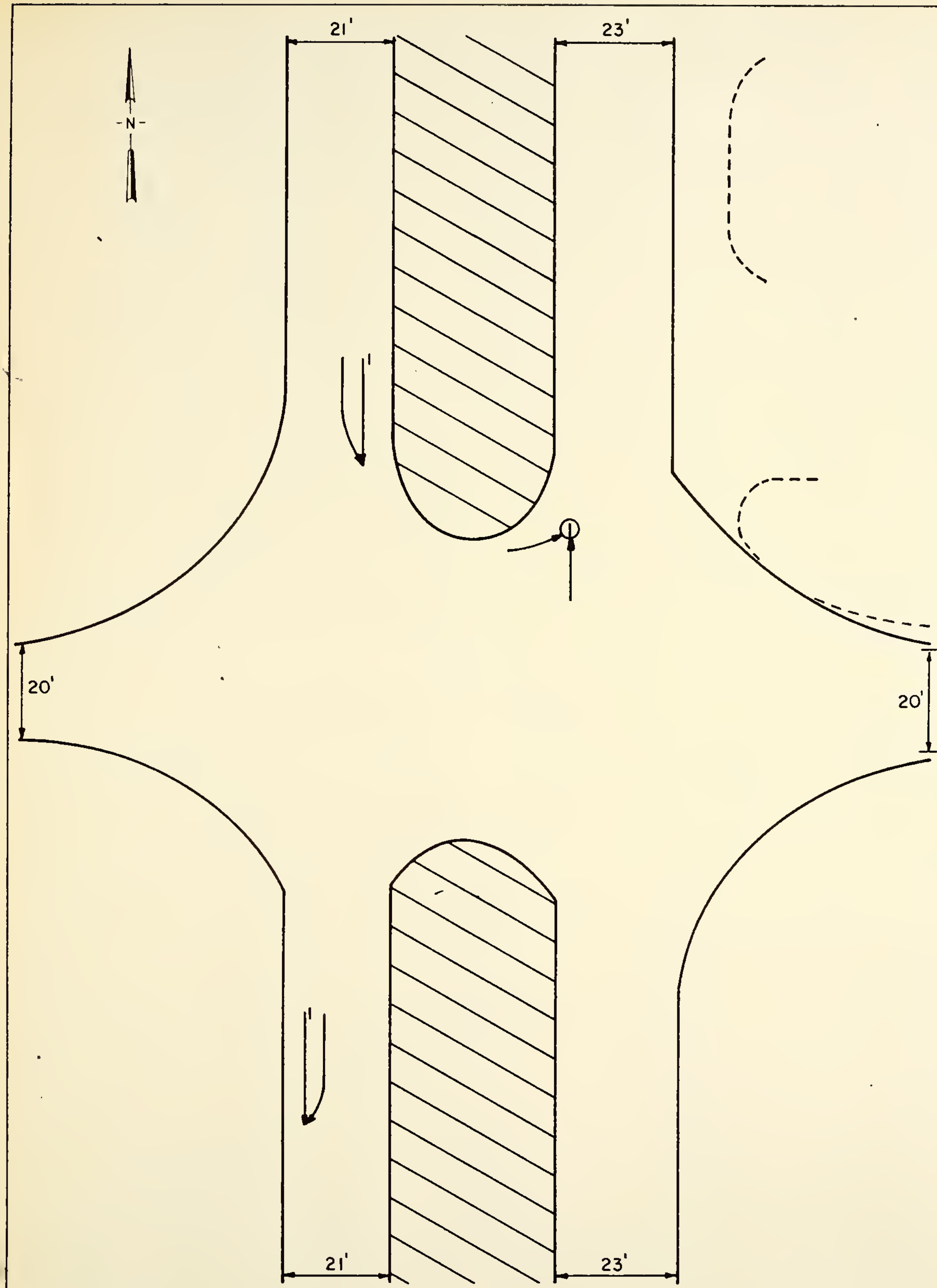


FIGURE B20. U.S. 52 BY-PASS & McCARTY LANE (1967)

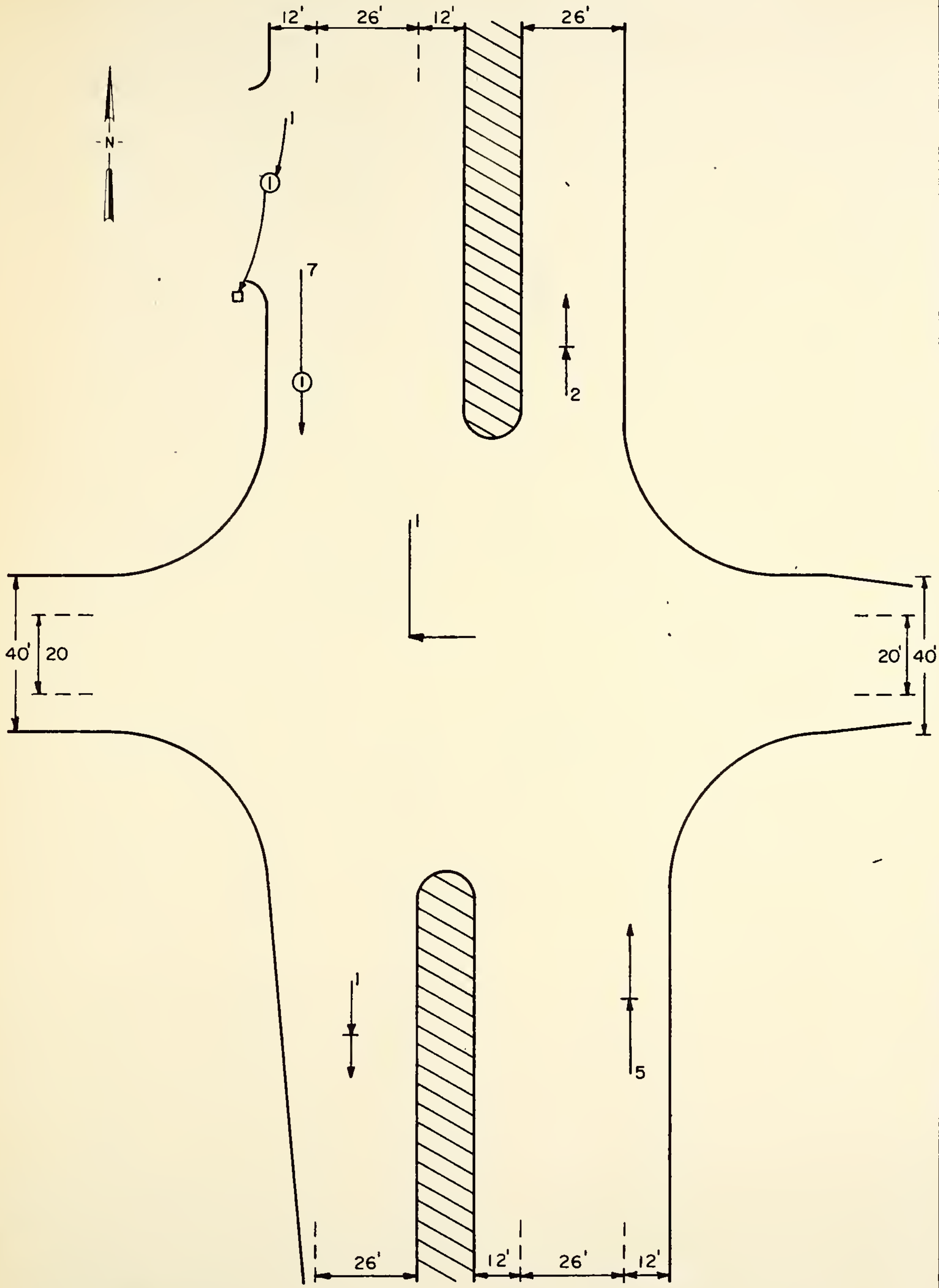


FIGURE B21. U.S. 52 BY-PASS & UNION (1970)

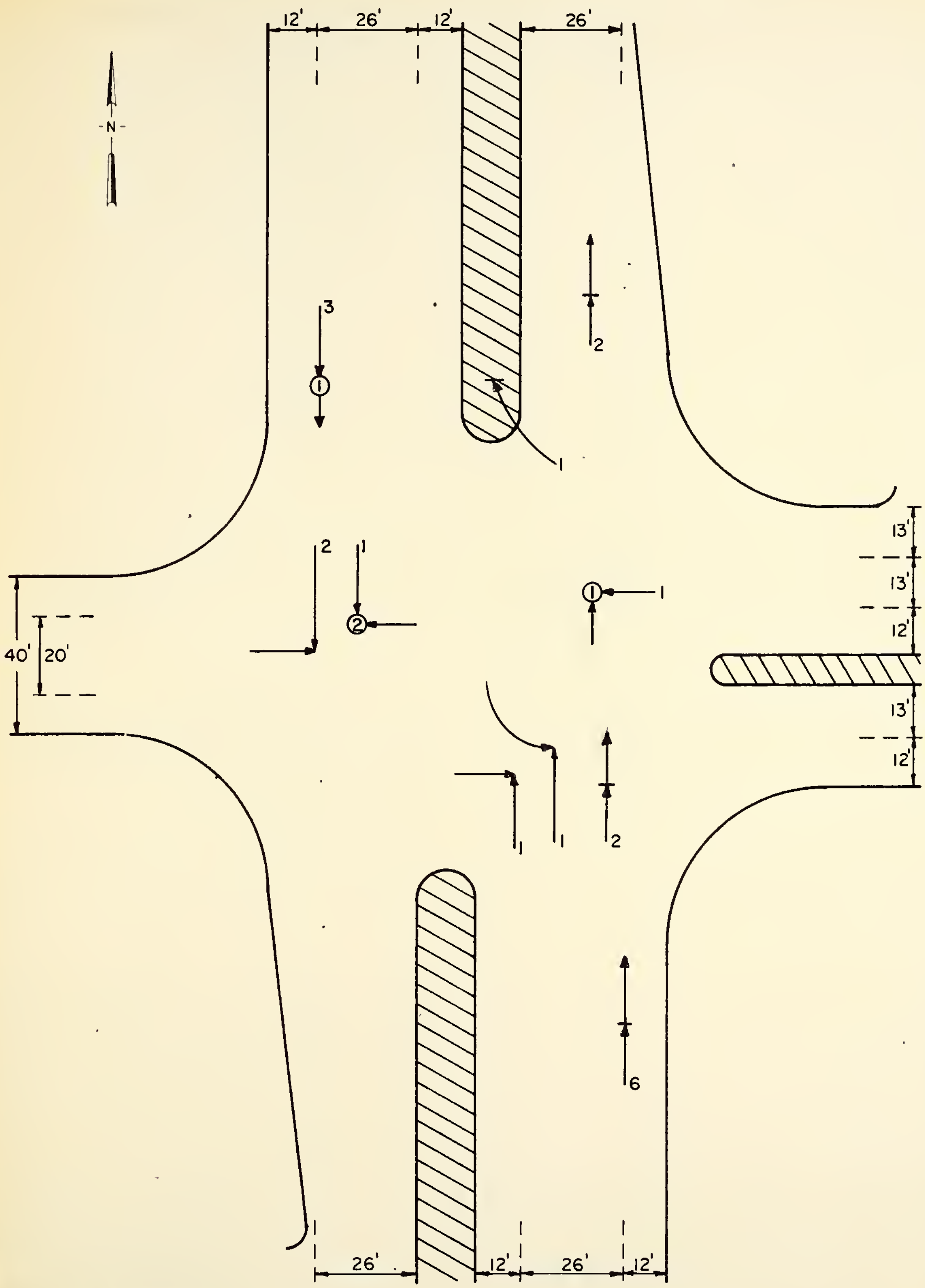


FIGURE B22. U.S. 52 BY-PASS & S.R. 26 (1970)

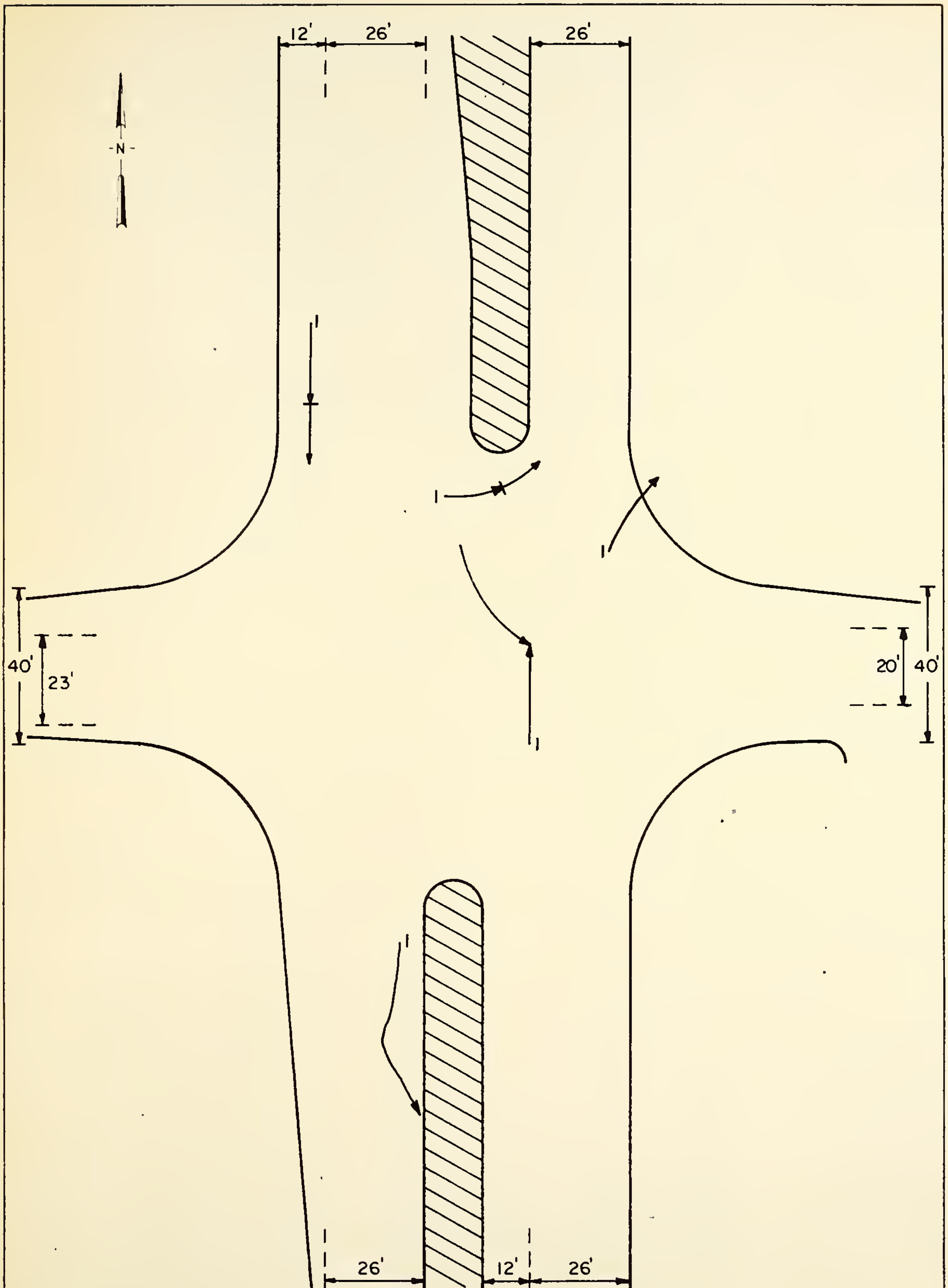


FIGURE B23. U.S. 52 BY-PASS & KOSSUTH (1970)

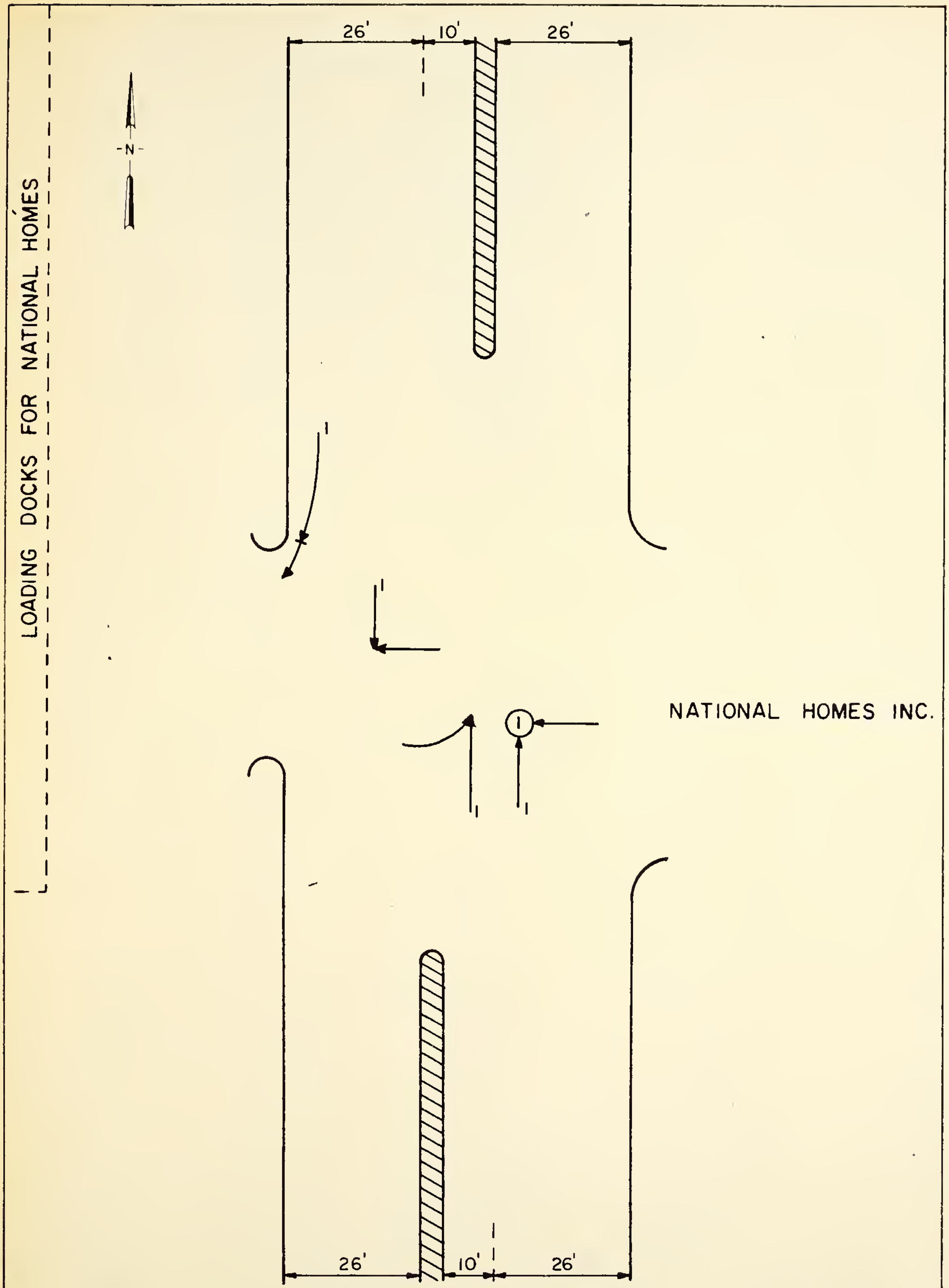


FIGURE B24. U.S. 52 BY-PASS & NATIONAL HOMES (1970)

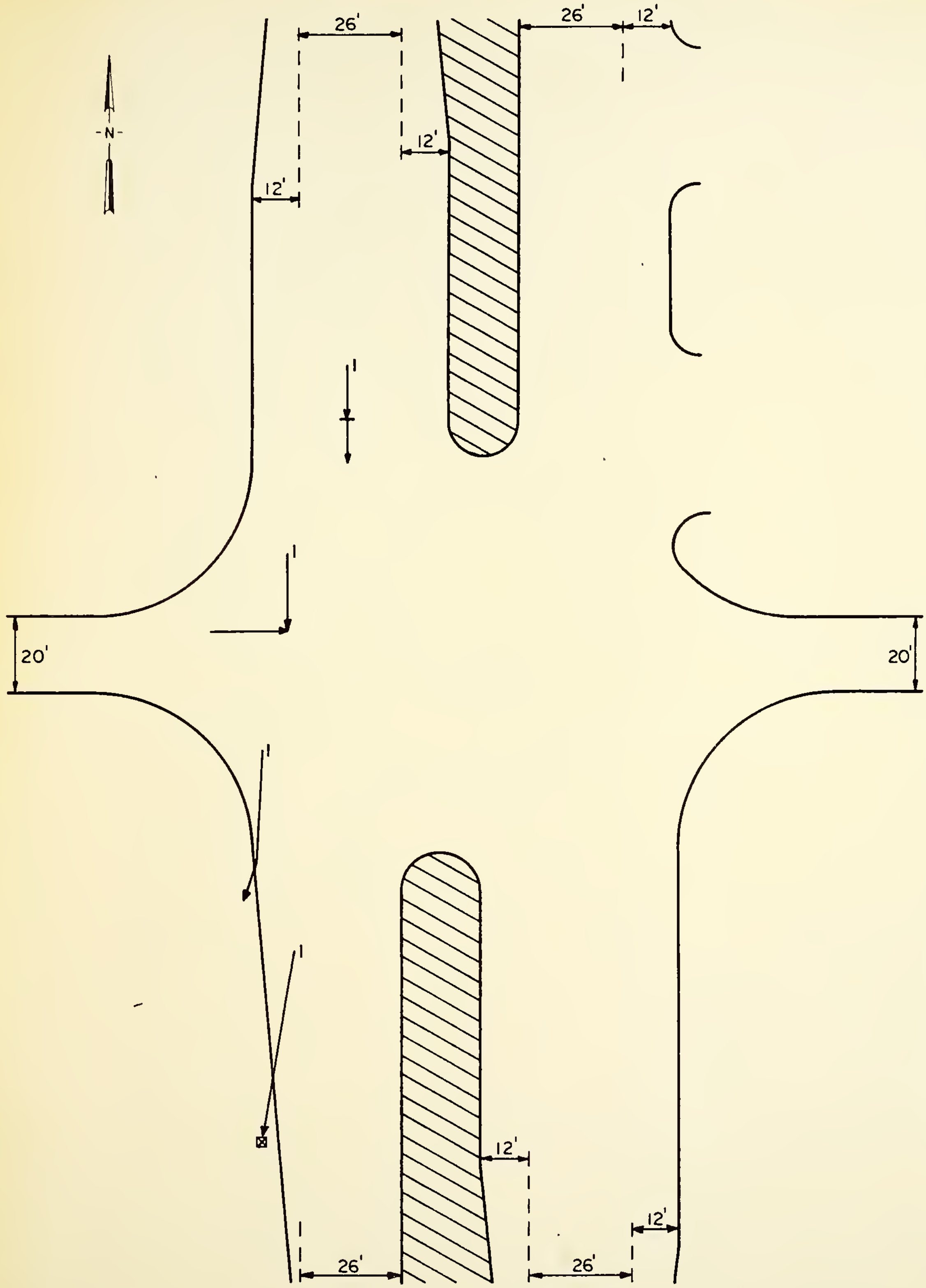


FIGURE B25. U.S. 52 BY-PASS & McCARTY LANE (1970)